Handbook RS525

ERTMS Handbook

Issue 1

RS525

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ERTMS Handbook
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First issued December 2022
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You will need this handbook if you need to understand how the European Rail Traffic Management System (ERTMS) operates on the GB network.

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1 Introduction to this Handbook

1.1 Concept

The European Rail Traffic Management System (ERTMS) is an in-cab signalling system which provides varying degrees of train speed and movement supervision based on the level and mode of operation.

An underlying principle of ERTMS is that trains should always operate in the highest level of supervision available.

For the purpose of this document ERTMS has three elements:

- European Train Control System (ETCS).
- Global System for Mobile Communications-Railway (GSM-R).
- Operating rules.

ETCS is the train control element of ERTMS, and to maintain the same terminology used in the Rule Book, this will be referred to as ERTMS in this document.

Trains are issued with a movement authority from the signalling system which gives permission to move to a specific location. The train's on-board equipment will supervise this movement so that the speed profile and distance are not exceeded and the system is designed to intervene if either is exceeded.

Trains which are fitted with ERTMS on-board equipment are also capable of operating on non-ERTMS lines.

There are lines where both ERTMS and conventional train protection systems are in place. These are usually referred to as overlay areas.

The extent of the area controlled by ERTMS cab signalling is shown in Table A of the *Sectional Appendix*.

This handbook is to support training of staff in front line roles who are directly concerned with the application of ERTMS and whilst it describes the basic functionality of the system as it now stands it should be noted that this will be subject to change as the functionality of ERTMS is developed and as more ERTMS implementation schemes are progressed. It should also be noted that the handbook does not contain any rules but merely describes how the system operates.

1.2 Trackside equipment

1.2.1 Balises

An ERTMS balise is a transponder that contains data which is mounted in the four-foot. The balise needs no external power supply as it is energised by the passing of a train. Once energised, the balise transmits an electronic message back to the train.

Example of a typical balise

The content of the message will depend on its purpose, for example, position reference markers and special stop messages. One of the main functions of balises in a Level 2 area is for odometry purposes (see section 1.3.4).

A balise can either send the same fixed message as a position reference marker in each transmission or it can be connected to a Lineside Electronics Unit (LEU) to transmit one of a set of different messages.

The train uses the order in which it passes over the balises to determine its direction of travel.

Balise messages are made up of individual 'packets' which contain the data required for the train. As trains can pass over balise groups in either direction, each packet can be made valid for either or both directions of travel.

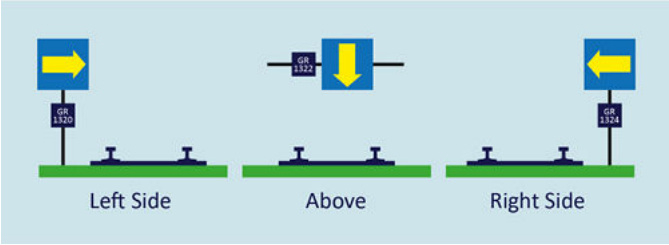
Data from a balise group form electronic messages which are sent to the train. Multiple balises within a balise group permit the transmission of more data. This also allows for individual balise failure as the same message can be transmitted from more than one balise. If one balise fails to be read for any reason, the other balise may be read instead, making sure the message is delivered to the train.

1.2.2 Lineside signage

Block markers

A block marker consists of a reflective square sign showing a yellow arrow on a blue background. The arrow shows which line the marker applies to.

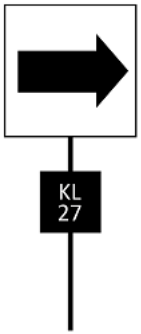
Each block marker is provided with a unique identification plate of white characters on a black background.



Location markers

A location marker consists of a reflective square sign showing a black arrow on a white background. The arrow shows which line the marker applies to.

This sign indicates a point of reversal or another location which needs to be identified at the lineside. It can also be used as a location reference for communication purposes. Each location marker is provided with a unique identification plate, of white characters on a black background.



Cab signalling boards

Warning of start of cab signalling board

This board indicates a warning that ERTMS signalling is about to start.

Start of cab signalling board

This board indicates the start of ERTMS.

End of cab signalling board

This board indicates the end of ERTMS signalling.

Shunt entry boards

Shunt entry boards consist of a reflective board showing a white chevron on a violet background. The chevron points toward the line to which the shunt entry board applies.

Shunt entry boards are provided to mark the entrance to a shunt route on certain ERTMS lines where lineside signals are not provided.

The identity of a shunt entry board is shown on an identification plate in white characters on a black background.

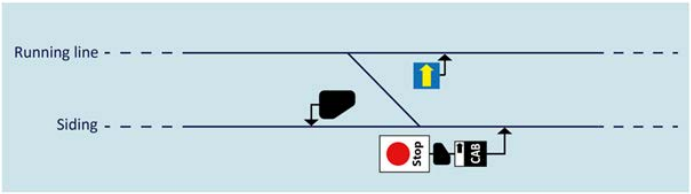
1.2.3 Position-light signals

Location of position-light signals

Position-light signals can be located on certain block markers and stop boards to cater for the following situations:

- Locally controlled infrastructure - the train is in Shunting (SH) mode and has to pass over locally controlled infrastructure before obtaining a movement authority.
- Start of mission - the train is in Staff Responsible (SR) mode because it does not have a valid position.

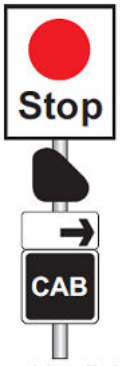
Where a position-light signal is located and is displaying two white lights, the train may proceed in SR mode without a Written Order or if in SH mode.



Typical position-light signal arrangement where there is a route from a siding onto a running line and a route from a siding along the siding

Stop board - position-light signal not displayed

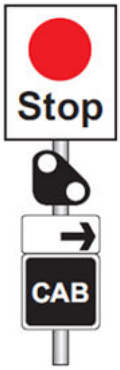
Can only be passed on the authority of the signaller or shunter.



Stop board - position-light signal not displayed

Stop board - position-light signal displayed

When a position-light signal is displayed with a stop board, it authorises the train to proceed at caution towards the next block marker, shunt entry board or buffer stops. The line ahead may be occupied.

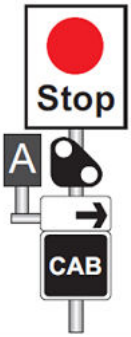


Stop board- position-light signal displayed

Route indications

If a position-light signal is provided because there is more than one route from that signal, in certain circumstances where route information is useful a route indicator may be provided.

Route indicators, where provided, are usually mounted to the left of the position-light signal.



Miniature alphanumeric route indicator

1.2.4 Radio Block Centre

The Radio Block Centre (RBC) sends electronic messages to, and receives electronic messages from, the ERTMS on-board equipment on trains within the area which the RBC is controlling.

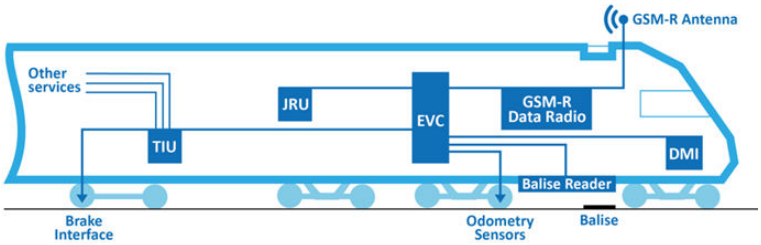
These messages are transmitted using GSM-R data radio. Each electronic message can contain one or more data packets.

The RBC monitors the interlocking and generates Movement Authority (MA) messages. An MA message is sent when the route has been set, all interlocking is in place and the conditions for the train movement have been satisfied, and the RBC is in communication with a train that is able to enter that route.

The RBC also contains data that describes the route and speed restrictions that will be encountered. This data is not contained in the interlocking but is necessary for the train to comply with the speed profile.

The RBC also receives information from the train, such as the location and status of the train.

1.3 On board equipment



Simplified image of on-board ERTMS equipment

Each train fitted with ERTMS in a level 2 area normally has the following equipment:

1.3.1 Balise reader

The balise reader is fitted beneath the train and energises the balise, allowing the balise to transmit messages to the train. The balise reader then receives the message and passes it on to the European Vital Computer (EVC).

1.3.2 European Vital Computer

The EVC provides the supervision of the train's movements from all the inputs received from the trackside equipment, on-board odometry, the driver and other stored information. The EVC provides outputs to the driver through the Driver Machine Interface (DMI), to other train systems and functions through the Train Interface Unit (TIU) and transmits information back to the RBC through the GSM-R.

1.3.3 Driver Machine Interface

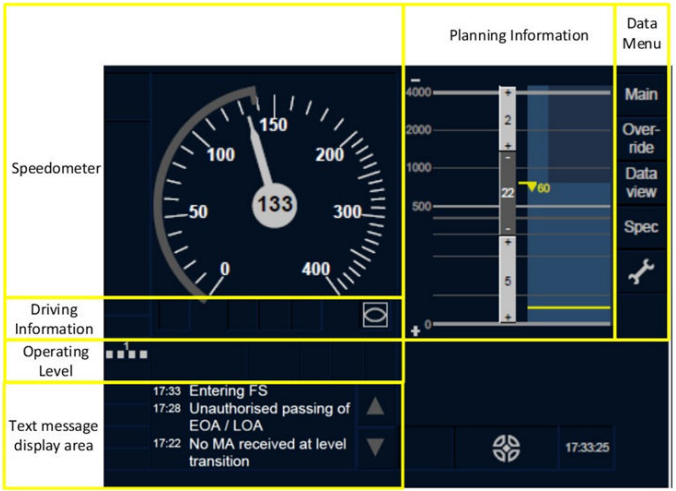
The ERTMS on-board equipment communicates with the driver through the DMI, an in-cab display located in a prime position on the driver's desk. This is where the MA sent from the RBC is displayed.

The DMI provides the driver with all necessary ERTMS information needed to determine:

- the distance that the train has authority to travel
- the maximum speed which the train must not exceed
- the point at which the driver needs to start braking to avoid intervention by the ERTMS on-board equipment.

The DMI also:

- provides the means for the driver to enter data into the on-board system (see section 3.2)
- displays actual train speed (a speedometer)
- displays supervised speed and changes ordered by the ERTMS trackside equipment
- displays information about the route ahead (the planning information)
- alerts the driver to changes in supervision, errors and other warnings (visually and audibly), including text messages.



Driver machine interface (DMI) typical view

1.3.4 Odometry

The on-board odometry system provides the train with both speed and distance travelled information. The EVC receives input from tachometers and also from a speed radar device mounted underneath the train. The EVC uses this information to calculate the train's speed and position so that it can supervise the train correctly. The EVC can also use this information to periodically report its position to the ERTMS trackside equipment.

1.3.5 Juridical Recording Unit

The Juridical Recording Unit (JRU) records all the messages and telegrams sent and received by the train, driver interactions and certain EVC commands. The JRU may be part of the on-train data recorder, or provided in addition.

1.3.6 Train Interface Unit

The TIU is the means by which ERTMS interfaces to other train systems, such as:

a) Train braking systems. An interface is provided to command service braking and emergency braking.

b) Master controller. To determine the position of the direction controller and whether the cab desk is open or closed.

c) Traction control systems. An interface is provided to command a cut in traction power.

d) Train function control systems. For example, ERTMS is able to provide information for the command to raise or lower an overhead pantograph.

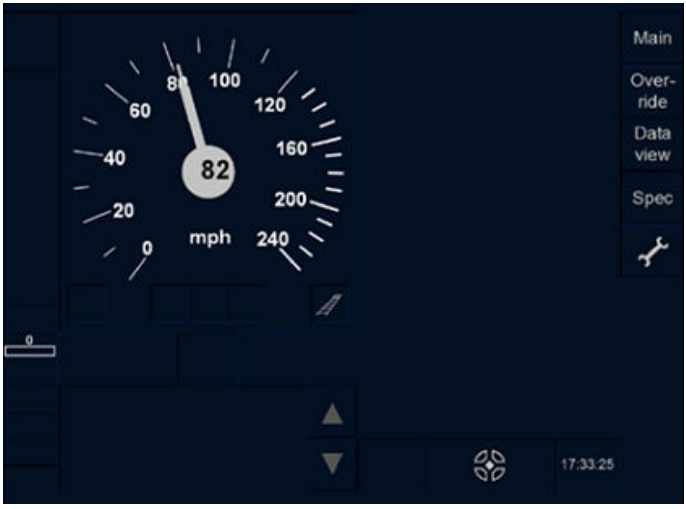
2.1 Levels

2.1.1 Introduction to Levels

ERTMS technical functionality is defined by levels. The levels are characterised by how information is transmitted to trains, how a train's position and integrity is determined, and which train protection system is actively supervising the train.

2.1.2 Level 0

Level 0 allows ERTMS fitted trains to operate on infrastructure not fitted with ERTMS, and where there is no alternative train protection or warning system for example, in some possessions or on lines under construction. It provides speed supervision based on the ceiling speed of the operating mode.

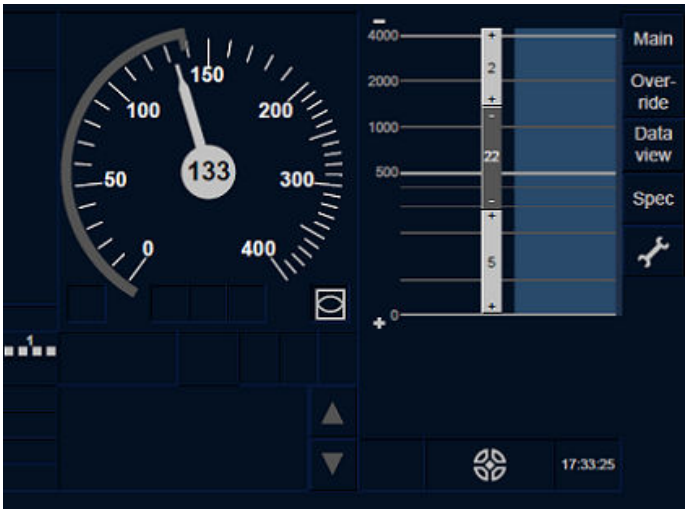


Level 0 displayed on a DMI

2.1.3 Level 1

Level 1, ERTMS provides varying degrees of speed and distance supervision dependent on the operating mode. In this level:

- ERTMS messages are passed from the track to the train by track mounted balises only
- depending on the location, the speed can be in km/h or mph.

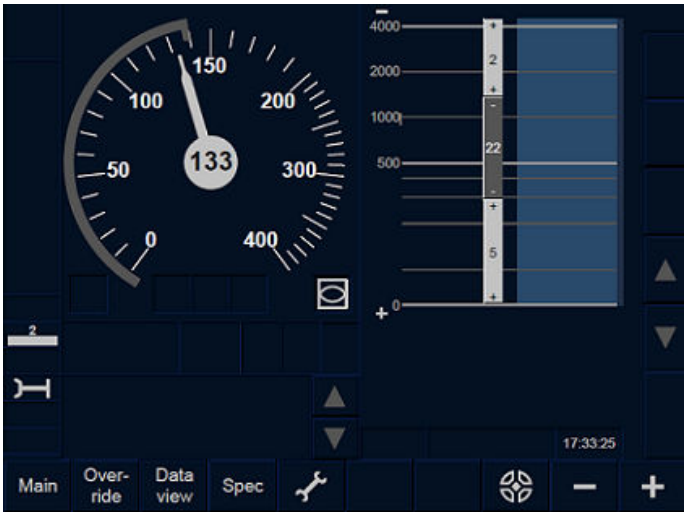


Level 1 displayed on a DMI

Level 1 will be used at some depot exits in the form of a Level 1 Launch (see section 3.9).

2.1.4 Level 2

Level 2 is the normal level of operation in ERTMS areas on the GB railway at present. This level provides speed and distance supervision dependent on the operating mode. In this level ERTMS messages are passed to and from the train by a combination of radio messages from the RBC and track mounted balises. In this level the trackside elements of the ERTMS use trackside train detection systems to make safety decisions about the position and integrity of trains. Depending on the location, the speed information may be displayed in km/h or mph.



Level 2 displayed on a DMI

2.1.5 Level NTC

Level NTC is used by ERTMS fitted trains operating on infrastructure where automatic warning systems (AWS), train protection and warning system (TPWS) or automatic train protection (ATP) are in operation. This level provides no on-board ERTMS supervision and the train is protected by the conventional protection systems.

There are two variants to this level as described below.

Able to transition

This variant is used by drivers who are competent to operate in ERTMS Level 2. When a train operating in this variant enters an area where Level 2 is available, the train will transition to Level 2.

Not able to transition

When a train operating in this variant enters an area where both Level 2 and the national protection systems (AWS, TPWS) are available, the train will not transition to Level 2 but will remain in the national train protection system. This variant is used when a driver is not trained in ERTMS.

If national train protection systems are not available in the Level 2 area, the last lineside signal will be maintained at danger by the system. This is to prevent drivers that are not authorised to operate in Level 2 from entering the area.

2.2 Modes

2.2.1 Introduction to Modes

ERTMS modes are technical modes that support the operational state of the railway. Modes are common to levels, but not all modes are available in all levels.

2.2.2 Full Supervision

In Full Supervision (FS) mode, ERTMS provides the highest level of supervision as it provides the driver with constant speed and distance supervision (see section 3.3.1).

FS can only be granted to a train when the signalling system indicates that the line is clear up to the Supervised Location (SvL) associated with the End of Authority (EoA).

The following table shows the Levels in which FS mode is available:

Level 0	Level NTC	Level 1	Level 2
No	No	Yes: MAs are transmitted by balises based on inputs from lineside signal aspects	Yes: MAs are transmitted over the GSM-R radio network

2.2.3 On Sight

On Sight (OS) mode enables a train to enter a section which could be occupied by another train, obstructed by any kind of obstacle or is unable to be detected as clear and enforces a limited speed of 25 mph (40 km/h). (See section 3.3.6).

The following table shows the Levels in which OS mode is available:

Level 0	Level NTC	Level 1	Level 2
No	No	Yes: MAs are transmitted by balises based on inputs from lineside signal aspects	Yes: MAs are transmitted over the GSM-R radio network

2.2.4 National system

In National System (SN) mode, ERTMS provides no supervision. The on-board ERTMS equipment uses other train protection systems such as AWS, TPWS and ATP.

The following table shows the Levels in which SN mode is available:

Level 0	Level NTC	Level 1	Level 2
No	Yes	No	No

SN is only available in Level NTC areas and can be used in forward and reverse directions.

2.2.5 Shunting

Shunting (SH) mode allows for shunting movements to take place including reverse movements. It provides limited speed supervision in the form of a ceiling speed normally set at 18 mph (30 km/h).

Trains in SH mode will not receive any emergency stop commands from the RBC as the GSM-R data connection is automatically terminated. If it is necessary to stop trains in an emergency, the GSM-R Railway Emergency Call (REC) is the only method available to the signaller as the GSM-R voice call will still be active. In some locations a Danger for Shunting balise may be provided at the boundary of shunting operations (see section 2.4.5).

The method of entering SH mode will vary by location. In some locations, entry into SH mode will be authorised by the signaller. In other locations, drivers may be permitted to access SH mode on their own authority.

If SH is selected by the driver, the train needs to be at a standstill before SH is selected. The display of the SH icon on the DMI is not an authority to move the train.

The following table shows the Levels in which SH mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	Yes	Yes: Movements in SH mode will be tripped upon passing over any balise containing an active Danger for Shunting message, unless the Override function is used	Yes: SH mode can only be accessed when the train is connected to the RBC. Movements in SH mode will be tripped upon passing over any balise containing an active Danger for Shunting message, unless the Override function is used

2.2.6 Staff responsible

Staff responsible (SR) mode is used in the following circumstances:

- When the signalling system is unable to issue a MA.
- At Start of Mission when a train's position is invalid or unknown to the system.

SR becomes available when the driver presses Override and has a ceiling speed normally of 25 mph (40 km/h). In some locations the speed in SR can be manually increased by the driver. Such areas will be defined in the *Sectional Appendix*.

Entering SR can be achieved either by the trackside offering SR mode to the driver or by the driver following the Override Procedure.

Balise groups associated with block markers contain a 'Stop if in SR' message that will lead to a train being tripped if it passes a block marker without authority (see section 2.4.4).

The following table shows the Levels in which SR mode is available:

Level 0	Level NTC	Level 1	Level 2
No	No	Yes	Yes

2.2.7 Standby

Standby (SB) mode is a default mode that the ERTMS system enters when the driving desk is closed.

SB is not selectable by the driver. SB mode can be used for coupling or uncoupling. Movement is limited by Standstill Supervision which will intervene after 4 metres (13 feet).

The following table shows the Levels in which SB mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	Yes	Yes	Yes

2.2.8 Sleeping

Sleeping (SL) mode is the default mode for the on-board ERTMS equipment when the cab is closed and the train is electrically connected to another traction unit which has an active cab. It is not selectable by the driver.

The following table shows the Levels in which SL mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	Yes	Yes	Yes

2.2.9 Unfitted

Unfitted mode (UN) is used for train movements in areas that are not fitted with ERTMS trackside equipment and no other train protection trackside equipment. In UN mode, ERTMS provides limited speed supervision in the form of a ceiling speed (See section 2.1.2).

The following table shows the Levels in which UN mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	No	No	No

UN can be used in both forward and reverse directions.

2.2.10 Trip

Trip (TR) mode is activated when the on-board or trackside ERTMS equipment detects that the train has exceeded the end of authority. The on-board ERTMS equipment will command the emergency brake. In Level 1 and Level 2 the emergency brake will remain applied until the train has come to a stand. When at a stand the driver can acknowledge trip and the train will enter PT mode, releasing the brakes. Only then can another mode be selected by the driver.

The following table shows the Levels in which TR mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes: Acknowledging the trip will invoke a transition to either UN or SH mode	Yes: Acknowledging the trip will invoke a transition to either SN or SH mode	Yes: Acknowledging the trip will invoke a transition to Post Trip mode	Yes: Acknowledging the trip will invoke a transition to Post Trip mode

2.2.11 Post Trip

In Level 1 and Level 2 after a train has entered trip mode, and the trip has been acknowledged on the DMI, the train enters PT mode automatically. This releases the emergency brake. When it is safe for the train to proceed, if possible, an MA will be issued. If this is not possible, it will be necessary for the train to start in SR mode, and a Written Order will then be required (see section 8).

PT mode is only made available to the driver by acknowledging TR mode.

The following table shows the Levels in which PT mode is available:

Level 0	Level NTC	Level 1	Level 2
No	No	Yes	Yes

2.2.12 Non leading

Non leading (NL) mode is used:

- at Start of Mission (see section 3.2) by the trailing traction unit in tandem working
- when it is required to be operated for assisting the train in the rear
- when it is required to be operated for assisting a failed train.

The brake controller needs to be isolated. ERTMS performs no supervisory functions to the traction unit when in NL mode.

The following table shows the Levels in which NL mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	Yes	Yes	Yes

2.2.13 No power

No power (NP) mode is a default mode entered when the power to the on-board ERTMS equipment unit is interrupted. This causes the activation of the emergency brake. The train will come out of this mode when power is restored.

The following table shows in which NP mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	Yes	Yes	Yes

2.2.14 System failure

System failure (SF) mode is a default mode entered when the on-board ERTMS equipment unit detects a safety critical fault. This causes the activation of the emergency brake.

The following table shows in which SF mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	Yes	Yes	Yes

2.2.15 Isolation

Operation of the ERTMS isolation switch puts the on-board equipment in to Isolation (IS) mode which isolates the on-board ERTMS equipment from the train brakes and removes all ERTMS supervisory functions, for example if the train has a complete on-board system failure.

Entering IS Mode is an extreme activity only used when the train cannot enter any other mode and cannot receive any MAs. The selection of IS mode removes all speed supervision and may result in there being no active train protection system.

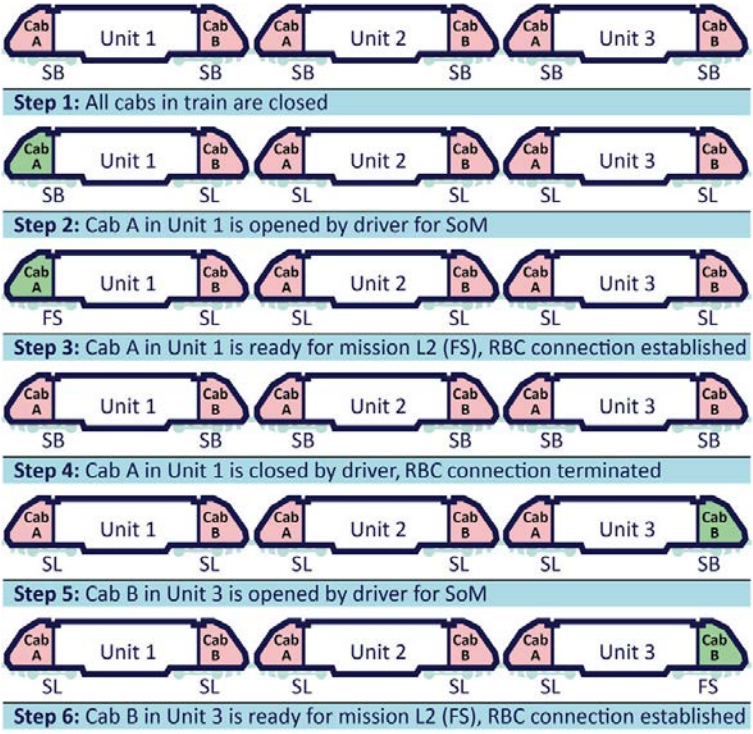
Once IS has been selected, a rolling stock technician is required to restore the on-board system. Company instructions will define the process for how recovery in IS will be made.

The following table shows in which IS mode is available:

Level 0	Level NTC	Level 1	Level 2
Yes	Yes	Yes	Yes

2.2.16 ERTMS modes during cab changes

The following diagram shows the modes which apply to the different steps of changing ends from one cab to another for trains in multiple:



2.3 Movement Authorities

2.3.1 General

In Level 2, movement authorities (MAs) are issued by the signalling system in the form of data which is transmitted to the on-board train equipment using GSM-R radio network. The on-board equipment interprets the data and displays this to the driver on the DMI.

The information displayed to the driver includes the distance the train can travel to the end of the MA and the maximum speed at which the train can operate. The ERTMS system constantly monitors the speed and distance of the train, and is capable of intervening at that instant when speeds are exceeded, to bring the train to a stand if required so that the MA distance is not exceeded.

In Level 1, MAs are transmitted by balises based on inputs from lineside signal aspects.

In Level 2, MAs are transmitted by the GSM-R radio network.

2.3.2 End of Authority

The End of Authority (EoA) is the location to which the train is authorised to proceed and must stop at.

EoAs are marked at the lineside if any of the following conditions are applicable to them:

- The EoA can be used as an EoA for a movement in SR (these are marked as the locations of the EoA and are not shown on the DMI when in SR). These are normally indicated with a block marker
- The driver needs to be aware of the exact EoA position to support a specific operational task (for example where a release speed is provided (see section 3.3.4) to enable the train to be drawn up close to the EoA to fully berth a train in a station platform or where there is a regular need to perform Start of Mission). These are normally indicated with a Location Marker
- In overlay areas, where the EoA is also applicable to trains not using ERTMS. These are normally indicated with a lineside signal.

EoAs where none of these conditions apply are normally not marked at the lineside and are referred to as unmarked EoAs. They assist with breaking up what would otherwise be long sections between marked EoAs in normal operation, consequently improving headway.

If the front of the train passes the EoA, the system is designed to transition the train to Trip mode and the emergency brake will be applied (see section 2.2.10).

2.3.3 Supervised Location

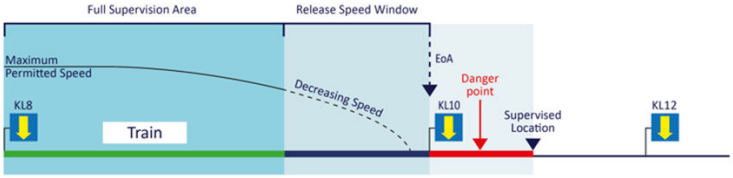
The SvL is a point beyond which the on-board ERTMS equipment will not allow trains to pass.

Where overlaps are provided, the SvL is located at the end of the overlap.

Where overlaps are not provided, the SvL is located at the same place as the EoA.

2.3.4 Danger Point

The Danger Point (DP) is a location beyond which the train must not pass to avoid a potentially hazardous situation. This could be the entry point of an occupied block section or a conflict point at a converging junction.



Danger Point and Supervised Location

2.4 Protection functions

2.4.1 Reverse movement protection

Reverse movement protection is only applicable to FS, SR, OS and PT modes.

This function applies the brake upon detection of a train movement in excess of 4 metres (13 feet) in the other direction to the permitted direction as determined by the mode. This means that the train can only move backwards with respect to the active cab.

Reverse movement protection in FS and OS

In FS and OS, the on-board ERTMS equipment applies Reverse Movement Protection to stop movements in the opposite direction to the MA.

Reverse movement protection in SR

In SR mode, the on-board ERTMS equipment applies Reverse Movement Protection to movements in the reverse direction from the active cab.

Reverse movement protection in PT

In PT mode, the on-board ERTMS equipment applies Reverse Movement Protection to movements in the forward direction from the active cab.

2.4.2 Roll away protection

Applicable to FS, OS, SR, SH, PT and UN.

This function applies the brake upon detection of train movement in excess of 4 metres (13 feet) in a direction opposite to that selected on the direction controller. Where the direction controller is in the neutral position, Roll Away Protection applies to movements in either direction.

2.4.3 Standstill supervision

Standstill supervision is only applicable to SB mode.

This function applies the brake upon detection of a train movement in excess of 4 metres (13 feet) in either direction.

2.4.4 Stop if in staff responsible

Where EoAs protect moveable infrastructure (for example, points), balises containing the Stop if in Staff Responsible (SR) message are positioned at the associated block marker. This message will cause a transition to TR mode for any train passing over the balise in SR mode.

If it is necessary to pass the EoA in SR mode, the driver will select Override prior to the movement. Authority to select Override can only be granted by the signaller using a Written Order (see section 8).

The Override function can only be selected when the train is at a stand. Once selected, the on-board ERTMS equipment will disregard the first trip message received within a fixed distance usually 60 metres (65 yards) or within a fixed time usually 255 seconds (whichever occurs first) from the point at which Override is selected. The trip functionality becomes inactive, and all further messages will be acted upon:

- once the train has travelled more than 60 metres (65 yards), or
- the inhibition function has been active for more than 255 seconds, or
- the on-board ERTMS equipment has successfully disregarded a trip message.

2.4.5 Danger for Shunting

Where regular shunting movements take place, balises containing the Danger for Shunting message may be positioned at the limit of these movements. This message will invoke a transition to TR mode for any train passing over the balise in SH mode.

If it is necessary for a movement to exceed this limit in SH mode, the driver will select Override prior to passing over the balise. Authority to select Override will be granted as shown in local operating instructions.

The Override function can only be selected when the train is at a stand. Once selected, the on-board ERTMS equipment will disregard the first trip message received within a fixed distance usually 60 metres (65 yards) or a fixed time usually 255 seconds (whichever occurs first) at the point at which Override is selected.

The Override function can only be selected whilst the train is at a stand. Once selected, the on-board ERTMS equipment will disregard the Danger for Shunting message received from the first balise group. The trip functionality becomes inactive, and all further messages will be acted upon.

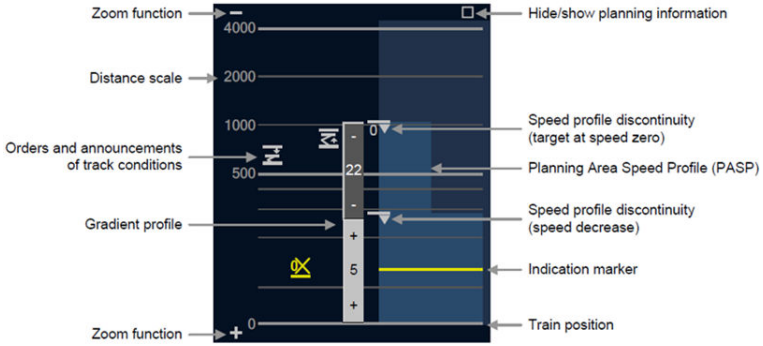
3.1 Driver machine interface (DMI)

The information presented to the driver on the DMI may be only displayed when relevant but may include the following:

Speedometer

- Actual speed.
- The speed limit that ERTMS is currently supervising to.
- Target speed.
- The mode and level the train is operating in.
- Audible alerts to the receipt of more restrictive information.
- Indications when ERTMS has tripped (and the train will be brought to a stand before the driver can regain control). (Will be shown as mode change).

Planning area



The planning area is always available in FS mode and can be available if required by the driver when in OS mode.The planning area consists of the following:

- Gradient profile.
- Indication marker.
- Speed profile.
- Planning area Speed profile.
- Target speed.
- Distance scale.
- Orders and announcements of track conditions.

3.2 Start of mission

The Start of Mission begins when the ERTMS cab is opened and the system is awakened.

3.2.1 Entering data

ERTMS on-board system needs information about the train. It records this and uses the information to configure the system so that it behaves correctly, for example when calculating braking curves. In most cases data is pre-programmed, but any variable data will need to be input by the driver. This includes but is not limited to the following:

- Driver ID.
- Train length.
- Train braking data
- Train Identification Number.
- Signal Number.

For regular operations, some of this data may be already set up into the on-board ERTMS equipment and the appropriate pre-set at Start of Mission can be selected.

Pre-sets may also be provided for various degraded scenarios for example, isolated brakes or other train-borne defects.

3.3 Train running in L2

3.3.1 Normal supervision

FS gives the highest level of supervision as it provides the driver with constant speed and distance supervision.

This is based on the train speed and braking characteristics and the speed and gradient of the line. If necessary, the on-board ERTMS equipment will intervene to make sure that the train is safely brought to a stand at the EoA.

A route must be set before an FS movement can be issued by the RBC.

3.3.2 Overspeed warning and intervention

The ERTMS system is designed to intervene should an overspeed occur.

When the train approaches a target where a brake command is needed, the speedometer and the pointer are coloured in yellow from the permitted speed to the target speed and in grey from 0 to the target speed.

If the current train speed exceeds the permitted speed, the speedometer and the pointer are coloured in orange from the permitted speed to the braking intervention speed limit and an audible warning is given.

If the current train speed exceeds the brake intervention speed limit the on-board equipment commands a service brake intervention. In this case, the speedometer and the pointer are coloured in red from the permitted speed to the brake intervention speed limit.

The three situations described are shown below. The permitted speed is 140 km/h, the target speed is 60 km/h and the target distance is 760 m.

3.3.3 Approaching an end of authority

On the approach to the EoA, the EVC will calculate a braking curve based on the following:

- Train characteristics, (for example, train weight, braking capacity, maximum permitted speed).
- Route characteristics (for example, gradient, speed profile).
- Distance to the EoA.

The system creates an alert on the DMI if the speed of the train exceeds this curve.

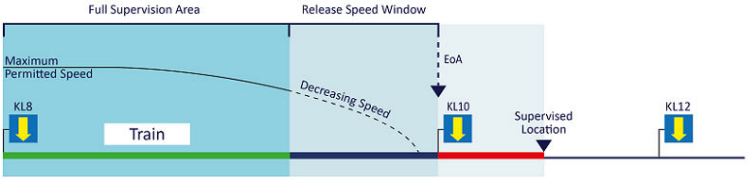
The train can be manually controlled by the driver to bring it within the curve, but if the train is not sufficiently controlled in time, the system will intervene and apply the service train brake or the emergency brake depending on how much the train is exceeding the speed curve.

If the train passes an EoA, the system is designed to bring the train to a stand before reaching the SvL.

3.3.4 Release speed monitoring

If minor odometry error occurs, it will prevent a train from reaching the full extent of its MA and closely approaching the EoA. In some situations, it is important that a train can closely approach the EoA, for example, where the EoA is at the end of a station platform which is only just long enough to accommodate the train. In these instances, the MA permits the use of a Release Speed. The ERTMS onboard equipment uses release speed monitoring to supervise this.

Release speed monitoring is not provided at unmarked EoAs.



Release speed monitoring

In the example shown above, a train is proceeding in FS and the route is set as far as block marker KL10.

The train will be supervised towards this block marker and the on-board equipment will use the train characteristics, and data from the trackside, to calculate a release speed.

At a point calculated by the on-board equipment, when the train speed is below the release speed the train enters into the RSM area.

Supervision will then only be provided against the release speed.

To allow the train to stop at the block marker, the speed of the train is controlled manually by the driver.

3.3.5 On Sight

OS allows a train to enter a portion of line on which a route has been set that could be:

- occupied by another train
- obstructed by any kind of obstacle
- unable to be detected as clear.

The transition to OS mode has to be acknowledged by the driver on the DMI. If it is not acknowledged within 5 seconds, a service brake application is triggered and the system supervises the train to a stand before entering the portion of line to which OS mode applies.

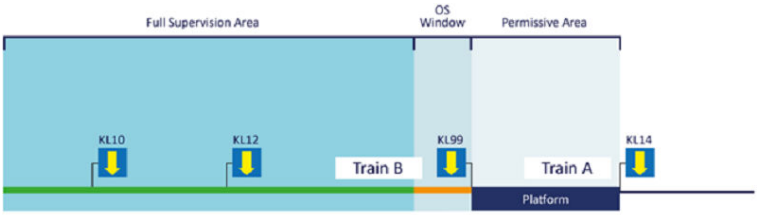
Whilst driving in OS mode, the driver is required to proceed at caution.

A ceiling speed is applicable in OS and is normally set to 40km/h (25mph) by the ERTMS trackside.The on-board system will monitor the train speed and if necessary, will intervene to bring the train in line with the ceiling speed if exceeded.

When a train is required to enter OS from FS, the on-board system will treat the start of the OS area as a new EoA. Once the train speed is below the ceiling speed and the train is within the portion of line where the MA is configured to allow the mode transition to occur the on-board system will offer the mode transition to the driver on the DMI. The driver is required to acknowledge the transition to OS.

The OS MA is displayed on the DMI in the cab as an icon. In OS, the planning area, with the distance to go and maximum permitted speed information, is not shown to the driver by default. However, the driver can manually select the display of the planning area information if needed.

3.3.6 Permissive working



Train B is proceeding towards Train A

On the approach to the permissive area, a transition to OS mode will be offered to the driver. Once acknowledged, the on-board ERTMS equipment will transition, and the permissive movement can take place.

The on-board ERTMS equipment will supervise the train to the permitted speed or OS mode ceiling speed, whichever is the most restrictive.

The driver is responsible for making sure the train is stopped at the required location, and short of any other vehicles in the platform.

If the transition to OS is not acknowledged within five seconds of entering the OS window, the train will be supervised to a stand by a service brake application before entering the permissive area.

3.3.7 Receiving an emergency stop

If an emergency stop is required, the signaller can withdraw either an individual movement authority to one train or use the emergency stop facility to stop a number of trains. In either case the distance to go on the driver's DMI will be immediately shortened to a point directly in front of the train and the train will then be tripped.

3.4 Train running in L-NTC

Level NTC is used by ERTMS fitted trains operating on infrastructure where automatic warning systems (AWS), train protection and warning system (TPWS) or automatic train protection (ATP) are in operation. This level provides no on-board ERTMS supervision and the train is protected by the conventional protection systems.

Trains are therefore driven to the appropriate signalling system concerned.

3.5 End of mission

The end of mission is accomplished when the ERTMS desk is closed.

3.6 Coupling and Uncoupling

SB mode can be used for coupling or uncoupling. Movement in SB mode is limited to a distance of 4 metres (13 feet), and is consequently not appropriate for setting back in most circumstances. Also, if a train has entered a permissive section with an OS MA, if the MA is still available, it can be used to couple to the train in front and there is no need to go to SB.

Company instructions will show how far the movement should proceed.

3.7 Reverse movements

The only ERTMS modes on the GB railway which allow movement in the reverse direction are SB, UN and SH.

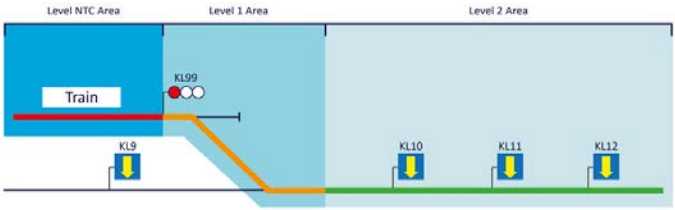
3.8 Propelling

If a propelling movement is required, SH mode is to be used. Further details on use of SH mode can be found in section 2.2.5 of this handbook.

3.9 Starting from a depot or siding using Level 1 launch

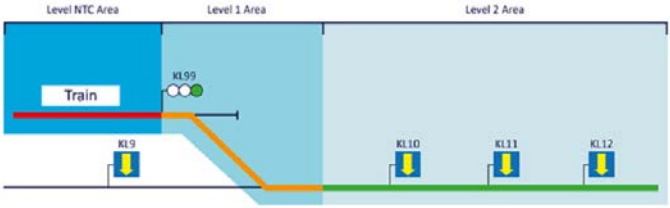
Level 1 Launch provides a method for trains to exit a Level NTC area and transition to Level 2.

Most depots and sidings will operate in Level NTC, however at some locations, Level 2 may be provided throughout the location.



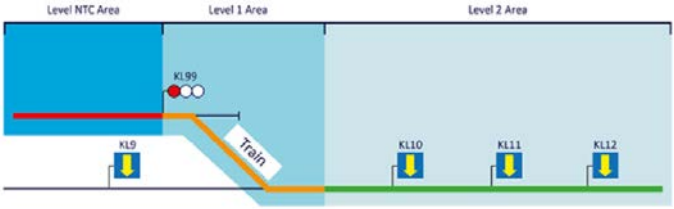
The train is waiting at the exit signal

Movements within the depot take place in Level NTC under the supervision of a competent person. When the train is ready to depart, a manual selection of SN mode is required, prior to approaching the depot exit signal.



The signal clears to a proceed aspect

The Lineside Electronics Unit (LEU) converts the lineside signal aspect into a Level 1 MA, which is transmitted to the train using a balise. When the train passes this balise, the on-board ERTMS equipment is commanded to transition to Level 1 and the train will receive a Level 1 FS MA. An in-cab acknowledgment is required for the transition to Level 1 within five seconds or the train is brought to a stand by a service brake application.



The train transitions to Level 1 and proceeds towards the Level 2 area

The train transitions to level 2

The train is also commanded to contact the RBC automatically, the train will then be instructed through a balise to transition to Level 2 automatically. Once the session with the RBC is established an updated MA will be issued for the extent of the set route. There is no requirement to acknowledge this transition.

4.1 Route setting

Routes are set in the normal manner for the signal box concerned.

4.2 Cancelling routes

When the signaller cancels or shortens a route in the normal way the RBC will send a shortened MA to the train with a new EoA. The on-board ERTMS equipment will recalculate the braking curve needed to stop at the new EoA which may result in an ERTMS brake intervention.

At certain locations, for example on the approach to a diverging junction, the signaller may also be provided with controls that enable them to make a co-operative shortening request.

When the signaller makes a co-operative shortening request, the RBC requests the train to accept a shortened MA with a new EoA.

The on-board ERTMS equipment will calculate if the train can be stopped at the new EoA without an ERTMS brake intervention. Requests that would result in an ERTMS brake intervention are rejected and those which would not result in an ERTMS brake intervention are accepted.

If the request is accepted, the updated MA information is presented to the driver on the DMI and the route beyond the new EoA will be released. This may then allow the signaller to set an alternative route for the train.

If the request is rejected, the route will remain set and the driver will receive no indication of the request.

Co-operative shortening requests can only be issued to trains operating in FS or OS mode.

The driver may observe the MA reduce in the planning information but there are no immediate actions to take.

4.3 Speed restrictions

4.3.1 General

Speed restrictions in ERTMS are mostly managed from a Speed Restriction Management System and are sent to the train as part of the MA. Speed restrictions are only sent to the train in FS or OS mode.

When operating in modes other than FS or OS, the signaller informs drivers of speed restrictions by way of a Written Order (section 8).

4.3.2 Permanent speed restrictions

The speed which is published in Table A of the *Sectional Appendix* which is programmed into the RBC for the route concerned.

4.3.3 Temporary speed restrictions

A temporary speed restriction on an ERTMS line without lineside signals is a speed restriction that has been programmed into the system and is supervised by the on-board equipment when a train is in FS mode. Trains running in OS mode will be supervised to speeds lower then than the ceiling speed 25 mph (40 km/h). Where it is not possible for an MA to be issued, for example in SR mode speeds lower then than the ceiling speed 25 mph (40 km/h) will be shown on the Written Order.

4.3.4 Emergency speed restrictions

Trains will be stopped and cautioned until such time as the speed restriction is either programmed into the system, or is no longer required. Once programmed into the system, the on-board will react to the speed restriction as it would do for any other speed restriction.

4.3.5 Blanket speed restrictions

The blanket speed restriction may be managed by the Speed Restriction Management System and the trains will be supervised to the speed. Any train travelling faster than the specified speed at the time of implementation will receive a brake intervention. This will reduce the speed of the train to comply with the blanket speed restriction.

Where the Speed Restriction Management System cannot apply blanket speed restrictions, existing rules apply.

4.4 Stopping trains in an emergency

Where it is necessary to stop trains in an emergency, the signaller will operate the signal group replacement control. The system will then take action to stop train movements within the affected area and prevent further trains from entering the affected area. The system can only take these actions for trains which are operating in FS or OS mode.

Depending upon where trains are at the time of the signal group replacement control being activated, they may receive a shortened MA, an ERTMS brake intervention or enter Trip mode.

A text message 'Incident ahead, await signaller' may be displayed on the DMI.

Trains which are not communicating with the RBC will need to be stopped by a GSM-R Railway Emergency Call (REC).

4.5 Position reporting

In Level 2, Position reports are sent to the RBC to identify the location the train has just passed.

In Level 2, the on-board ERTMS equipment will send position reports to the RBC when:

- passing over a balise
- changing mode
- completing certain other actions including Start of Mission and End of Mission.

The position of the train is always reported with reference to the last balise group the train has passed over.

As the train travels further from the balise group, the position becomes less certain but when the train passes over the next balise group the train's position is updated and the uncertainty is corrected.

If odometry errors of this kind are not corrected, this can sometimes cause the on-board ERTMS equipment to supervise trains to:

- a stand a long way short of the marked EoA, or
- a lower speed for a longer distance after a speed increase.

This could result in operational difficulties such as the train fouling a junction behind the train.

If the inaccuracy falls outside a certain limit to a point, the on-board ERTMS equipment will transition to System Failure (SF) mode which will command an emergency brake application preventing the movement of the train (see section 2.2.14).

5.1 Controlled crossings

At some locations, the crossing sequence may be initiated by either an approaching train requesting an MA to pass over the level crossing or by the position reports received from an approaching train. These arrangements are only applicable to trains operating in FS or OS modes. The crossing sequence is initiated by conventional means for trains not communicating with the RBC.

Trains will not be issued with an MA to pass over a controlled crossing until the crossing is confirmed as clear.

5.2 Automatic half barrier crossing

At some locations, the crossing sequence may be initiated by position reports received from an approaching train. This arrangement is only applicable to trains operating in FS or OS modes. The crossing sequence is initiated by conventional means for trains not communicating with the RBC.

There are no additional actions for the driver to take when passing over an automatic half barrier crossing (AHBC).

5.3 Automatic barrier crossing locally monitored and automatic open crossing locally monitored

The driver will be warned on the approach to a Locally Monitored Crossing by a text message on the DMI which is required to be acknowledged within five seconds and the approach speed to the crossing is displayed on the DMI.

ERTMS will supervise the train speed over the crossing. Once the front of the train is clear of the crossing, any crossing speed restriction is removed.

Movements will also remain in the current ERTMS mode.

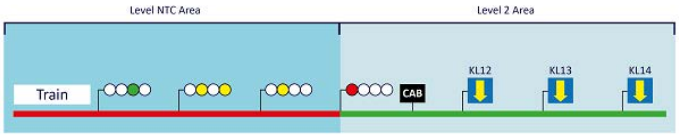
The driver retains responsibility for observing the driver's crossing indicator (DCI) and determining that the crossing is clear.

5.4 User worked and footpath crossings

There are no additional ERTMS requirements for user and footpaths crossings.

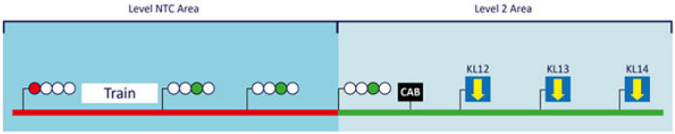
6.1 Level NTC to Level 2 transition

Trains that are configured by the driver to transition will have the TPWS and AWS active in the L-NTC area and ERTMS L2 active in the ERTMS area.



In the above diagram, the route is set across the boundary and into the Level 2 area, but the boundary signal is maintained at danger by the system until the train is communicating with the RBC and the forward MA is accepted by the train.

Balises command the train to contact the RBC. Once the train has connected to the RBC, the RBC sends an MA to the train. Once the train has confirmed to the RBC that it has received the MA, the system can permit the boundary signal to display a proceed aspect as shown in the diagram below.

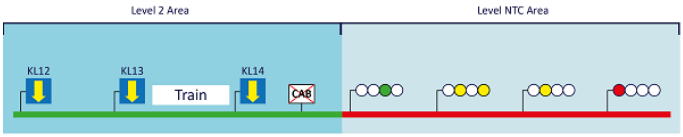


The MA is not displayed to the driver until the train enters the Level 2 area.

The boundary is marked on the lineside with a Start of Cab Signalling board (see section 1.2.2). If the transition is not acknowledged within five seconds of the transition acknowledgement icon appearing, the system applies the service brake. The service brake command is only removed when the transition is acknowledged. The train then continues with an FS MA.

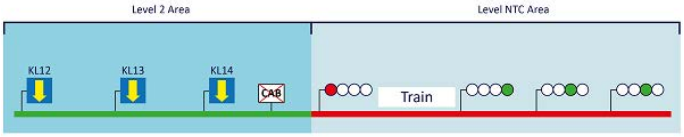
6.2 Level 2 to Level NTC transition

Trains in the Level 2 area approach the boundary under the supervision of an FS MA. Once the route is set into the Level NTC area, the RBC extends the MA before the actual transition point.



Train in Level 2 approaching the transition area

Before the last block marker, a Level Transition Announcement is sent to the train. Upon passing over the boundary, the train transitions to Level NTC in SN mode, the AWS and TPWS protection systems are active, and the train disconnects from the RBC. The train is controlled to the lineside signals by the driver and all the lineside speed restrictions that apply to it.



Train passes the end of cab signalling board and transitions to Level NTC

The boundary is marked with an End of Cab Signalling board (see section 1.2.2). The transition needs to be acknowledged within five seconds of the transition occurring.

If the transition is not acknowledged within five seconds of the 'transition acknowledgment icon' appearing on the DMI, the system then activates the service brake. The service brake activation is removed only when the transition is acknowledged. The train then continues in Mode SN in Level NTC.

7.1 Assisting a failed train

Where it is necessary for a train to be assisted, the leading traction unit of the assisting train always operates in the highest level of supervision available.

The level and mode of the trailing traction unit will be dependent on operational factors, including but not limited to:

- the nature of the failure
- the infrastructure the train is operating on
- driver competence and availability.

7.2 Passing an end of authority without a movement authority

Where the system is unable to issue an MA for a train, and it is necessary for the train to pass the EoA, the route will be set, and a Written Order issued (see section 8).

Once the Written Order has been completed, the Override can be operated to transition the train into SR mode. This inhibits the train trip functionality.

This function allows the train to pass over any balise group present at the EoA, (which contains a Stop if in SR message) without experiencing a trip (see section 2.4.4). The train can be stopped short of any obstruction within that section.

Once the RBC has received a position report and can issue an MA, the train will transition to OS or FS mode. If the RBC cannot issue an MA for the subsequent section, the train will remain in SR mode.

7.3 Tripping

Tripping is activated when an event (dangerous situation) causes a train to trip. The transition to Trip mode can be performed from FS, LS, OS, SR, SB, SH, SN or UN modes, when one of the Trip conditions is fulfilled. The driver is informed by the ERTMS system about the reason for the train trip (see section 2.2.10).

7.4 Transition failures

7.4.1 Level NTC to Level 2

Transition into a Level 2 area will always occur when passing the boundary, when the onboard ERTMS equipment is working. In all the failure modes below, the transition still happens, but if the instructions are not adhered to, the train may be tripped.

Failure of the boundary signal

Where the boundary signal has failed at a Level NTC to Level 2 transition, and the train has been brought to a stand at the lineside signal at the boundary, a route will be set for the driver to be authorised to pass the signal at danger.

Failure beyond the boundary signal

The train is brought to a stand to the lineside signals as shown in module S5 *Passing a signal at danger or an end of authority (EoA) without a movement authority (MA)*. A route is set, before authority is given to pass the signal at danger. As it will not be possible to issue an MA for the forward section, the ERTMS Override function is operated in the cab. This makes sure that upon passing the boundary, and transitioning to Level 2, the on-board ERTMS equipment will enter SR mode. Once in SR mode, the on-board ERTMS equipment will step up to FS or OS mode when possible.

Train does not receive an MA

If the train cannot connect to the RBC due to on-board ERTMS or trackside equipment failure, it will not be possible to issue an MA, and therefore, the line side signal at the boundary will be maintained at danger. The train is brought to a stand at the lineside signal at the boundary.

A manual connection to the RBC is then attempted by the driver. If successful, an MA will be issued, the boundary signal will clear, and the train can proceed.

No connection to the RBC due to trackside failure

If contact cannot be established with the RBC and the on-board ERTMS equipment is working correctly, a route is set, before authority is given to pass the signal at danger. As it is not possible to issue an MA for the forward section, the ERTMS Override function will need to be operated in the cab.

This will make sure that as the train passes the boundary and transitions to Level 2, the on-board ERTMS equipment will enter SR mode. Once in SR mode, the on-board ERTMS equipment connects to the RBC when possible. Once connected, the on-board ERTMS equipment steps up to FS or OS mode as soon as it is able.

No connection to the RBC due to on-board ERTMS equipment failure

If contact cannot be established with the RBC due to an on-board ERTMS equipment failure, the train cannot enter the Level 2 area.

No connection to the RBC due to train operating in an incorrect level

Where a train is configured incorrectly and is unable to transition, there will be no connection to the RBC and the train will not receive an MA.

A change of level is then required. Once the train is in Level 2 an MA will be issued and the train can proceed.

7.4.2 Level 2 to Level NTC

MA unable to be issued into Level NTC area

If it is not possible to issue an MA from the Level 2 area into the Level NTC area due to trackside failure, the signaller and driver apply the rules for passing an EoA without an MA as shown in Rule Book module S5 *Passing a signal at danger or passing an end of authority (EoA) without a movement authority (MA)*. Once the train passes the border, the on-board ERTMS equipment will transition to Level NTC and SN mode. The driver applies the rules for the Level NTC area.

7.4.3 Level 1 Launch transition failures

Signal failure

Where the line side signal at the boundary for a Level 1 Launch has failed, the train is authorised to pass the signal at danger and additionally the ERTMS override is selected. When the train has passed the signal at the boundary, it will transition into SR mode and the DMI updates with an MA when connected to the RBC.

Lineside electronics unit failure

The exit signal will be then held at danger and will be dealt with as a signal failure.

Driver selects incorrect mode

If the train is in the incorrect level or mode, the train will be tripped at the L1 launch boundary.

Level 1 to Level 2

If the train does not connect to the RBC, the Level 1 MA will not be updated, and the train will not transition to Level 2. The train will be brought to a stand at the end of the Level 1 MA, and Level 2 is then manually selected. If the on-board ERTMS equipment successfully connects to the RBC, the train will receive an updated MA and can proceed.

If the onboard cannot connect to the RBC and once instructions have been given for the train to proceed, the driver overrides the EoA and enters SR mode. Once in SR mode, the train will proceed as shown on the Written Order. When the RBC receives a position report, the RBC issues an MA, and the train will transition to OS or FS mode.

If the RBC cannot issue an MA for the subsequent section, the train will remain in SR mode and will be brought to a stand by the driver at the limit of the Written Order, where it will be necessary for the signaller to issue another Written Order for the train to proceed.

If there is no connection to the RBC due to an on-board ERTMS equipment failure, the train is not allowed to proceed on the Level 2 railway and will be returned to the depot.

7.5 Stop and examine

When it is necessary to stop a train and arrange for it to be examined, the signaller will stop the train as shown in section 4.4. Once the train is at a stand, the rules for the specific scenario concerned are applied by the signaller and driver.

7.6 Wrong direction movements

Un-signalled wrong-directions movements can only be authorised by the signaller as shown in module TW7 *Wrong-direction movements*. Either SH or SR mode can be used depending on the circumstances and a Written Order is required.

8 European harmonised instructions

European harmonised instructions also known as Written Orders are instructions issued by a signaller to a driver to authorise certain actions.

The instructions in the Written Orders can be transmitted verbally, verbally to be written down, by using the Written Order forms or by electronic means.

The following Written Orders are used on the GB railway network:

- Written Order No. 1 (RTWO01): Permission to Start in SR or to Pass an EOA.
- Written Order No. 2 (RTWO02): Permission to Proceed after a Train Trip.
- Written Order No. 3 (RTWO03): Instruction to Run at Caution.
- Written Order No. 4 (RTWO04): Permission to Make a Wrong-Direction Movement.
- Written Order No. 5 (RTWO05): Permission to Proceed under Modified Working Arrangements and Bi-Directional Lines.

Each Written Order contains the following:

- Signal box.
- Date and time.
- Train identity.
- The line on which it applies to.
- Any additional instructions.
- Authorisation Number.

Depending on the action being authorised, Written Orders may also include the following:

- The EoA to be passed without an MA.
- The maximum speed the train can travel at including speed restrictions.
- SR speed (where other than the default is to be used).
- SR distance (where other than the default is to be used).
- Permission to start in SR mode.
- Instruction to examine the line.
- Instruction to report findings.
- Instruction to run on sight.

9 Abbreviations used in this handbook

DCI

Driver's Crossing Indicator.

DMI

Driver Machine Interface.

DP

Danger Point.

EoA

End of Authority.

ERTMS

European Rail Traffic Management System.

ETCS

European Train Control System.

FS

Full Supervision mode.

IS

Isolation mode.

LEU

Lineside Electronics Unit.

LS

Limited Supervision mode.

MA

Movement Authority.

NP

No Power mode.

NTC

(Level) National Train Control.

OS

On Sight mode.

9 Abbreviations used in this handbook

PS

Passive Shunt mode.

PT

Post Trip mode.

RBC

Radio Block Centre.

ROC

Rail Operating Centre

RSM

Release Speed Monitoring.

SF

System Failure mode.

SH

Shunting mode.

SN

System National mode.

SR

Staff Responsible mode.

SvL

Supervised Location.

TR

Trip mode.

UN

Unfitted mode.

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