X2Rail-5

Project Title:	Completion of activities for Adaptable Communication, Moving Block, Fail Safe Train Localisation (including satellite), Zero on site Testing, Formal Methods and Cyber Security
Starting date:	01/12/2020
Duration in months:	30
Call (part) identifier:	S2R-CFM-IP2-01-2020
Grant agreement no:	101014520

Deliverable D4.2
Moving Block Enhancements

Due date of deliverable	Month 30
Actual submission date	21-Apr-2023
Organization name of lead contractor for this deliverable	SMO
Dissemination level	PU
Revision	Final

This project has received funding from Shift2Rail Joint Undertaking (JU) under grant agreement 101014520.The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Shift2Rail JU members other than the Union.

Authors & Version Management

Authors	Siemens Mobility (SMO) Bombardier (BTSE) MERMEC (MERMEC) Network Rail (NR) Thales (TD)

Version Management

Version Number	Modification Date	Description / Modification
A	19-Aug-22	First version, combining separate contributions
B	22-Aug-22	Updated version of section 4, addition of Conclusions
C	13-Oct-22	Updated for comments received, prior to WP4 Review
01	17-Oct-22	First version in cooperation tool
02	31-Jan-23	Updated after checking
03	03-Feb-23	Clean version of 02
04	03-Mar-23	Updated after WP4 Review
05	03-Mar-23	Clean version of 04 for TMT/SC Review
06	21-Apr-23	Updated after TMT/SC Review
07	21-Apr-23	Clean version of 06
08	21-Apr-23	PDF version of 07

Executive Summary

This document forms X2Rail-5 Deliverable D4.2 Moving Block Enhancements.

The document examines several proposed enhancements to the current conception of ETCS Level 3, and assesses the impact these enhancements could have on the main deliverable from X2Rail-5 WP4, which is Deliverable D4.1 Moving Block Specification.

Deliverable D4.1 has been written for ETCS Level 3 based on the following baseline:

Baseline 3 Release 2 [BL3 R2] + CR940 [CR940]

The proposed enhancements examined are:

Proposed Enhancement	Source
Mobile Object Locator	RCA
Always Connected, Always Reporting	CR1350
Cab Anywhere	CR1367
Merge of L2 and L3 to create LR	CR1342
Standstill Reporting	CR1363
Mode “AD” for ATO	CR1238

For each of these proposed enhancements, the following process was followed:

A) State the assumptions relating to the topics, and the likely solution within the existing specifications, if this is applicable
B) Study the impact on D4.1 Moving Block Specification
C) Form a conclusion as to the scale of the impact on D4.1 Moving Block Specification

The conclusions divide the proposed enhancements into three groups, depending on their potential impact on D4.1 Moving Block Specification:

1) Minor impact – almost editorial
2) Medium impact – with minor changes required
3) Large impact – significant changes required

Table of Contents

Table of Figures

Table of Tables

Abbreviations and acronyms

Abbreviation / Acronyms	Description
AD	Proposed new ETCS Mode: “Automatic Driving”
ATO	Automatic Train Operation
BG	Balise Group
CCM	Change Management system for TSIs
CCS	Control Command and Signalling
CR	Change Request
DAC	Digital Automatic Coupler
DMI	Driver Machine Interface
EoA	End of Authority
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FFFIS	Form Fit Functional Interface Specification
FMB	Full Moving Block
FS	ETCS Mode: Full Supervision
GoA2	Grade of Automation 2. Semi-automated train operation
GoA3/4	Grade of Automation 3 / 4. Driverless / Unattended train operation
L2	ETCS Level 2
L3	ETCS Level 3
LOC&PAS	TSI for Locomotives and Passenger Rolling Stock
LR	Proposed new ETCS Level Radio, to replace L2 and L3
LS	ETCS Mode: Limited Supervision
LX	Level Crossing
MA	Movement Authority
MB	Moving Block
MOL	Mobile Object Locator
MSFE	Maximum Safe Front End
mSFE	Minimum Safe Front End
NL	ETCS Mode: Non-Leading
NP	ETCS Mode: No Power
OPE	TSI for Operation and Traffic Management
OS	ETCS Mode: On Sight
PT	ETCS Mode: Post Trip
RCA	Reference CCS Architecture
SB	ETCS Mode: Standby
SH	ETCS Mode: Shunting
SM	Proposed new ETCS Mode: Supervised Manoeuvre
SR	ETCS Mode: Staff Responsible
SRS	System Requirement Specification. Used to refer to documents in CCS TSI.
SvL	Supervised Location
THR	Tolerable Hazard Rate
TIMS	Train Integrity Monitoring System
TMS	Train Management System (context AD mode)
TR	ETCS Mode: Trip
TSI	Technical Specification for Interoperability
TTD	Trackside Train Detection

1 Introduction

This document forms X2Rail-5 Deliverable D4.2 Moving Block Enhancements.

The document examines several proposed enhancements to the current conception of ETCS Level 3, and in particular assesses the impact these enhancements would have on the main deliverable from X2Rail-5 WP4, which is Deliverable D4.1 Moving Block Specification.

Deliverable D4.1 has been written based on the following baseline for ETCS Level 3:

Baseline 3 Release 2 [BL3 R2] + CR940 [CR940] dated 16-04-2020

The Methodology section below describes the process used to create this document, and also lists the Enhancements which have been assessed.

2 Methodology

2.1 Method

The process followed in X2Rail-5 WP4 Task 4.3 was as follows:

1) Identify a list of possible enhancements to the Moving Block system described in Deliverable D4.1 Moving Block Specification, which is in turn based on ETCS Baseline 3 Release 2 plus CR940
2) For each of these topics the process followed was:
    A) State the assumptions relating to the topics, and the likely solution within the existing specifications, if this is applicable
    B) Study the impact on D4.1 Moving Block Specification
    C) Form a conclusion as to the scale of the impact on D4.1 Moving Block Specification

2.2 Topics

The following topics were identified, and are listed in the table below. Where applicable, an ERA Change Request number is also given.

Topic	ERA Change Request if applicable
Mobile Object Locator	-
Always Connected, Always Reporting	CR1350
Cab Anywhere	CR1367
Merge of L2 and L3 to create LR	CR1342
Standstill Reporting	CR1363
Mode “AD” for ATO	CR1238

Table 1: Table of Enhancement Topics

Where applicable, the solutions for the CRs available during the preparation of this document in the 3rd quarter 2022 were used.
These solutions have been updated in parallel with the preparation of this document.

For each of these, there is a section below.

3 Mobile Object Locator

3.1 Background

In 2020, a topic called “Moving Block Architecture - Gap Analysis” was assigned from Linx4Rail to the TD2.3 Moving Block work package. The goal of the task was to “Identify any gaps between the RCA architecture and TD 2.3 architecture assumptions.”. The results of this task are described in a report [Linx4Rail]. The major gap identified in comparing the System Boundaries of the TD2.3 Moving Block and the RCA Architecture is the Mobile Object Locator (MOL) which is not part of the TD2.3 architecture.

3.2 Assumptions

MOL provides the position of a track bound or a non-track bound object on the railway network topology. This is intended for objects other than communicating trains to be automatically located within the trackside system.

Neither X2Rail-3 D4.1 nor ETCS as defined in the CCS TSI contain an equivalent interface. The concept in D4.1 was that any other item on the track would possibly be represented by a non-sweepable “Unknown” Track Status Area which can be created, updated, and cleared by the Control System. These actions could be performed automatically by the Control System, depending on the level of automation within the Control System.

3.3 Impact on ETCS System

For ETCS On-Board there is no impact.

The ETCS Trackside could possibly be impacted by a new interface to the MOL.

3.4 Impact on D4.1 Moving Block Specification

If the functionality related to MOL is required to fulfil SIL4, a new interface is required between L3 Trackside and the MOL. L3 Trackside would then need to process information from the new external interface. The impact would be changes to existing requirements relating to train positioning and track status, and extra system requirements to manage the creation of “Unknown” track status based on the information received.

If the functionality related to MOL is required to fulfil SIL2, the interface between the MOL and L3 Trackside would be via the Control System. In this case the Control System processes the information from the MOL. The impact would be largely editorial since the L3 Trackside would receive the same commands as if the “Unknown” area were created by the Dispatcher.

The current assumption is that the MOL information is represented by an “Unknown” Track Status Area within L3 Trackside. Either L3 Trackside creates/updates/removes “Unknown” Track Status Areas, or this is done via the Control System depending on how the interface is implemented. Which solution is selected may be influenced by the Safety Integrity Level required. The solution

selected will also determine the impact. If there is a new direct interface to the L3 Trackside, then there is considerable impact. If the interface is via the Control System, then there is little impact.

Once the MOL interface requirements are defined the use of “Unknown” Track Status Area should be re-visited. For example, to manage the MOL information, Non-Sweepable “Unknown” Track Status areas could be used. Or there may be a need to introduce new status information like “Forbidden” which would not allow a train to enter the area at all.

3.5 Conclusions

Consideration of the MOL could possibly result in a new external interface and requirements.

4 Always Connected, Always Reporting

4.1 Background

The Infrastructure Managers and representatives of the freight/cargo businesses met in November 2016 to discuss how shunting activities should be managed on a railway. One of the conclusions was that a first step to improving the safety management of movements in SH was for the ETCS Onboard to remain connected and be able to report a position and accept emergency stop messages.

In a Level 3 environment where there may be multiple trains within a single trackside train detection (TTD) section, or there may be no TTD provided, then the safety of the system relies on the Trackside being aware of the position of all vehicles within the control area. The maintenance of communication sessions and reporting of train position in all relevant modes supports the safe operation of the system particularly in degraded scenarios.

4.2 Assumptions

Despite CR1350 being raised primarily to improve the management of movements in Shunting mode, the scope of the solution was reduced within the ERA Change Control Management procedure. The agreed solution only allows for sessions to be maintained following an EoM to Standby mode with the desk closed. The solution maintains the radio session until instructed by the Trackside to terminate the session.

4.3 Impact on ETCS System

Implementation will lead to an increase in the number of safe communication sessions and the radio bearer will need to have the necessary capacity.

The ETCS Trackside and Onboard will need to maintain the safe radio connections in accordance with Subset 026, Chapter 3.

The ETCS Trackside will need to be capable of requesting that the ETCS Onboard terminates sessions in accordance with the project's engineering rules and those rules will need to be established.

4.4 Impact on D4.1 Moving Block Specification

The impact of the solution to CR1350 means that Train Position Reports can now be received in SB mode after End of Mission has been performed. This means that, with the appropriate changes to the L3 Trackside, some mitigation can be implemented for hazards listed in D4.1 Part 6. Specifically, the following hazards regarding undetected train movement:

a) H-Movements-001 – Undetected backwards movement after standstill
b) H-Movements-004 – Undetected movement after End of Mission

In the current version of Part 6, maintaining a communication in SB mode is specifically mentioned as a mitigation for both these hazards. To implement this, there would also need to be changes to the Requirements in Part 3, most likely additional Requirements:

- To ensure that Train Position Reports are received in SB mode, by not requesting session termination.
- To process Train Position Reports received in SB mode, to detect if they indicate a hazardous situation.
- If a hazardous situation is detected, to react to protect the train which has moved.

Given implementation of the mitigation outlined above, the corresponding Engineering Rule in Part 5, which requires provision of TTD where trains are regularly left without a communication session, should be re-assessed.

4.5 Conclusions

The solution to CR1350 provides an opportunity to implement mitigation for some hazards associated with undetected train movements in SB Mode. This would have a medium impact on D4.1.

5 Cab Anywhere

5.1 Background

For the shunting movements the existing specification of the ERTMS/ETCS system can only provide a partial protection consisting in a ceiling speed monitoring by the on-board (speed profiles cannot be supervised because train data are not required in SH mode) and in the check of the boundaries of the SH area. The SH area may be protected by the on-board supervising a list of BGs (received from trackside) that are expected in the area and applying brake reaction when a BG not in the list is passed. A SH area can also be protected by balise groups sending "Danger for SH" information, which triggers a transition to TR mode. When in SH mode the ETCS on-board is not connected to trackside and this is an outstanding issue, especially for Moving Block applications without TTDs.

To improve the overall shunting operations, the enhancement CR1367 "*Cab Anywhere*" has been submitted in the CCM process of ERTMS specification as part of Level 3 Game Changers for the CCS TSI to be updated in 2022.

The main goal of the CR1367 is to introduce speed and distance supervision of shunting movements in Level 2 and Level 3. To achieve this goal, the proposal of the CR is to assign an MA also to the trains performing shunting operations. This solution may provide a more complete protection together with an enhancement of the performances of this important railway process.

The possibility to have trains reporting their positions during shunting movements is also beneficial for the Full Moving Block applications without TTDs, because the trains can be always localised.

5.2 Assumptions

The operational constraints at the base of the CR1367 solution can be defined by the train configurations described in the following Figure 1 and Figure 2 where the positions of the leading engine and of the active cab have been identified. In particular the driver can be positioned in the front, in the middle or in the rear of the train and, from each position, the driver can initiate forward or backward movements, as usually done in shunting operations. When the driver has no visibility of the track ahead, because not located in the front of the train or because moving backward, external measures outside the scope of the ERTMS/ETCS have to be provided to support the operations defined in CR1367 (e.g. cameras, staff in the front of the train, etc.).

For all shunting movements, the trackside shall be able to assign an MA protecting the track crossed by the train and the on-board shall be able to accept it. Since during shunting the train moves back and forth to reach the correct destination, both subsystems shall be able to quickly request and assign the correct MA.

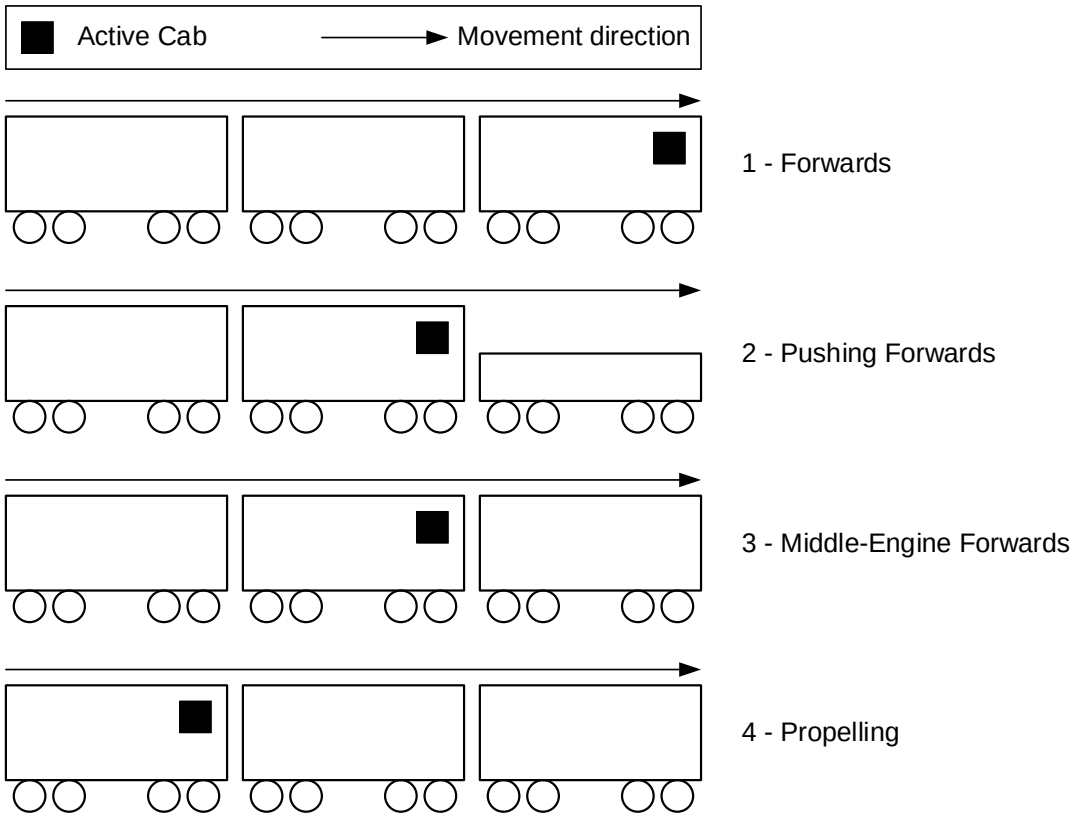

Figure 1 – Configurations for forward shunting movements

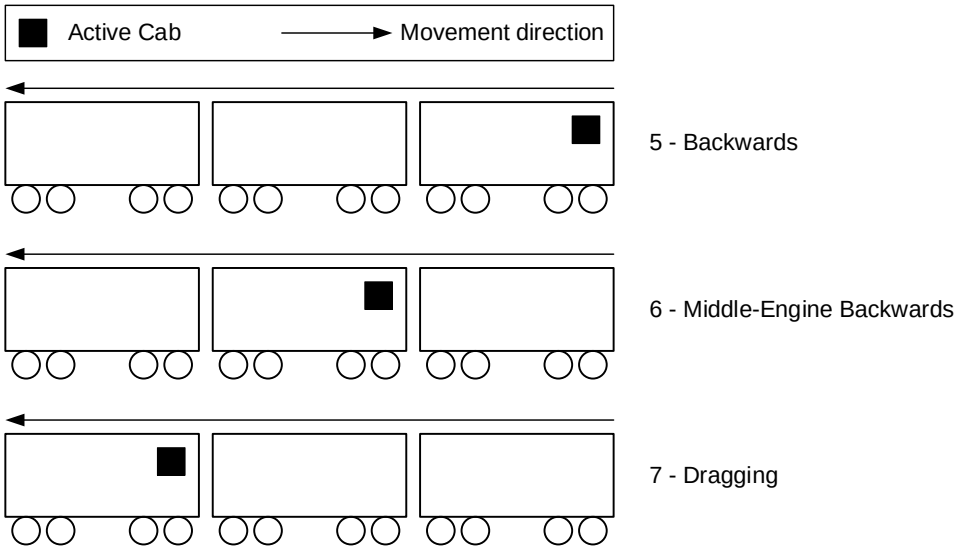

Figure 2 – Configurations for backward shunting movements

The introduction of this CR1367 has a relevant impact on many different aspects, both at technical and operational level. The availability of devices (e.g. TIMS, DAC) fit for the purpose of "Cab anywhere" needs and the harmonisation of all TSI (not only CCS but also LOC&PAS and OPE)

to cope with this concept is not in the scope of this analysis carried out in the context of X2Rail-5, Task 4.3.

At the time being, the discussion on CR1367 is still in progress and this document is based on the state of the CR solution at the end of 2022.

The discussion on CR1367 has exported some constraints also on the agreed solution of CR940 "*Minimum Safe Rear End position and position reporting ambiguities*" already published in the ERA Technical Opinion 2017/2020 and used as a basis for all the Moving Block specification in all Shift2Rail projects for TD 2.3 "Moving Block Systems". The changes on the CR940 are also shortly mentioned in the present section. Also the development of CR1304 "Missing Level 3 safety requirements" is proceeding in parallel with the "Cab anywhere" proposal and is impacting the ETCS specification by the SIL for both train integrity and train length. Some topics of CR1304 are mentioned in this section if relevant for the CR1367 and CR940.

In conclusion, the following technical assumptions can be considered agreed in the solution proposal of CR1367 (see paragraph 5.3 for more details):

- shunting movements can be protected with this enhanced concept only in Level 2 and Level 3;
- the enhanced SH will be performed in a new mode, named SM "Supervised Manoeuvre"; the transition to SM is possible from SB, FS, AD, OS, LS, SR, PT while the possible transitions from SM are to NP, SB, SH, NL and TR (plus the degraded modes IS and SF);
- trackside and on-board must determine the position of the supervised front end of the train, regardless of the position of the leading engine (i.e. active cab);
- trackside shall be able to provide an MA to trains regardless of the position and orientation of the leading engine;
- train length for enhanced SH movements shall be acquired by technical means different from the driver (who shall not be involved, neither in the validation process) with an adequate THR that has been assumed to be at least SIL2 (input from CR1304)
- train length for enhanced SH movements will be composed by the sum of two parts:
    - distance from the front of the leading engine to the front end of the train;
    - distance from the front of the leading engine to the rear end of the train.

However, it is confirmed that the overall train length sent in position report shall be of a quality corresponding with SIL4.

5.3 Impact on ETCS System

The extent of changes on the ETCS system given by the CR1367 is relevant for both trackside and on-board subsystems.

The protection of shunting movements has required the addition of a new mode, completely different from SH, that is able to support the MA management either in the direction of the train orientation or in the opposite direction. The new SM (Supervised Manoeuvre) mode and related

function can be compared with the existing modes where a complete supervision and cab signalling is active, e.g. FS, OS, even if many differences exist for this mode.

A new procedure has been defined for the management of this enhanced shunting. The SM mode is only entered following a driver request (DMI action and new train to track message "*Request for Supervised Manoeuvre*"), and a consequent trackside authorisation containing the SM Movement Authority (new track to train message "*SM Authorisation*"); trackside could also reject the request (new track to train message "*SM refused*").

The MA for supervised manoeuvres contains (like in FS) only unidirectional information and will determine the train orientation. Since in SM mode the orientation is determined by trackside, when the orientation of an MA is opposite to the current train orientation all the on-board stored data will be deleted. Also, the train position shall be reverted moving the Estimated Front End, MSFE and mSFE backward according to a defined rule that takes into account the train length (determined by an ETCS external source). The driver will see on the DMI the forward/backward direction of the assigned MA. In the current solution, when a train in SM arrives at the EoA, the MA extension (in the same or in the opposite direction), can be assigned by the Trackside, or requested by the Driver, with the on-board remaining in SM mode. The trackside is the only responsible to assign the new MA in SM mode. The driver indeed has no means to inform the trackside about the expected direction of the next MA.

The SM mode (i.e. an MA for a protected shunting movement) can be initiated at the end of a SoM (from SB mode) or after a journey in FS, AD, OS, LS or from SR and PT mode.

On a shunting consist, the supervision of movements against a dynamic speed profile is not possible without train data. Since it is not operationally acceptable to insert train data into a leading engine performing shunting movements, the CR1367 solution introduces the new concept of "Default Train Data" configured on-board. These configurations can be defined once in the data preparation / engineering process, being dimensioned for the worst-case scenario.

The train length is obviously an exception to the default train data concept because the real length must always be used for the overall system safety operation (both for the on-board speed profile supervision, and for trackside track status determination). A new definition "safe consist length" has been added in the ETCS specification for determining the length of the whole train and is applicable to the configurations described in Figure 1 and Figure 2. The safe consist length information comprises the following six elements:

- L_CONSISTFRONTENGINENOM = nominal distance from the front of the leading engine to the train front end
- L_CONSISTFRONTENGINEMAX = maximum distance from the front of the leading engine to the train front end
- L_CONSISTFRONTENGINEMIN = minimum distance from the front of the leading engine to the train front end
- L_CONSISTREARENGINENOM = nominal distance from the front of the leading engine to the train rear end

- L_CONSISTREARENGINEMIN = minimum distance from the front of the leading engine to the train rear end
- L_CONSISTREARENGINEMAX = maximum distance from the front of the leading engine to the train rear end

Only if the safe consist length has been received by the train interface a mission in SM mode can be performed and the Default Train Data shall be used (entering in SM mode invalidates the Train Data). When the "safe train length" is available on-board for a train performing a normal mission, the variable L_TRAIN will be set to L_CONSISTREARENGINEMAX because it is assumed that the leading cab is located at the front of the train.

The applicability of SM mode to RBC handover is limited by an ETCS engineering rule in order to avoid the transmission of an SM Authorisation across borders involving RBCs having a system version X.Y lower or equal to 2.1.

In SM mode the level transitions towards levels different than Level 2 or Level 3 are not permitted by engineering rules and the permitted level transitions are managed as for SH mode: the announcements have to be ignored and the immediate/conditional orders stored on-board are evaluated at the exit of SM mode.

Hereafter some grey areas of the CR1367 proposal at the time of writing.

The TIMS devices shall support detection of integrity loss not only in rear of the leading engine but also in advance of it. Even if this is an implementation topic, the current X2Rail Train Integrity workstream has not followed this principle.

The existing concept of the ETCS train integrity function, as defined in SRS / CR940, is based on reporting to trackside the current estimated train front position and its confidence interval (i.e. position of the leading engine) and the position of the train rear end frozen at the location where the min safe rear end was at the last time the train integrity was confirmed. In this track extent all the train parts shall be located (assuming vehicles not rolling back due to downhill gradients). But now, assuming that the integrity can be lost also in the front part of the train, there can be some uncertainty about the actual extent of track occupancy. The current solution proposal requests to continue considering the train front as before when integrity is lost.

The safe consist length concept has been integrated also in CR940 together with the new SM mode: they have been added in the definition of the Train Integrity Reporting and in the Train Integrity transition table. When an SM mission is performed, the availability on-board of the safe consist length is necessary to transition to "TI confirmed by an external source". When the on-board is configured to receive the safe consist length via the Train Interface, there could be a transition to integrity lost information regardless of any available information about the safe consist length. For example, when a loss of integrity is detected, the safe consist length value reported at the interface is not relevant.

5.4 Impact on D4.1 Moving Block Specification

There would be considerable impact on D4.1 Moving Block Specification, because of the complexity of the proposed solution:

- New Mode: Supervised Manoeuvre.
  The proposed new Mode "SM" is considerably different from other modes.
- New rules required to determine the track occupancy of a train in SM mode.

5.5 Conclusions

Whilst there may be a large benefit in being able to supervise all shunting manoeuvres, this new function has a large impact on the ETCS system. This means that considerable work is required to fully understand the impact of the solution.

6 Merge of L2 and L3 to create LR

6.1 Background

CR1342 questions the need for co-existence of Level 2 and Level 3. The CR argues that for a mixed Level 2 and Level 3 area there is no difference between trains operating in Level 2 (without a train integrity device) or Level 3 (with train integrity device) in respect to the received MA. Furthermore, the ETCS on-board behaviour is not clear in the case where the ETCS Trackside orders both Level 2 and Level 3 (e.g. level transition). The CR proposes a solution to make the definition of Level 2 and Level 3 exclusive or merge the two.

6.2 Assumptions

The current solution proposal for this CR suggests merging Level 2 and Level 3 into a new level called Level R (R for Radio). Translation of values for different system versions will be required.

From an operational rule perspective [OPE] there is currently no need to differentiate between Level 2 and Level 3.

6.3 Impact on ETCS System

For ETCS On-Board and ETCS Trackside there is no significant functional change according to the current ERTMS specification.

The ETCS On-Board DMI will need to display Level R.

Systems interfacing to ETCS Trackside may be impacted by CR1342 (e.g. diagnostics, TMS). In some projects drivers may see Level R displayed on the DMI while trackside Level 2 or Level 3 is logged or presented to the dispatcher.

6.4 Impact on D4.1 Moving Block Specification

The impact on the Moving Block Specification is for the most part editorial by simply replacing Level 2 and/or Level 3 with Level R.

However, Part 1 of the Moving Block Specification states that the “Moving Block Specification assumes ETCS Level 2 [BL3 R2] together with the Change Request associated with Train Integrity, CR940 [CR940], as a baseline.”. As Level 2 and Level 3 will be replaced by Level R, this text needs to be changed in order to avoid defining all requirements for Level R. For example, the sentence could be changed to read: “Moving Block Specification assumes what was previously known as ETCS Level 2 [BL3 R2] …as a baseline.”

It may also be sensible to re-emphasise the scope of D4.1. At present, D4.1 only covers changes required for ETCS Level 3 beyond ETCS Level 2, based on the team’s understanding of the functions, configuration, and application of ETCS Level 2. This would become the changes required for ETCS Level R, beyond ETCS Level 2.

In addition, when replacing Level 3 in “Level 3 Trackside” by Level R it should be considered that some text to explain the scope is needed to avoid misunderstandings in respect to the contents of the specification.

6.5 Conclusions

The impact of CR1342 on the Moving Block Specification is of editorial nature.

7 Standstill Reporting

7.1 Background

The current ERTMS/ETCS SRS requests from an on-board to report its position to trackside when the train reaches standstill through the Message 136 “Train Position Report”. But in this message, there is not an explicit indication of the standstill condition but only the train speed that is provided through the variable V_TRAIN which has a resolution of 5 km/h. This means that, depending on specific on-board implementation, the train speed might be reported to trackside as 0 km/h or 5 km/h whenever the train estimated speed is in this range. In particular, 0 km/h may be reported before the train has come to a stand.

This on-board system behaviour exports to each trackside specific implementations the responsibility to determine when a train has actually stopped. For example, more Train Position Reports might need to be received before the trackside can conclude that the train has stopped (e.g. by evaluating if speed and location of the train do not change). These implementation constraints generally delay the trackside tasks related to, e.g. releasing the routes, guaranteeing the flank protection, etc., negatively affecting the line performance.

It has to be noted that reporting the standstill condition state each time it changes (i.e. also when the train leaves standstill) might be used by trackside to perform tasks with major benefits in a FMB system without TTD (a possible benefit has been presented in section 7.4).

7.2 Assumptions

The solution of the CR1363 “Standstill report to trackside” considered for this document is the “analysis completed” version issued on 04/05/2022. The on-board will be requested to provide the indication of the standstill condition in the position report transmitted when the standstill is reached by the train and in all the following Train Position Reports, as long as the train is at standstill. With this direct information the trackside will quickly perform all the tasks connected to the information of a train reaching to a stand.

A further enhancement consisting in the transmission of a Train Position Report when the train leaves standstill, has been also implemented by this CR.

The standstill will be reported setting the variable V_TRAIN at the special value 127 “Standstill” in the Train Position Report. This special value (i.e. the standstill condition) will be reported only to RBCs having version 2.2 or higher, while the speed 0 km/h will be reported to RBC of older versions.

7.3 Impact on ETCS System

Since the standstill condition is not standardised but is a supplier specific condition (e.g. different thresholds of speed may be used to enter or leave the standstill state), it cannot be excluded that, after reaching standstill, a train can move again without reporting a change of state (i.e. the train

moves at a speed lower than the threshold for leaving standstill or the new position report can be lost).

For this reason, it is a trackside specific implementation responsibility to determine that the train is not moving after having reported the standstill prior to release of infrastructure. This could be critical in particular for trains not having an MA (i.e. for which it is not possible to rely on the supervision of the SvL) and for trackside that does not use TTD.

7.4 Impact on D4.1 Moving Block Specification

The implementation of this function in the ERTMS/ETCS on-board does not directly impact the Moving Block Specification, because this enhancement is applicable also to Level 2 and not only to Level 3 systems (the Moving Block Specification does not currently use the standstill information from a train).

However, it could be worth to add (in blue text as provision for future ETCS specifications) an extra guidance to the requirement REQ-Reserved-8 to link the train standstill report to the release of parts of the track (e.g. the overlap). But, as already described in section 7.3, this guidance should also mention that the standstill report has to be carefully handled by the trackside.

To increase the performance of the overall railway system, the trackside could optimise the closing time of LX barriers, e.g. triggering a request to close the barrier only when a train standing in rear of a LX, restarts moving. This function would minimise the interference of trains with the road traffic.

7.5 Conclusions

The implementation of this change would bring a benefit because the explicit reporting of the standstill condition will be a more efficient means for the Trackside to determine that this train is at a standstill. This would reduce the time for the trackside to command all the functions needing the standstill as a pre-condition (e.g. route release) that today have to be derived implicitly through the evaluation of more Train Position Reports.

Moreover, when TTDs are not used, the information that a train is leaving status of standstill might be used to trigger specific actions (e.g. close LX).

Even if this feature can be used in all system types and all levels to improve the capacity performances, the L3 without TTDs is the application where the benefit is greater and it is important to assure the standstill condition for the flank protection.

The impact on D4.1 deliverables is minor and consists only in giving guidance on the potential use of this new functionality.

8 Mode “AD” for ATO

8.1 Background

The definition of an Automatic Train Operation (ATO) integrated in the ERTMS/ETCS system is one of the game changers that will be included in the next CCS TSI.

The ATO technology is a powerful tool to achieve higher capacity, punctuality, energy saving and power distribution planning in the European Railway.

The main scope of the ATO over ERTMS/ETCS specification (hereinafter ATO/ERTMS) is to define a set of non-safety-related functions, currently assigned to drivers, like speed control (traction and braking), accurate stop at EoA or operational stopping points, door control (opening and closing), etc., and other functions aimed to connect trains to the trackside planning systems (TMS) to better manage route conflicts and, in general, an optimised use of the railway infrastructure. The safety of operation is out of the scope of ATO and remains allocated to ETCS or other safety related train systems.

The inclusion of ATO/ERTMS in the CCS TSI has the aim to avoid proliferation of many different national solutions.

8.2 Assumptions

The ATO/ERTMS is a flexible system supporting the operation with 4 different Grades of Automation (GoA), depending on how much the train staff is involved in train operation. The GoA of ATO/ERTMS finally depends on user requirements, i.e. how both trackside and trains have been fitted with ATO technologies.

The current analysis is limited to GoA2 (Semi-automated train operation), that is the only system specified in the enhancement CR1238 “Automatic Train Operation over ETCS”.

In GoA2 ATO/ERTMS a train driver is always in the cabin, is responsible to authorise the start of automated driving and can take at any time the control of the system overriding the automatic commands on traction / brakes or doors.

The X2Rail-4 project is currently working on the specification of GoA3/4 (driverless/unattended train operation) ATO/ERTMS that will not be part of the next CCS TSI.

8.3 Impact on ETCS System

The ATO/ERTMS specifications cover the whole system, including on-board and trackside ATO subsystems but the impact on ERTMS/ETCS can be summarised with the following changes:

- definition of a new ETCS on-board mode “AD” (Automatic Driving”);
- integration on the DMI of new ATO information;
- introduction of a new FFFIS for the exchange of information between ATO and ETCS on-board.

The AD mode shall be entered, upon driver request, when the ATO/ERTMS on-board has all the information and conditions to automatise the driver actions on traction/brakes and doors. The AD mode is not determined by a trackside related condition (e.g. there is not a mode profile associated to the MA) but the driver can trigger the transition in this mode only from FS mode.

As defined by CR1238 in the new requirement of Subset 026 4.4.16.1.4, when in AD mode: "*The ERTMS/ETCS on-board equipment shall supervise train movements in the same way as in Full Supervision mode, except that for the speed and distance target speed monitoring when an SBI supervision limit is exceeded neither a brake command nor the intervention status shall be triggered*".

Apart from the relevant development of the ATO subsystems and on ERTMS/ETCS on-board, the major impact on the ETCS trackside system is given by the introduction of a new mode and its backward compatibility management (in train to track airgap and RBC/RBC interface) since an extension of variables depending on the ETCS mode (i.e. M_MODE, M_MODETEXTDISPLAY) has been necessary.

8.4 Impact on D4.1 Moving Block Specification

The definition of ATO/ERTMS has in principle no significant impact on the Moving Block Specification because, as described in section 8.2 and section 8.3, in GoA2 the only effect of ATO is to assign to a different entity some of the train controls, without specific new signalling functions. It must be specified in the MB Specification that all the requirements / rules applicable to FS mode are also valid for AD mode: a specific assumption (e.g. in Part 2 "System Definition") or a systematic mention of the AD mode should be added to all the instances of FS mode in the MB documentation.

One of the ATO functional requirements defined in Subset 125 [SS125] that could possibly be of interest for Moving Block specification is the section 9.1.2.1 that defines the ATO engagement conditions, i.e. the conditions to allow automatic driving (i.e. AD mode). In particular, the following conditions have to be met by the MA assigned to trains that are standing to allow the restart of the automatic driving:

a) *While the train is stopped at a platform area, the MA shall be such that the train is able to leave the platform completely based on estimated rear end;*

b) *While the train is stopped outside a platform area, the MA allows the train to move (the minimum distance to allow proceeding is train specific).*

Even if this rule is already covered in D4.1 Moving Block Specification – Part 3 – System Specification by REQ-MA-4 "*The L3 Trackside shall be configurable to only issue Movement Authority updates relevant for operation of the railway*", where a specific mention to ATO is already given in the related guidance, a more explicit hint may be provided (e.g. on those tracksides where an MA that does not respect the clause 9.1.2.1 a) is transmitted for operational reasons, drivers should be instructed to manually depart).

The display to trackside operators of the AD mode maybe considered as a project specific choice that does not deserve to be defined in the MB specifications.

8.5 Conclusions

The impact of ATO/ERTMS on Moving Block specification is not relevant in GoA2, mainly editorial changes are requested to add the AD mode in the documentation.

Much more effort will be needed when integrating higher levels of automation, but these are not part of the current specification and have not been considered in this paper.

A guidance on the engineering of MA updates is already provided in the current System Specification, even if a possible extension of the guidance of the existing requirement REQ-MA-4 could be added for a better understanding of the possible impacts of short MAs on ATO performances.

9 Conclusions

The potential enhancements described within this document are divided into three groups, depending on their potential impact on D4.1 Moving Block Specification:

1) Minor impact – almost editorial
2) Medium impact – minor changes required
3) Large impact – significant changes required

9.1 Enhancements with Minor Impact

Enhancements with Minor Impact	Notes
Merge of L2 and L3 to create LR	Editorial impact
Standstill Reporting	Minor impact. Some system benefits, for example faster route release
Mode “AD” for ATO	Minor impact. “AD” mode is similar to “FS” mode, from the point of view of the ETCS Trackside

Table 2: Enhancements with Minor Impact

It is recommended that D4.1 Moving Block Specification is updated with these enhancements, in a future project.

9.2 Enhancements with Medium Impact

Enhancements with Medium Impact	Notes
Always Connected, Always Reporting	Current CR solution enables some hazard mitigation for undetected movement in SB mode. Potential additional benefits, if a more general solution is adopted.

Table 3: Enhancements with Medium Impact

It is recommended that D4.1 Moving Block Specification is updated with this enhancement, in a future project.

For “Always Connected, Always Reporting”, there would be some potential additional benefits in being able to reduce or remove the Trackside Train Detection (TTD) if all cabs of all trains can report their location in all Modes except for NP. This would be a change to the current CR1350 solution. If this change is made, then the impact on D4.1 Moving Block Specification would become “Large Impact”.

9.3 Enhancements with Large Impact

Enhancements with Major Impact	Notes
Mobile Object Locator	Significant impact, if there is new safety interface for the ETCS Trackside, which would require new or modified algorithms within the ETCS Trackside to calculate track occupancy.
Cab Anywhere	Significant impact, as there are new or modified algorithms required within the ETCS Trackside to calculate track occupancy.

Table 4: Enhancements with Major Impact

It is recommended that alternatives are studied before implementation of these enhancements in D4.1 Moving Block Specification.

For the Mobile Object Locator, consideration should be given to the alternative of using the Control System interface of the ETCS Trackside to provide the function of protection between Trains and other Mobile Objects on the railway.

10 References

The following references are used in this document:

[BL3 R2] Set of specifications # 3 (ETCS Baseline 3 Release 2 and GSM-R Baseline 1) according to Annex A of Commission Implementing Regulation (EU) 2019/776 of 16 May 2019.It is publicly available:
https://www.era.europa.eu/content/set-specifications-3-etcs-b3-r2-gsm-r-b1

[CR940] The Change Request is held within the ERA Change Request database, together with the proposed solution.

The solution is publicly available within Opinion ERA/OPI/2020-2:
https://www.era.europa.eu/library/opinions-and-technical-advices_en
The description of CR940 is available in Annex 3 of the above.

The work in X2Rail-5 WP4 is based on the CR940 solution published as part of the 2020 Technical Opinion. Further changes to the solution have subsequently been proposed, which have not been considered.

[Linx4Rail] Linx4Rail Topic Report
Comparison of X2Rail-3 D4.2 and RCA Architecture
Contributors: NR, ProRail, SBB, DB, Siemens, Thales, CAF, Bombardier
Version 3 26 March 2021

[SS125] ERTMS/ATO – System Requirement Specification
SUBSET 125
Version 0.2 24 March 2022

11 Ownership of results

The following Table 5 lists the ownership of results for this deliverable.

Ownership of results			
Company	**Percentage**	**Short Description of share/ of delivered input**	**Concrete Result (where applicable)**
SMO			
BTSE			
MERMEC			
NR			
TD			

Table 5: Ownership of results

This deliverable is jointly owned by the organisations listed above. The last three columns in the table are intentionally left empty.