# X2Rail-3

| | |
|---|---|
| Project Title: | Advanced Signalling, Automation and Communication System (IP2 and IP5) – Prototyping the future by means of capacity increase, autonomy and flexible communication |
| Starting date: | 01/12/2018 |
| Duration in months: | 36 |
| Call (part) identifier: | H2020-S2RJU-CFM-IP2-01-2018 |
| Grant agreement no: | 826141 |

# Deliverable D4.4
# Report on Technology Demonstrators

| | |
|---|---|
| Due date of deliverable | Month 24 |
| Actual submission date | 14-Dec-20 |
| Organization name of lead contractor for this deliverable | SIE |
| Dissemination level | PU |
| Revision | Draft |

# Authors & Version Management

| | |
|---|---|
| **Author(s)** | **Siemens (SIE)** |
| **Contributor(s)** | **Bombardier (BTSE)** |
| | **Thales (TD)** |
| | **Hitachi Rail STS (STS)** |

| **Version Management** | | |
|---|---|---|
| **Version Number** | **Modification Date** | **Description / Modification** |
| a | 29-Apr-20 | Outline and early demonstrator information |
| 01 | 13-Aug-20 | Updated with STS demonstrator information, added to co-operation tool (01) |
| 02 | 07-Sep-20 | Updated after Task Meeting 02-Sep-20 |
| 03 | 06-Nov-20 | Updated after all sections drafted, ready for review |
| 04 | 06-Nov-20 | Further update |
| 05 | 27-Nov-20 | Update after review by participants |
| 06 | 14-Dec-20 | Version for submission to the JU |
| 07 | 14-Dec-20 | PDF of version 06, for submission to the JU |
| 08 | 21-Mar-21 | Editorial corrections after JU review |
| 09 | 21-Mar-21 | PDF of version 08, for re-submission to the JU |

# Executive Summary

This is Deliverable D4.4 “Report on Demonstrators” from X2Rail-3 WP4 Moving Block. This deliverable is a report on the four separate Moving Block demonstrators created as part of WP4 Task 4.6:

| Technical Demonstrator | Supplier |
|---|---|
| Urban / Suburban | Siemens (SIE) |
| Overlay | Bombardier (BTSE) |
| High Speed Lines | Thales (TD) |
| Low Traffic / Freight | Hitachi Rail STS (STS) |

The Moving Block Technical Demonstrators in X2Rail-3 are implementations of the results from X2Rail-1 WP5 Moving Block in the deliverables [X2R1-D51] and [X2R1-D52], with some account taken of results achieved within X2Rail-3 WP4 Moving Block.

For each Moving Block Technical Demonstrator there is a statement of the coverage of the requirements from X2Rail-1 [X2R1-D51], a description of the Technical Demonstrator, and a summary of the results achieved.

Results which may impact the requirements and rules contained within X2Rail-3 D4.2 Moving Block Specifications [X2R3-D42] are identified as Observations and Suggestions. These will be considered for update within X2Rail-5, the final step in the Moving Block specification process.

# Table of Contents

**EXECUTIVE SUMMARY** ........ **3**
**TABLE OF CONTENTS** ........ **4**
**TABLE OF FIGURES** ........ **5**
**TABLE OF TABLES** ........ **6**
**ABBREVIATIONS AND ACRONYMS** ........ **7**
**1 INTRODUCTION** ........ **8**
1.1 SYSTEM TYPES ........ 9
1.2 RAILWAY TYPES ........ 9
1.3 DATA COLLABORATOR ........ 10
1.4 X2RAIL-1 D5.1 REQUIREMENTS COVERAGE ........ 11
1.5 SCENARIOS TO BE TESTED ........ 18
**2 TECHNICAL DEMONSTRATORS** ........ **19**
2.1 URBAN / SUBURBAN TECHNICAL DEMONSTRATOR – SIEMENS ........ 19
*2.1.1 Objectives ........ 19*
*2.1.2 Scope ........ 19*
*2.1.3 Outcome ........ 23*
2.2 OVERLAY TECHNICAL DEMONSTRATOR – BOMBARDIER ........ 26
*2.2.1 Objectives ........ 26*
*2.2.2 Scope ........ 26*
*2.2.3 Outcome ........ 29*
2.3 HIGH SPEED LINES TECHNICAL DEMONSTRATOR – THALES ........ 33
*2.3.1 Objectives ........ 33*
*2.3.2 Scope ........ 33*
*2.3.3 Outcome ........ 36*
2.4 LOW TRAFFIC / FREIGHT TECHNICAL DEMONSTRATOR – HITACHI RAIL STS ........ 39
*2.4.1 Objectives ........ 39*
*2.4.2 Scope ........ 39*
*2.4.3 Outcome ........ 43*
**3 CONCLUSIONS** ........ **47**
**4 REFERENCES** ........ **48**
**APPENDIX A - OWNERSHIP OF RESULTS** ........ **49**

# Table of Figures

Figure 1: Bournemouth Mainline in London ........ 20
Figure 2: Sample prototype view from the Dispatcher control panel ........ 20
Figure 3: Annotated Photograph of Urban/Suburban Technical Demonstrator ........ 21
Figure 4: Architecture for Urban/Suburban Technical Demonstrator ........ 22
Figure 5: Ådal-Botnia ERTMS/ETCS Level 2 lines in northern Sweden ........ 27
Figure 6: Overall System Architecture (logical scheme) for the Overlay TD ........ 28
Figure 7: HSL demonstrator – sample area ........ 33
Figure 8: Sample prototype view from the Dispatcher control panel ........ 34
Figure 9: Overall System Architecture (logical scheme) ........ 35
Figure 10: Novara-Padova area ........ 40
Figure 11: Sample prototype view from the Dispatcher Control Panel ........ 41
Figure 12: Overall Low Traffic /Freight Prototype System Architecture (logical scheme) ........ 42

# Table of Tables

Table 1 – X2Rail-3 WP4 Moving Block Technical Demonstrators ........ 8
Table 2 – Moving Block System Types ........ 9
Table 3 – Moving Block System Types ........ 9
Table 4 – Data Collaborators ........ 10
Table 5 – Requirements Coverage ........ 17
Table 6 – Scenario Coverage ........ 18
Table 7: Ownership of results ........ 49

# Abbreviations and acronyms

| Abbreviation / Acronyms | Description |
|---|---|
| CRE | Confirmed Rear End<br>As defined in [CR940] |
| EoA | End of Authority<br>The end of a Movement Authority as sent Trackside to Train |
| EoM | End of Mission |
| ERA | European Agency for Railways |
| ERTMS | European Rail Traffic Management System |
| ETCS | European Train Control System |
| FMB | Full Moving Block<br>One of the Moving Block System Types defined in [X2R3-D42] |
| FS | Full Supervision |
| FVB | Fixed Virtual Blocks<br>One of the Moving Block System Types defined in [X2R3-D42] |
| HMI | Human Machine Interface |
| HSL | High Speed Line |
| HW | Hardware |
| IXL | Interlocking |
| L3 | Level 3<br>The ETCS Level corresponding to Moving Block |
| MA | Movement Authority |
| NTC | National Train Control<br>Used in the context of ETCS Level NTC |
| OBU | On Board Unit<br>Used to refer to the On-Board component of ETCS |
| OPE | Operational and Traffic Management<br>Used in the context of OPE TSI |
| RBC | Radio Block Centre<br>Component of L3 Trackside |
| REQ | Requirement<br>Used in the context of references to Requirements within [X2R1-D51] |
| SoM | Start of Mission |
| SR | Staff Responsible |
| TD | Technical Demonstrator<br>Used in the context of Shift2Rail |
| TGV | Train à Grande Vitesse |
| TIMS | Train Integrity Monitoring System |
| TMS | Traffic Management System |
| TSI | Technical Specifications for Interoperability<br>As controlled by ERA |
| TTD | Trackside Train Detection<br>Typically Axle Counters or Track Circuits |
| TVM | Transmission Voie-Machine<br>French cab signalling system |

# 1 Introduction

The present document constitutes Deliverable D4.4 “Report on Technology Demonstrators” in the framework of the Project titled “Advanced Signalling, Automation and Communication System (IP2 and IP5) – Prototyping the future by means of capacity increase, autonomy and flexible communication” (Project Acronym: X2Rail-3; Grant Agreement No 826141).

This document has been prepared to provide a report on the results from the four Moving Block Technical Demonstrators, which are in Task 4.6 within X2Rail-3.

The four different Moving Block Technical Demonstrators within X2Rail-3 WP4 Moving Block are shown in Table 1:

| Technical Demonstrator | Supplier |
|---|---|
| Urban / Suburban | Siemens (SIE) |
| Overlay | Bombardier (BTSE) |
| High Speed Lines | Thales (TD) |
| Low Traffic / Freight | Hitachi (STS) |

**Table 1 – X2Rail-3 WP4 Moving Block Technical Demonstrators**

The Moving Block Technical Demonstrators are based on the results from X2Rail-1 WP5 Moving Block, which are in X2Rail-1 Deliverable D5.1 [X2R1-D51] and D5.2 [X2R1-D52], with the aim of implementing the system requirements defined in [X2R1-D51].

This section contains some tables, which enables comparison between the Technical Demonstrators. The following section provides more details of each of the Technical Demonstrators, and provides results.

## 1.1 System Types

The following table shows the Moving Block System Types implemented by the Moving Block Technical Demonstrators. The Moving Block System Types are defined in X2Rail-1 D5.1 [X2R1-D51].

| System Type | SIE | BTSE | TD | STS |
|---|---|---|---|---|
| FMB, no TTD | | | | |
| FMB, with TTD | | Yes | | |
| FVB, no TTD | | | | Yes |
| FVB, with TTD | Yes | | Yes | |

**Table 2 – Moving Block System Types**

## 1.2 Railway Types

The following table shows the different railway types of the Moving Block Technical Demonstrators.

| Railway Type | SIE | BTSE | TD | STS |
|---|---|---|---|---|
| Urban / Suburban | Yes | | | |
| Overlay | | Yes | | |
| High Speed | | | Yes | |
| Low Traffic / Freight | | | | Yes |

**Table 3 – Moving Block System Types**

## 1.3 Data Collaborator

The following table shows the source of the track data for the different Technical Demonstrators.

| Data Collaborator | SIE | BTSE | TD | STS |
|---|---|---|---|---|
| NR | Yes | | | |
| TRV | | Yes | | |
| SNCF | | | Yes | |
| RFI | | | | Yes |

**Table 4 – Data Collaborators**

## 1.4 X2Rail-1 D5.1 Requirements Coverage

This section is based around the Requirements within X2Rail-1 D5.1 [X2R1-D51]. The section numbers are section numbers within [X2R1-D51], and specific requirements referenced are using the requirement reference numbers from [X2R1-D51]. Note that the specific requirement references may be different in [X2R3-D42].

“Yes” at section level is taken to imply all requirements in that section. “No” is taken to imply none of the requirements. “Some” means that further detail is given.

| X2R1 D5.1 Requirements | SIE | SIE Notes | BTSE | BTSE Notes | TD | TD Notes | STS | STS Notes |
|---|---|---|---|---|---|---|---|---|
| 6.1 Train Location | Yes | No trains in NL | Some | No ‘safety’ margin | Some | REQ-TrainLoc-9 only partly covered yet.<br>REQ-TrainLoc-8 not realised. Instead Train Position Reports in SB are considered to establish train location. | Some | No ‘safety’ margin (whether rear or front) as there are FVBs.<br>REQ-TrainLoc-10: prototype is not interfaced with a TMS, however the required train information is displayed to the RBC operator. |

| X2R1 D5.1 Requirements | SIE | SIE Notes | BTSE | BTSE Notes | TD | TD Notes | STS | STS Notes |
|---|---|---|---|---|---|---|---|---|
| 6.2 Track Status | Some | | Some | No removing of sweepable areas from TMS and no propagation as there is TTD. | Some | E.g. No TMS interface implementation for setting Track Status from Clear to Unknown and vice versa. | Some | No creation of unknown areas from Dispatcher.<br>No Propagation. |
| 6.3 Reserved Status | Yes | | Yes | | Some | E.g. No Reserved Area for SR movement yet. | Yes | |
| 6.4 Fixed Virtual Blocks | Yes | | No | | Yes | | Yes | |
| 6.5 Trackside Train Detection | Yes | | Some | No Latency Timer and no clearing by TMS | Some | No Latency Timer and no clearing by TMS | Some | A single TTD is configured in the line (between two adjacent stations). |

| X2R1 D5.1 Requirements | SIE | SIE Notes | BTSE | BTSE Notes | TD | TD Notes | STS | STS Notes |
|---|---|---|---|---|---|---|---|---|
| 6.6 Points Control | No | | Some | No means to move points in Unknown areas and clear the alternate leg as there is TTD | No | | No | There are no points or derailers in the line. Stations are conventionally equipped |
| 6.7 Movement Authorities | Yes | | Most | Not REQ-MA-9 as its use is not clear | Some | Sweeping requirements not realised yet. | Yes | |
| 6.8 EoA Exclusion Area | No | | Yes | | No | | No | |
| 6.9 Start of Train | Some | No approximate position managed. | Most | | Most | E.g. TMS interface implementation | Most | No approximate position managed. |
| 6.10 SR Movement | No | | Yes | REQ_MovSR-1 and -2 need to be amended | No | | Some | Only REQ-SR-3 override (SR movement requested by driver) will be Implemented. |

| X2R1 D5.1 Requirements | SIE | SIE Notes | BTSE | BTSE Notes | TD | TD Notes | STS | STS Notes |
|---|---|---|---|---|---|---|---|---|
| 6.11 First MA | Some | Always trains with TI confirmed | Yes | | Yes | | Yes | |
| 6.12 Loss of Communications | Yes | | Yes | | Some | No mute timer (as this is application specific) | Yes | |
| 6.13 Movement of a Non-Communicating Train | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] |
| 6.14 Recovery Management after Loss of Communications | Yes | | Some | No REQ related to Unknown areas as there is TTD | No | | Yes | |
| 6.15 Radio Hole | No | | No | No radio holes expected | Some | No Radio Hole timer | No | |
| 6.16 Reverse Movement | No | | No | | No | | No | |

| X2R1 D5.1 Requirements | SIE | SIE Notes | BTSE | BTSE Notes | TD | TD Notes | STS | STS Notes |
|---|---|---|---|---|---|---|---|---|
| 6.17 End of Mission | Yes | | Some | No REQ related to ‘safety’ margins | Yes | Safety Margin | Yes/ Some | Front margin implementation has been regarded not necessary to an FVB-based system. |
| 6.18 Loss of Train Integrity | Some | | Some | No ‘safety’ margins as there is TTD<br>No reaction to loss of integrity<br>No integrity wait timer | Yes | REQ-LossTI-11 not realised yet. | Some | No requirements related to Joining and Splitting scenarios. |
| 6.19 Level Transition | Yes | | Yes | | Yes | | Yes | |
| 6.20 Trackside Initialisation | No | | No | Not needed as there is TTD | Some | No utilisation of stored information for faster initialisation, no TMS interface. | Yes | |
| 6.21 Handover | No | | No | | No | | No | |

| X2R1 D5.1 Requirements | SIE | SIE Notes | BTSE | BTSE Notes | TD | TD Notes | STS | STS Notes |
|---|---|---|---|---|---|---|---|---|
| 6.22 Shunting Movement | No | | Some | Not REQ-SH-3 as there is TTD | Some | REQ-SH-3 not implemented. | No | |
| 6.23 Joining | No | The related REQs need to be amended | No | The related REQs need to be amended | No | The related REQs need to be amended | No | The related REQs need to be amended |
| 6.24 Splitting | No | The related REQ needs to be amended | No | The related REQ needs to be amended | No | The related REQ needs to be amended | No | The related REQ needs to be amended |
| 6.25 Recovery | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] |
| 6.26 Mixed Traffic | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] | N/A | No REQ defined within [X2R1-D51] |

| X2R1 D5.1 Requirements | SIE | SIE Notes | BTSE | BTSE Notes | TD | TD Notes | STS | STS Notes |
|---|---|---|---|---|---|---|---|---|
| 6.27 Traffic Management System Interface | No | Train Information, Track Status, Reserved Area, etc. is displayed to the dispatcher, but the only requirement in this chapter REQ-TMS-1 is not realised. | Yes | | No | Train Information, Track Status, Reserved Area, etc. is displayed to the dispatcher, but the only requirement in this chapter REQ-TMS-1 is not realised. | No | Some basic requirements (train information to be shown to the operator, clean unknown areas) have been implemented at the RBC operator HMI. |

**Table 5 – Requirements Coverage**

## 1.5 Scenarios to be Tested

The following table shows the coverage of the test scenarios. This is based around the list of Use Cases used in X2Rail-3 WP4.

| Test Scenario | SIE | BTSE | TD | STS |
|---|---|---|---|---|
| Normal Train Movement | Yes | Yes | Yes | Yes |
| Splitting | | | | |
| Joining | | | | |
| Loss of Communications | Yes | Yes | Yes | Yes |
| Initialisation of Trackside | | | Yes | Yes |
| Release of Points | | | Yes | |
| Loss of Train Integrity | Yes | Yes | Yes | Yes |
| Sweeping | Yes | Yes | | Yes |
| Shunting | | | | |
| Moving in SR | | Yes | Yes | Yes |
| Handover | | | | |
| Transitions | Yes | Yes | | |
| Reversing | | | | |
| End of Authority Exclusion | | Yes | | |
| Radio Holes | | | | |
| TTDs | Yes | Yes | Yes | Yes |
| Mixed Traffic | | Yes | | |

**Table 6 – Scenario Coverage**

# 2 Technical Demonstrators

This section provides information about each Moving Block Technical Demonstrator, with a separate subsection for each Technical Demonstrator.

## 2.1 Urban / Suburban Technical Demonstrator – Siemens

### 2.1.1 Objectives

The objective of this task is the implementation and testing of an ETCS Level 3 Moving Block system Technical Demonstrator (TD2.3) with FVB and TTD for a given Urban/Suburban Line. The TD aims for TRL 6 which focuses on tests of a system in a simulated operational environment or laboratory. Throughout the Shift2Rail X2Rail-x projects, the development of this TD is expected to cover the typical phases of a system life cycle like requirements elicitation (including safety requirements) and analysis, design and implementation, verification and validation tests using target hardware.

Testing of the TD also requires data preparation/engineering and validation using appropriate tools and processes as well as the deployment of a test and simulation environment suitable for ETCS Level 3 Moving Block systems.

The Urban/Suburban TD is a subsequent development of the X2Rail-1 demonstrator based on the corresponding deliverables in particular the System Specification defining the requirements which were used for development and test of the system.

### 2.1.2 Scope

#### 2.1.2.1 Railway Type

As for the specific trackside application modelled, the Bournemouth Mainline in London Line between Clapham Junction and Esher station has been selected for this prototype.

The demonstrator was constructed using real data from an area of existing operational infrastructure in the UK. The line is a busy commuter corridor into central London, with services operating in both stopping and non-stopping patterns. The yellow highlight in Figure 1 below shows the area of railway used.

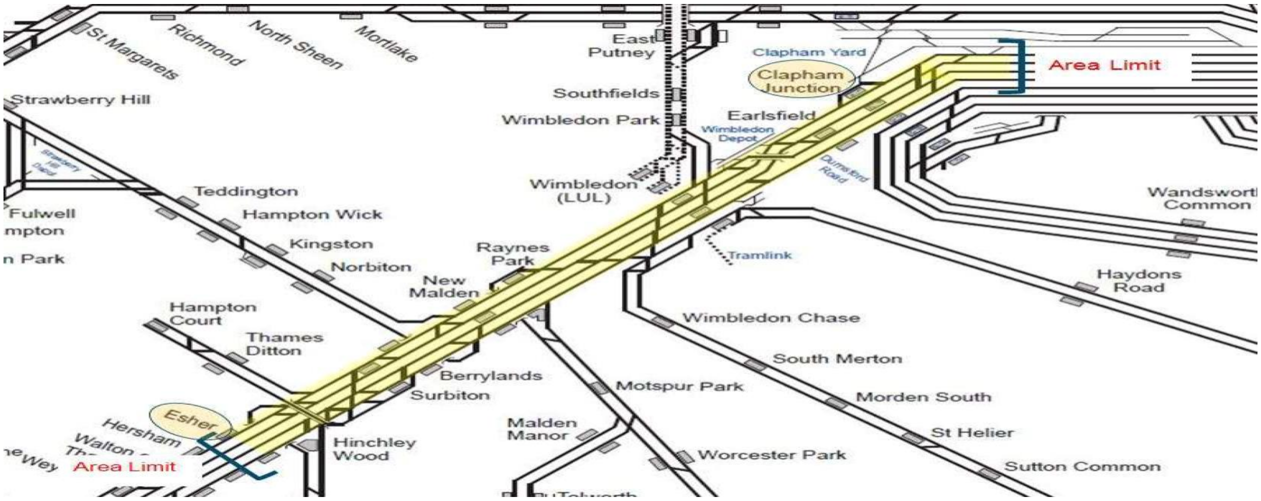


**Figure 1: Bournemouth Mainline in London**

The area modelled is 20km in length with four tracks (Up & Down lines both with Fast & Slow tracks). For the prototype two tracks from Esher to Clapham Junction were engineered. The selected track has eight stations but for the prototype, trains stop in one of them to perform an End of Mission/Start of Mission. The original line is fitted with TTDs and light signals. For the purposes of the simulation environment, all gradients were levelled to a value of 0%. Approximately 270 services operate in each direction, every day. The maximum frequency of service currently in operation is 17 trains per hour.

### 2.1.2.2 System Type

The system type is Fixed Virtual Blocks with Trackside Train Detection (FVB with TTD).

In order to engineer the line, most of the existing TTDs have been maintained. Each TTD, depending on its length, has been engineered with three or four FVBs, in most cases FVBs in a TTD have the same length. This allows to increase the headway and have several trains in one TTD in normal movement.

The line has an entry signal and an exit signal per track at level border locations. In order to allow Dispatcher to request paths for the trains, the current signals have been maintained.

Figure 2 below shows a sample of the prototype view of the Dispatcher control panel.

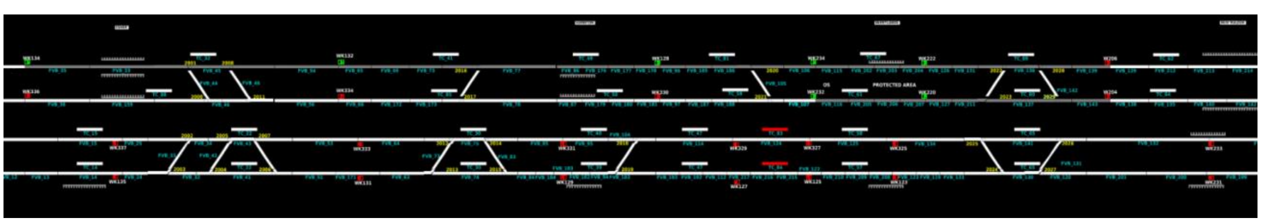

**Figure 2: Sample prototype view from the Dispatcher control panel**

#### 2.1.2.3 Architecture

Figure 3 shows a photograph of the physical prototype equipment:

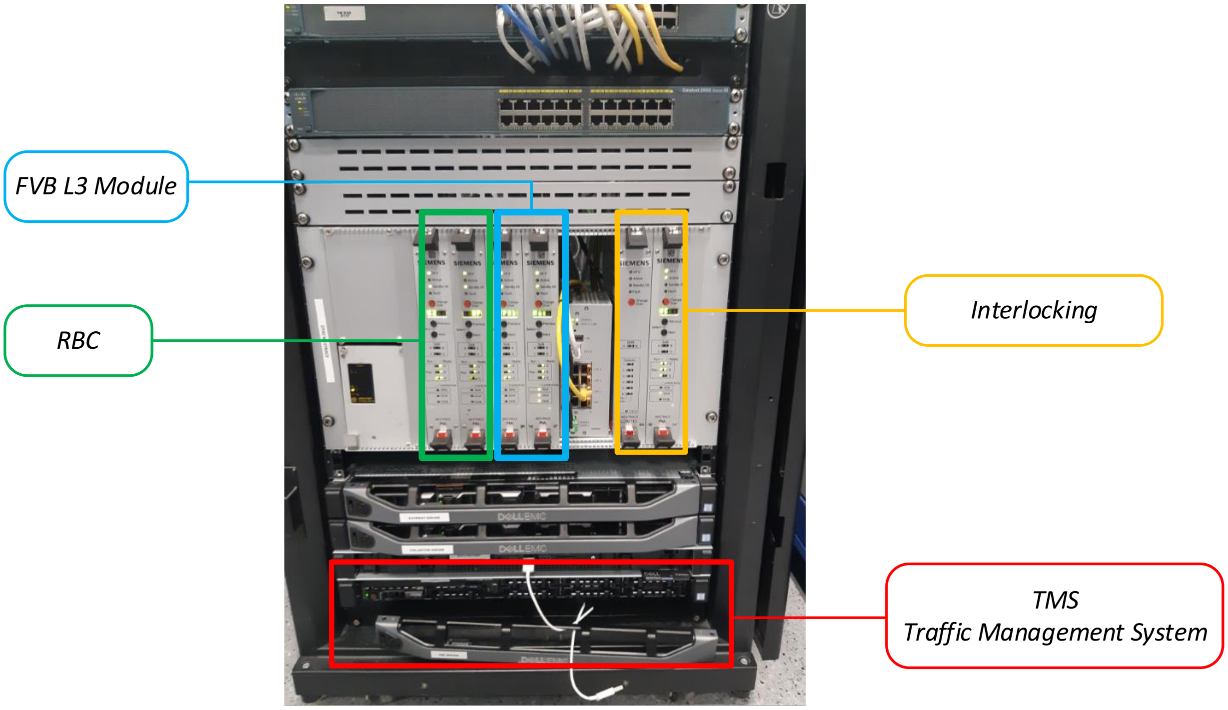


**Figure 3: Annotated Photograph of Urban/Suburban Technical Demonstrator**

The prototype system included a PC simulation of the trackside and trains, including the ETCS behaviour. The L3 Trackside consists of Interlocking, RBC and L3 FVB Module. They are operated on target hardware platforms and are in charge of managing Track Status and calculate Authorisations sent to the train. TMS operates on the same platforms used in commercial projects.

The Railway Environment Train Simulator (RETS) is in charge of simulate the train, provides ETCS On-board functionality (Baseline 3 [BL3 R2]), messages sent to the L3 Trackside and the possibility of trigger events to manage Train Integrity functionality or a loss of communications (such as Mute timer). RETS is also in charge of providing the status of the different elements of the trackside as balises, points or TTD state.

The system has the functional architecture given in Figure 4.

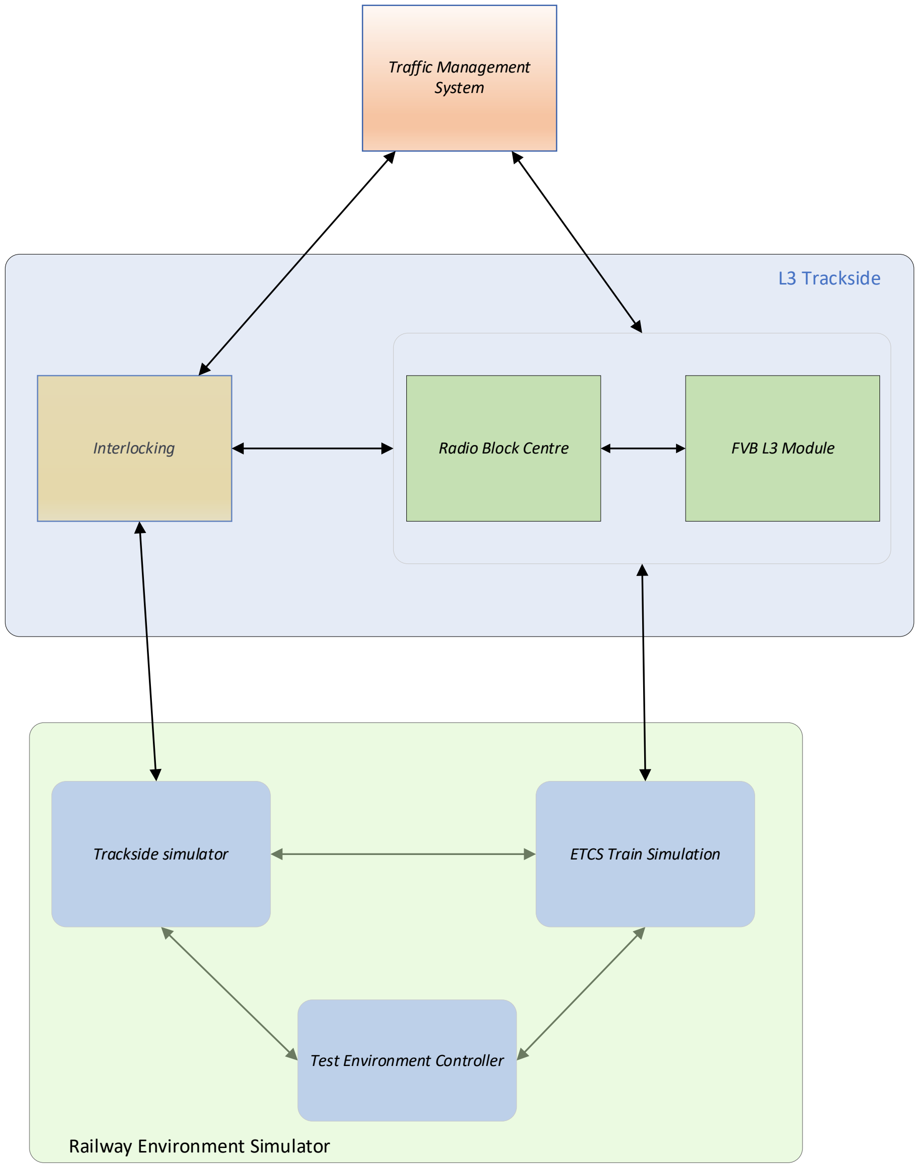


**Figure 4: Architecture for Urban/Suburban Technical Demonstrator**

### 2.1.2.4 Functions Included

The functions tested with this Technical Demonstrator focus on the main track and its normal operation performed and degraded situations that happens there, i.e. normal movement with train persecution, loss and recovery of Train integrity and communications, entry and exit of L3 Areas. Sweeping functionality has been implemented as it is key for managing degraded situations, though in systems with TTDs, in many cases, these might avoid sweeping the track. Although there are no specific requirements for Level Transitions functionality the entry and exit in L3 areas were tested.

Some functionalities were not implemented as the requirements were not mature enough, i.e. Joining and Splitting. As already mentioned, for some functionalities i.e. Trackside initialisation, Shunting movements the used of TTDs protect the areas where they are performed and they are not so interesting to be implemented.

No Radio Holes are expected as for this system as they would have a big impact in the headway.

Handover functionality was not possible to test as there are only one L3 Trackside with adjacent Unfitted areas.

### 2.1.3 Outcome

#### 2.1.3.1 Result from tests

The prototype has proven L3 system with FVB and TTD, in normal operation in areas with Level Transitions based on the requirements in [X2R1-D51] and [X2R1-D52].

For this demonstrator, the size of the FVB has been adapted so that the functionality can be tested. As result, it is project specific to define FVBs size, shorter FVBs increases the engineering of the track and reduce the headway but leads to L3 Trackside to issue more frequently updated MAs to the train and this is not a desired behaviour.

In the main track, the number of TTDs can be reduced and their length increased as they will have impact in stations and degraded situation.

The following functionalities and scenarios were tested:

##### *2.1.3.1.1 Normal Train Movement*

Several trains moving on the track in the same direction, a train is chasing the train in front of it and is chased by train in its rear. As soon as a FVB of the line becomes Clear in rear of a train (the FVB corresponding to the train occupation change its status as the train moves), the L3 Trackside extends the MA for the chasing train up to the end of the last clear FVB in rear of the FVB occupied by the CRE of the chased train. In the meanwhile, the L3 Trackside assigns an extended MA to the first train as the FVB in front of it are clear.

##### *2.1.3.1.2 End of Mission*

A train is moving as in Normal Movement in the track. The train stops in a station, at this point the FVBs in with the train is located is Occupied, the adjacent FVB states are Clear. The train performs an EoM and when the L3 Trackside receives this message, the FVB in which the train is located becomes Unknown.

##### *2.1.3.1.3 Start of Mission*

This is the continuation of the EoM test. The train is on an FVB with Unknown status and the TTD is Occupied. When the train establishes the communication and reports a valid location with Train Integrity Confirmed, the TTD becomes occupied which in turn provokes the transition to the state Unknown for the affected FVBs, also the L3 Trackside sends an MA to the train. When train reports

FS Mode and Train Integrity Confirmed, the L3 Trackside changes the FVB from Unknown to Occupied. Train moves off as in Normal Movement.

##### *2.1.3.1.4 Loss of Communications*

This scenario starts the same way as the normal train movement. The first train stops sending messages and the L3 Trackside frozen its. No longer MAs are sent to the chasing train. When the mute timer expires, the FVB state where the train last reported its CRE and the ones included in the reserved area (which in this case matches the MA) becomes Unknown. Train moves forward on the current TTD. Before leaving the TTD a new message from the train is received with Train Integrity Confirmed, communications are regained and FVBs update their states to Clear for those in rear of the CRE, Occupied for those in which L3 Trackside establishes the train location and clear for those in front of the Max Safe Front End of the train.

##### *2.1.3.1.5 Loss of Train Integrity*

This scenario starts the same way as the normal train movement. When the chased train reports loss of Train Integrity, the FVB where the CRE of the train is becomes Unknown and no longer MAs are sent to the chasing train. Note that in the video also the CRE of the train is frozen. As the train moves forward and the front end of the train reaches a new FVB in the TTD, FVB becomes Unknown. Before fully exiting the TTD, train recovers Train Integrity. When the L3 Trackside receives a position report with Train Integrity Confirmed, the Unknown FVBs become Clear but the FVBs where the train is located which became Occupied. The MA for the chasing train is extended up to the border of the last Occupied FVB.

##### *2.1.3.1.6 Sweeping*

In this scenario the first train reports Loss of Train Integrity and keeps travelling through the track creating an Unknown area. The train moves on and the L3 Trackside extends the Unknown area until the train stops before exiting the TTD. Note: train stops so that the following train can sweep the Unknown area. When the sweeping train is in the vicinity of the Unknown area, the TMS will request to the dispatcher confirmation to sweep. Upon the reception of the confirmation from the Dispatcher a new MA with an OS Mode Profile is sent to the sweeping train. Train can then proceed into the Unknown FVB and sweep the Unknown area. As the sweeping train enters an FVB as it is reporting with Train Integrity Confirmed L3 Trackside update the state of the FVB from Unknown to Occupied as Occupied has precedence over Unknown. When the first train reports again with Train Integrity Confirmed the Unknown area in the FVB becomes Occupied and both trains can move forward in Normal Movement.

##### *2.1.3.1.7 Transitions*

- <u>Entry to L3</u>: a train in NTCS Mode is on the approach to the L3 border, located at virtual signal WK134. The state of the FVBs are initially Clear. The train establishes a communication session with the L3 Trackside and starts reporting a valid location with Train Integrity Confirmed by External device. The L3 sends an MA to the train before the train reaches the border. The train reaches the L3 border, the first TTD in the L3 area becomes Occupied and the train reads the border balise group. When L3 Trackside receives that the first TTD in the Level 3 area is Occupied and a position report with Train Integrity Confirmed by External device and with the Train mode Full Supervision in Level 3, the state for the first FVB transitions from Clear to Occupied.

- Exit from L3: a train moving in FS in the L3 Area is on the approach to the L3 border exit location as in Normal Movement. When the train reaches the Level Transition Location, reads the border balise and transits to NTC.

#### 2.1.3.2 Observations

All tests have been executed successfully. Occasionally in the TMS can be observed that the MA sent to a train overlaps an Occupied FVB. This is due to synchronisation issues detected which result in the MA being received by the TMS before the FVB was updated. An analysis of the logs in the L3 Trackside confirmed that the MAs generated were correct and that they do not exceed the Occupied FVB.

Deviation from current specification:

SoM: following the approach explored in the Use Cases, after Validated Train Data are received, even if the train is in Standby, when Train Integrity is received, the FVB becomes Occupied.

#### 2.1.3.3 Suggestions

During the workshops to develop the Use Cases and update the specification the questions raised were proposed.

## 2.2 Overlay Technical Demonstrator – Bombardier

### 2.2.1 Objectives

The objective of this task is the implementation and testing of an ETCS Level 3 Full Moving Block system Technical Demonstrator (TD2.3) as an Overlay to a conventional signalling system with TTD. The TD aims for TRL 6 which focuses on tests of a system in a simulated operational environment or laboratory. Throughout the Shift2Rail X2Rail-x projects, the development of such a TD is expected to cover the typical phases of a system life cycle like requirements elicitation (including safety requirements) and analysis, design and implementation, verification and validation tests using target hardware.

Testing of the TD also requires data preparation/engineering and validation using appropriate tools and processes as well as deployment of a test and simulation environment suitable for ETCS Level 3 Moving Block systems.

The Overlay TD is a subsequent development from the X2Rail-1 project based on the corresponding deliverables in particular the [X2R1-D51] System Specification defining the requirements used for development and test of the system. However, the Overlay TD has, as far as possible, followed the recent development foreseen from the Open Points created when preparing the Use Cases while analysing the X2Rail-1 deliverables in this project.

### 2.2.2 Scope

#### 2.2.2.1 Railway Type

An ETCS Level 3 Overlay system can be applied on any of the railway types listed in the table in section 1.2. Originally, this Overlay TD was intended for an urban/suburban type of project. Unfortunately, the start of that target project was delayed and it could not be used for this TD. Instead, the test and verification of the Overlay TD have been performed on parts of a common test yard for the Bombardier EBICom 2000 RBC. This is based on the Botnia line, the blue part in the figure below of the Ådal-Botnia ERTMS/ETCS Level 2 projects for Trafikverket (TRV) in Sweden, an urban/suburban type of railway.

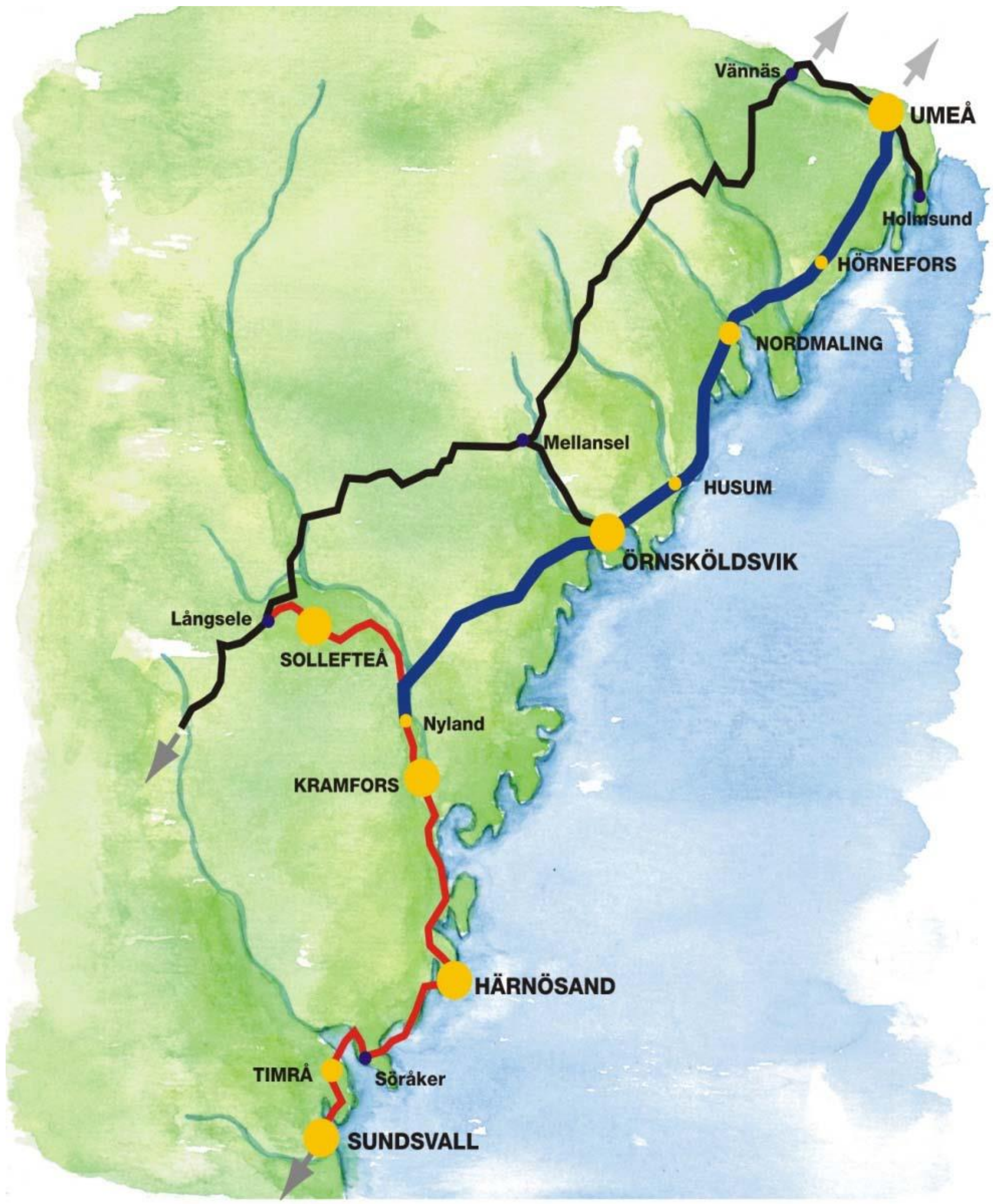


**Figure 5: Ådal-Botnia ERTMS/ETCS Level 2 lines in northern Sweden**

#### 2.2.2.2 System Type

The Overlay TD is implemented as a Full Moving Block system with TTD. As the test yard is based on an ETCS Level 2 system with few and long TTD sections, the number of TTD sections was increased to facilitate the tests for the Overlay TD so that each route has at least two TTD sections. The reason to base the test yard on an ETCS Level 2 system was that then the Interlocking had already an interface to the RBC.

#### 2.2.2.3 Architecture

Figure 6 shows the architecture of the ETCS Level 3 Overlay system prototype:

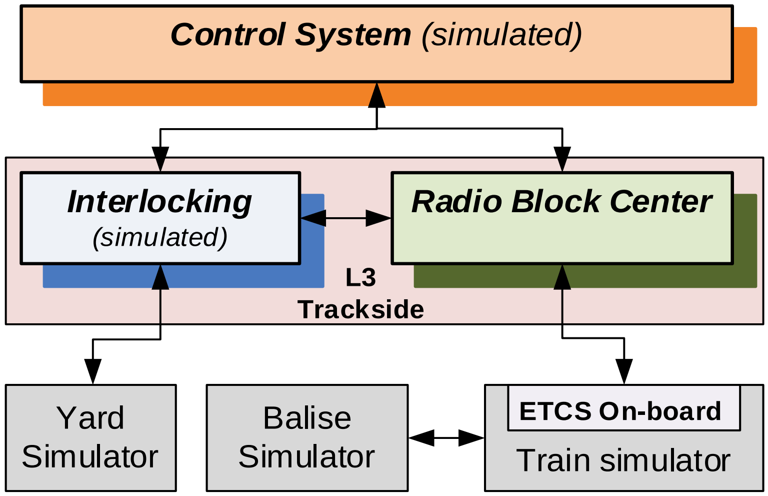


**Figure 6: Overall System Architecture (logical scheme) for the Overlay TD**

The components used in the test environment are:

- a simulated Control System,
- an RBC emulator, configured with the RBC Test Yard,
- a simulated Interlocking, configured with RBC Test Yard,
- a Yard simulator for the field elements in the RBC Test Yard,
- a Balise simulator for the Balise telegrams in the RBC Test Yard,
- a Train simulator with an ETCS On-board emulator and a TIMS.

The simulated Control System is the interface for the testers to the Interlocking and RBC.

The RBC emulator executes the real software for the ETCS Level 3 Overlay system by interacting with the simulated environment, i.e. the trains, the Interlocking and the Control System.

The Interlocking simulator provides status information for routes and TTD sections to the RBC.

The Train simulator is used to simulate train movements, either with a real or an emulated ETCS On-board system. Trains unknown to the RBC are simulated via the Yard simulator by sequentially occupying TTD sections. A Balise simulator provides relevant telegrams to the Train simulator.

#### 2.2.2.4 Functions Included

The functionality initially included in the Overlay Technical Demonstrator (see section 1.5) focus on what is needed for normal operation of an ETCS Level 3 Overlay system and for handling of the expected degraded situations, i.e. Mixed Traffic with some trains equipped for ETCS Level 3 operation (with TIMS) and the impact from Loss of Train Integrity and Loss of Communications.

Functionality specifically intended for system types without TTD has not been implemented, i.e. Initialisation of Trackside and Release of Points, as with TTD this is not expected to be different compared to ETCS Level 2. For the same reason also Shunting, Handover, Reversing and Radio Holes were excluded, at least for now.

Functionality for Sweeping has been implemented as it is related to managing areas with status Unknown or Occupied, even if there is limited need for sweeping the tracks when there is TTD.

Functionality related to Joining and Splitting has not been fully implemented yet as requirements were not considered mature enough.

### 2.2.3 Outcome

#### 2.2.3.1 Result from tests

The tests have proven the feasibility of the Level 3 Overlay Technical Demonstrator in the normal and degraded situations mentioned in the subsections below.

As far as possible, the tests are based on [X2R3-D41] and the Use Cases that were prepared when analysing the rules and requirements developed in X2Rail-1, [X2R1-D52] and [X2R1-D51] respectively.

All tests passed as expected except as noted in the sections below. When some expectation was not met, an observation and/or a suggestion has been added to sections 2.2.3.2 or 2.2.3.3.

##### *2.2.3.1.1 Normal Train Movement*

One train following another train, both equipped for ETCS Level 3 and with continuous TIMS. MA for the following train given to the Confirmed Rear End of the first train. Currently the MA is given without any margin between the trains as the “Safety Margin” from [X2R1-D51] was going to be removed and the new concept was still being prepared.

##### *2.2.3.1.2 End of Mission*

A train performs End of Mission with and without train integrity confirmed after standstill. When needed and possible, the location of the train is adjusted according to TTD information.

##### *2.2.3.1.3 Start of Mission*

A train performs Start of Mission with valid position (Q_STATUS) and the L3 Trackside recovers all or part of the Unknown area where the train is positioned depending on the length of the train. The tests also included Start of Mission with a train reporting an invalid, unknown or unexpected position, for which the TMS/Dispatcher assigned a position for the train.

##### *2.2.3.1.4 Loss of Communications*

A train is running in FS mode when the connection is temporarily lost; the train then reconnects either before the Mute timer has expired, after the Mute timer has expired, or after the ETCS session timer has expired.

##### *2.2.3.1.5 Loss of Train Integrity*

A train reports loss of integrity during Normal Movement, then either the train integrity is confirmed again (by external device) or the train performs End of Mission.

##### *2.2.3.1.6 Moving in SR*

A train moves with an SR authorisation from either a known or approximate position. The test had to be modified for giving an SR authorisation over an Unknown area, as in [X2R1-D51] there is a conflict between the need for a Reserved area for giving an SR authorisation and for a Reserved area with an Unknown area this area is given with a mode profile for On-sight.

##### *2.2.3.1.7 Transitions*

Tested transitions from Level 0 to Level 3 and from Level 3 to level 0, including using Override to enter/exit the Level 3 area.

##### *2.2.3.1.8 End of Authority Exclusion*

A train equipped for ETCS Level 3 follows another train equipped for ETCS Level 3 over an EOA Exclusion Area during Normal Movement. The authorisation for the second train is not extended until it fits between the confirmed rear end of the first train and the end of the EOA Exclusion Area.

##### *2.2.3.1.9 TTDs*

Tested impact from TTD on Unknown and Occupied areas, e.g. a TTD becoming occupied without any ETCS Level 3 train located in this TTD and with a TTD becoming clear with an ETCS Level 3 train located in this TTD.

##### *2.2.3.1.10 Mixed Traffic*

A train equipped for ETCS Level 3 follows a train not equipped for ETCS Level 3 and the MA is extended as routes are detected clear.

#### 2.2.3.2 Observations

The following observations were noted when testing the ETCS Level 3 Overlay prototype.

##### *2.2.3.2.1 Normal Train Movement*

In case a Driver closes the desk while the train is still moving, the latest location of the train is changed from Occupied to Unknown and the Reserved Area is removed. This means that the train is still moving (with desk closed) beyond its latest location. A rule in the TSI OPE prevents this behaviour, but from experience, it is not uncommon to do this when approaching the end station. Thus, even if drivers are not allowed to close the desk while the train is moving, the L3 Trackside should be able to handle this situation.

##### *2.2.3.2.2 Start of Mission*

In case a trainset is split in three parts after End of Mission and the middle part starts first, it is not clear from [X2R1-D51] how the Unknown area should be split in two and how to divide the train length that remains between the two separated Unknown areas.

The TMS/Dispatcher may need to assign an approximate position also for trains reporting a valid position at Start of Mission if this position is ambiguous to the L3 Trackside due to the presence of points between the front of the train and the LRBG.

##### *2.2.3.2.3 Loss of Communications*

In case a train for which the communication is (considered) lost is “located” by an Unknown area over three TTD sections and the middle TTD becomes clear, then it is not clear how to handle the Unknown area that represents the lost train. This could happen if the first and/or last of the three TTD sections is also occupied for some other reason.

##### *2.2.3.2.4 Loss of Train Integrity*

After a train has reported loss of integrity, contrary to what is requested in REQ-LossTI-1 [X2R1-D51], the CRE ‘moves’ as TTD sections are detected clear.

##### *2.2.3.2.5 Moving in SR*

When setting an Unknown area to pass over a track which cannot be reserved (locked), e.g. if points are not controlled, there is a contradiction in the requirements as a Reserved area is needed also for then intended/expected SR authorisation, while when an Unknown area is included in an authorisation it is expected to be given with an OS mode profile.

Similar to the observation for Loss of Communication, when moving a train equipped for ETCS Level 3 in SR mode (or without a working TIMS) over several TTD sections, it may happen that a TTD section in the middle is detected clear when only part of the train (length) is on the next TTD. In this situation, when the TTD section in rear of the clear one is still occupied (for some reason), it is not clear how to handle the Unknown area that represents the train.

##### *2.2.3.2.6 End of Authority Exclusion*

REQ-EoAExclusionArea-2 [X2R1-D51] does not consider the confidence interval for the train that follows a train over an EOA Exclusion Area, so the train may fit when authorised to pass the EOA Exclusion Area but not when it has passed if the confidence interval continuous to grow.

#### 2.2.3.3 Suggestions

The following suggestions are derived from the observations mentioned in the previous section.

##### *2.2.3.3.1 Normal Train Movement*

The L3 Trackside should be able to handle the situation in case a Driver closes the desk while the train is still moving, as else the train may stop outside the Unknown area created for the train.

##### *2.2.3.3.2 Start of Mission*

Need to specify how to handle an Unknown area that is split by a train performing Start of Mission in the middle of this area and only accounting for a part of the train length stored for this area.

REQ-StartTrain-3 should apply also for trains reporting a valid position at Start of Mission if this position is ambiguous to the L3 Trackside due to points between the train front and the LRBG.

##### *2.2.3.3.3 Loss of Train Integrity*

REQ-LossTI-1 [X2R1-D51] must be amended for considering systems with TTD, because the CRE will ‘move’ as TTD sections are detected clear.

##### *2.2.3.3.4 TTD*

Suggest specifying how to handle an Unknown area associated with a train when a TTD section in the middle of this Unknown area becomes clear.

##### *2.2.3.3.5 End of Authority Exclusion*

REQ-EoAExclusionArea-2 [X2R1-D51] should be amended to somehow consider the confidence interval for the train that follows a train over an EOA Exclusion Area, because a train may fit when authorised to pass the EOA Exclusion Area but not when it has passed if the confidence interval continuous to grow.

## 2.3 High Speed Lines Technical Demonstrator – Thales

### 2.3.1 Objectives

The objective of this task is the implementation and testing of an ETCS Level 3 Moving Block system Technical Demonstrator (TD2.3) with FVB and TTD for a given High Speed Line (HSL). The TD aims for TRL 6 which focuses on tests of a system in a simulated operational environment or laboratory. Throughout the Shift2Rail X2Rail-x projects, the development of this TD is expected to cover the typical phases of a system life cycle like requirements elicitation (including safety requirements) and analysis, design and implementation, verification and validation tests using target hardware.

Testing of the TD also requires data preparation/engineering and validation using appropriate tools and processes as well as the deployment of a test and simulation environment suitable for ETCS Level 3 Moving Block systems.

The HSL TD is a subsequent development of the X2Rail-1 demonstrator based on the corresponding deliverables in particular the System Specification defining the requirements which were used for development and test of the system.

### 2.3.2 Scope

#### 2.3.2.1 Railway Type

The HSL Paris – Strasbourg was selected for the demonstrator. This line is equipped with ETCS L2 (B2) and TVM and is used by passenger trains either 200m or 400m long. Non-passenger trains are used for maintenance reasons. The current timetable allows one train every 5 minutes each direction. There are no radio holes and no non-stopping areas.

The SNCF interest in L3 is to increase capacity in peak hours (every 3 minutes), with trains fitted with TIMS without installing additional TTD. In non-peak hours trains not fitted with TIMS (e.g. old TGV) could use the line.

Figure 7 below shows the area used for the HLS demonstrator.

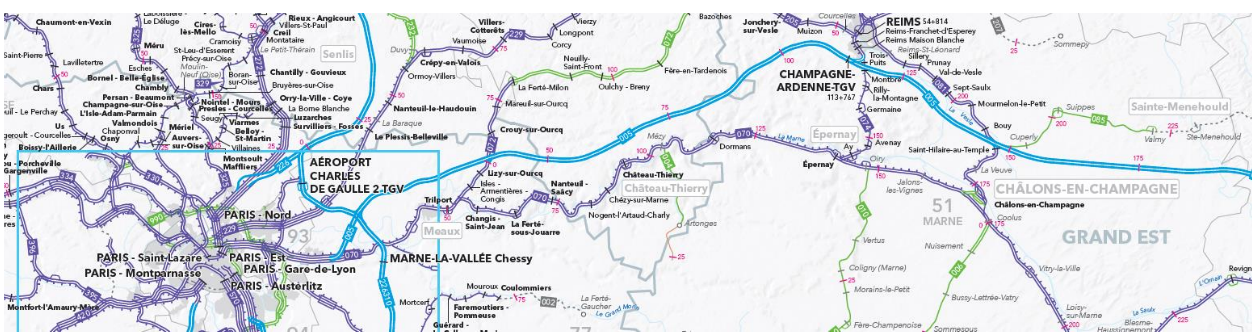


**Figure 7: HSL demonstrator – sample area**

### 2.3.2.2 System Type

In order to investigate the impact of ETCS Level 3 and possible gains in capacity a sample area from the HSL was selected. This sample area starts from the station Champagne-Ardenne-TGV and covers 50 km of double track westwards including a transition from L-NTC to L3 and L3 to L-NTC at each end of the area. There are no optical signals except at the level borders.

Taking this sample schema as a starting the track layout was rearranged for the ETCS Level 3 Moving Block demonstrator in the following way:

- The TTD in the station, point areas and borders were retained,
- The open lines were reconfigured with only one TTD section,
- The main tracks in stations were also sub-divided in FVBs,
- Each TTD section of the open line was sub-divided in FVB of 400m length.

In total 163 FVBs were engineered.

Figure 8 below shows a sample prototype view of the Dispatcher control panel.

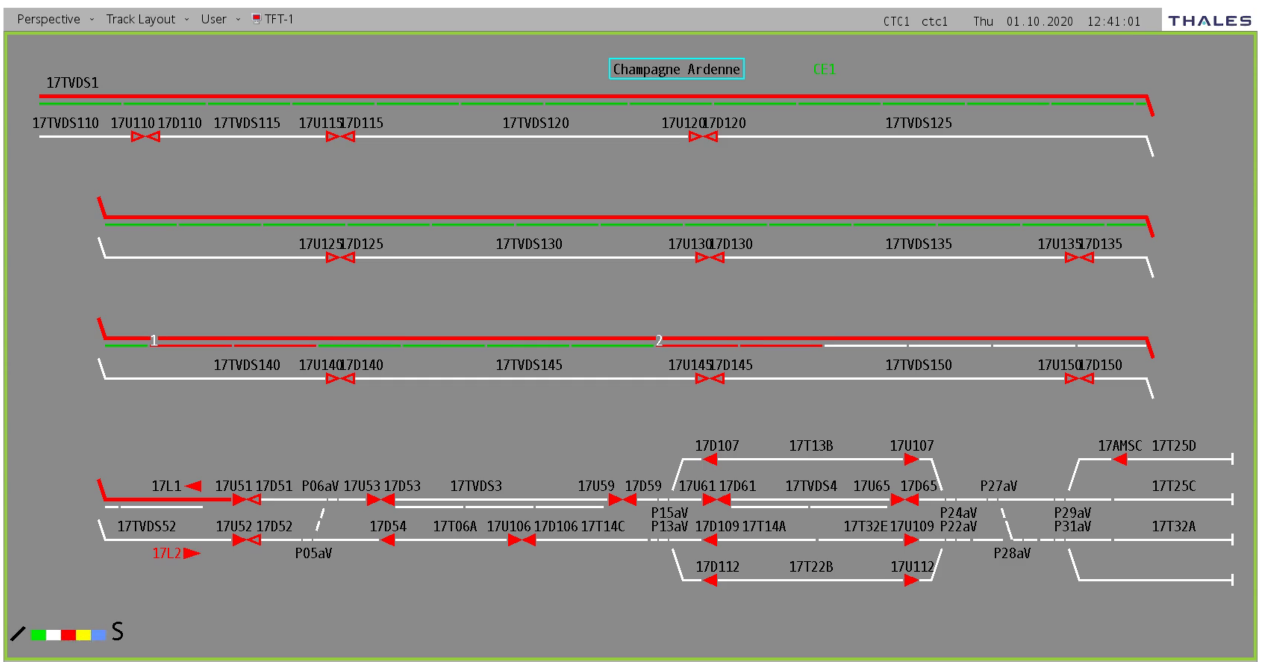


**Figure 8: Sample prototype view from the Dispatcher control panel**

#### 2.3.2.3 Architecture

The following figure shows the architecture of the demonstrator:

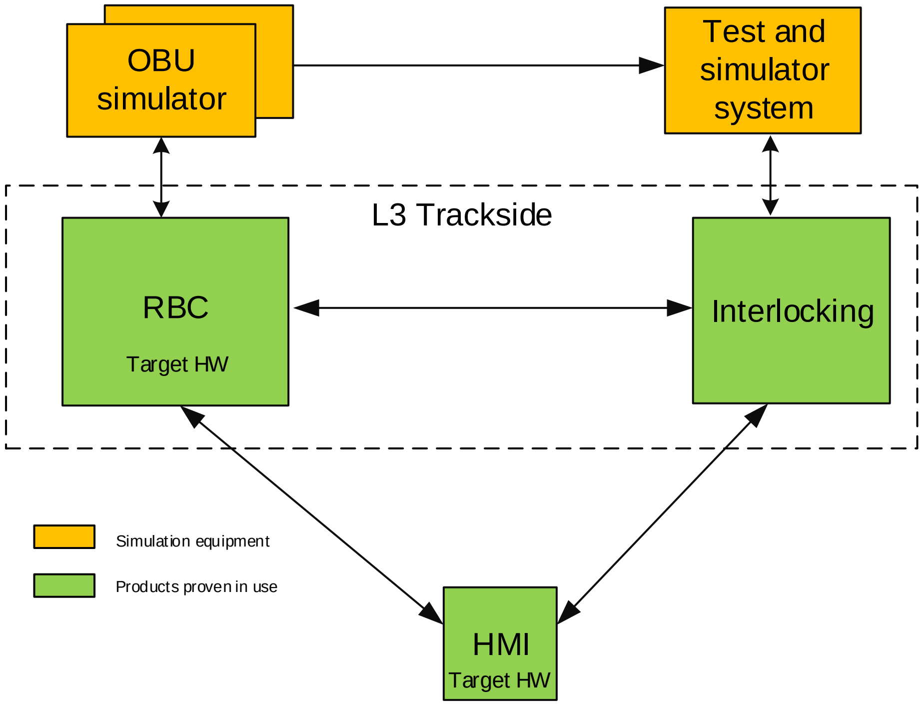


**Figure 9: Overall System Architecture (logical scheme)**

The demonstrator consists of an Interlocking, an RBC, an HMI, an OBU simulator and a test and simulation system.

The Interlocking handles the central interlocking functions like route setting, route checking, route protection, flank protection and route release.

The HMI maintains and displays the track layout, field equipment and train information. The functionality incudes safety and also non-safety related operations for the dispatcher like route setting, entering Temporary Speed Restrictions etc.

The RBC covers ETCS train control system functions and algorithms to maintain Track Status and Reserved Status information.

The simulation environment consists of the OBU simulator, trackside simulator and a platform to integrate the different products. The OBU simulator is an implementation of SUBSET-026 on-Baseline 3 [BL3 R2] including CR 940 [CR940] (this includes a TIMS simulator with the possibility of adding the frequency of sending the confirmation of position reports, etc.) It allows to instantiate more than 10 OBUs if deemed necessary for the test runs and also includes an automatic mode to support capacity tests. The trackside simulator simulates field elements like points and TTDs.

For the HMI it was decided to display the FVB status in addition to the indication of the TTD status in order to better analyse the system behaviour.

#### 2.3.2.4 Functions Included

The functions included in the Technical Demonstrator cover what is need for normal operation and handling of degraded situations with focus on the biggest issues for an ETCS Level 3 Moving Block system for example trains reporting train integrity or failing to do so.

Compared to ETCS Level 2 algorithms to maintain awareness of the Track Status are unique to an ETCS Level 3 Moving Block Trackside System. Therefore, the selection of the functions to develop for the demonstrator was also motivated by fact to prepare the core of the Track Status algorithms to allow an efficiently migration to the new baseline of X2Rail-3 deliverables currently being prepared. Hence functions like EoA Exclusion area were not considered for implementation in this demonstration.

Requirements for Joining and Splitting have not been included as considered not to be mature enough.

### 2.3.3 Outcome

The prototype demonstrated the feasibility of a Level 3 System with FVB and TTD for a HSL based on the requirements and rules developed in X2Rail-1, [X2R1-D51] and [X2R1-D52] respectively.

As indicated above the development of the demonstrator covered various verification and validations activities including the execution of the test scenarios outlined in the section below. These tests were executed with aim to elaborate and demonstrate normal and degraded situations of the Level 3 System composed of different products in a simulated environment.

All test scenarios were passed successfully. Observations and experiences with the demonstrator are described in sections 2.2.3.2 or 2.2.3.3.

#### 2.3.3.1 Result from tests

##### *2.3.3.1.1 Trackside Initialisation*

The test goal mainly consists of the utilisation of TTD information to update the Track Status of the FVBs during L3 Trackside initialisation.

##### *2.3.3.1.2 Start of Train*

The test goals mainly consist of:

- Determination and update of Train Location
- Determination and update of Track Status mainly based on the Train Location
    - Especially using the Stored Information (e.g. train length, etc.) to update the Track Status after Start of Mission.
- Issue a first MA during the Start of Mission process

##### *2.3.3.1.3 Normal Train Movement*

The test goal mainly consists of applying the algorithm for determining the Track Status derived from the Train Location which is based on Position Reports, TTD Information and the Safety Margin.

##### *2.3.3.1.4 Loss of Communications*

The test goals mainly consist of the algorithm for updating the Track Status after a loss of communication, resp. after the communication is restored.

##### *2.3.3.1.5 End of Mission*

The test goals mainly consist of:

- Updating the Track Status after End of Mission considering the safety margins.
- Storing the train location, train length, etc. in the Stored Information.

##### *2.3.3.1.6 Loss of Train Integrity*

The test goals mainly consist of:

- Updating the Track Status after Loss of Train Integrity, resp. after expiration of the ‘wait integrity timer’.
- Updating the Track Status after anew confirmation of Train Integrity.

##### *2.3.3.1.7 Mixed Traffic*

The test goal mainly consists of the Track Status algorithm for trains not equipped with a TIMS, i.e. not confirming the train integrity.

##### *2.3.3.1.8 Traffic Management System interface*

The test goal mainly consists of the interface tests of the information sent to the TMS, e.g. Track Status or Reserved Status.

#### 2.3.3.2 Observations

The development of the demonstrator involved detailed analysis to derive subsystem requirements of the involved product from the system level requirements. In particular, one abstract requirement, namely that the overlap of unknown areas should be handled in a “safe” way (REQ-TrackStatus-14), is worth mentioning here. On the one hand the requirement allows for different implementations. On the other hand it requires a thorough safety analysis to ensure that the resulting Track Status is correctly determined. In this context it was necessary to analyse almost every requirement with respect to a possible overlapping of certain areas. As indicated above the development of demonstrator was based on the X2rail-1 deliverables, consequently the detailed requirement analysis work was carried out in parallel with X2rail-3 activities which now addresses the overlapping issue in more detail with Track Status Areas and Consolidated Track

Status. It turned out that system tests are less suited to verify the design choices due to the combination of the different scenarios and the resulting complexity.

Furthermore, the visualisation of the Consolidated Track Status (REQ-TrackStatus-12) could lead to misinterpretations by the Dispatcher while being unaware of overlapping Track Status Areas. When clearing an Unknown Track Status Area (see REQ-TrackStatus-5) the Dispatcher may not see the full extent of this area.

#### 2.3.3.3 Suggestions

It is suggested to mention in the Guidance part of the Operational rules like OPE-Generic-1 and OPE-TrackInit-1 etc. that the Track Status Areas may Overlap and that this information should be made available to the Dispatcher according to project specific decisions.

## 2.4 Low Traffic / Freight Technical Demonstrator – Hitachi Rail STS

### 2.4.1 Objectives

The objective of this task is the implementation and testing of an ETCS Level 3 Moving Block system Technical Demonstrator (TD2.3) for a given Low Traffic or Freight line. This TD aims for TRL 6 which focuses on tests of a system in a simulated operational environment or laboratory. Throughout the Shift2Rail X2Rail-x projects, the development of this TD is expected to cover the typical phases of a system life cycle like requirements elicitation (including safety requirements) and analysis, design and implementation, verification and validation tests using target hardware.

Testing of this TD also requires data preparation/engineering and validation using appropriate tools and processes as well as the deployment of a test and simulation environment suitable for ETCS Level 3 Moving Block systems.

The Low Traffic/Freight TD is a subsequent development of the X2Rail-1 demonstrator based on the corresponding deliverables, in particular the System Specification defining the requirements which were used for development and test of the system.

The specific objective of the STS Low Traffic/Freight TD developed within this project has been to achieve infrastructure cost reduction, without penalising headway and capacity of the line, which, on the contrary, have been improved as well by the implementation of the before-mentioned Moving Block Specification.

### 2.4.2 Scope

#### 2.4.2.1 Railway Type

The Railway type achieved is “Low Traffic/Freight”.

As for the specific trackside application modelled, the ERTMS L2-based “Novara-Padova” Line has been selected for this prototype.

This Italian line is included within the European CNC (Core Network Corridor) Project designed from Lisbon to Kiev (CNC V), and intersecting Italy for about 1000km, from Turin to Venice, as shown within Figure 10 (the green path between red indicators).

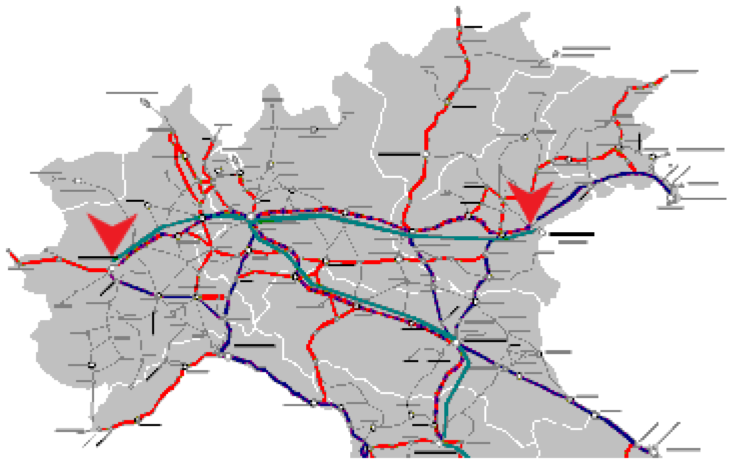

**Figure 10: Novara-Padova area**

A migration from the pre-existent SCTM (Sistema di Controllo Marcia Treno) National System to the pure BL3 R2 ERTMS/ETCS L2 system has been planned for the Italian part of this Corridor, throughout the progressive activation planned for each composing branch, including “Novara-Padova”.

The application “Novara-Padova” is double track and will have TTDs and virtual signals in the main line. It includes about 20 station, among which there are some relevant nodes such as those located in Milano Greco and Verona. These nodes provide connection with the regional railways, for which the national signalling system (SCMT) will be maintained. Both passenger and freight trains are admitted, and the maximum speed allowed is 160 km/h.

The portion of this line from Trecate to Magenta station has been selected for being re-engineered according to D5.1 and D5.2 Specification, as well as the L2 Trackside application software has been replaced with the one developed within the TD2.3, and based on D5.1 Specification. Stations have not been re-engineered since not relevant for the functionalities implemented for this prototype. The selected portion of line has no points and no shunting areas.

#### 2.4.2.2 System Type

The trackside system type designed is basically a Moving Block with Fixed Virtual Block system type without TTDs within the main line. A single axle counter between the adjacent stations of Trecate and Magenta has been maintained. This specific configuration is due to the following considerations:

- On one side, there was the objective of reducing infrastructure costs, whereas the pre-existing infrastructure characterising the line selected for prototype includes TTDs in the stations and this was to be taken into account as well, especially considering a future in-site testing activity within X2Rail-5. The best trade-off has been not to change the pre-existing configuration within stations, but this has implied that an inter-station axle counter should be kept as the minimum equipment required to preserve the conventional detection of train arrival and departure in/from each station as well.

- FVBs have been deemed necessary for being associated with in-field markers, that may be necessary to define the boundaries of some specific areas.
- Both Low Traffic and Freight services may also benefit from FVBs by achieving the maximum capacity possible according to their characteristics without requiring Full Moving Block, since an ETCS Level 3 Moving Block with Fixed Virtual Block system can be properly engineered to provide the same capacity of a Full Moving Block system.

The line from Trecate to Magenta Station is about 25km long and has been re-engineered with FVBs of about 700m each. There were no line elements that could condition the length of the FVBs, therefore the chosen length has been based on the average length of the admitted trains. Passenger trains are always shorter (no more than 450m long) while freight trains are always longer (no more than 1000m long) than this medium value, therefore in both cases this length provides more separation between trains running in the same direction than that provided only by using their CRE, with no need for any additional safety margin to be implemented for this application. Each FVB is delimited by virtual markers, visible to the Operator on his Display Panel. A view of the Operator Display Panel is shown in Figure 11:

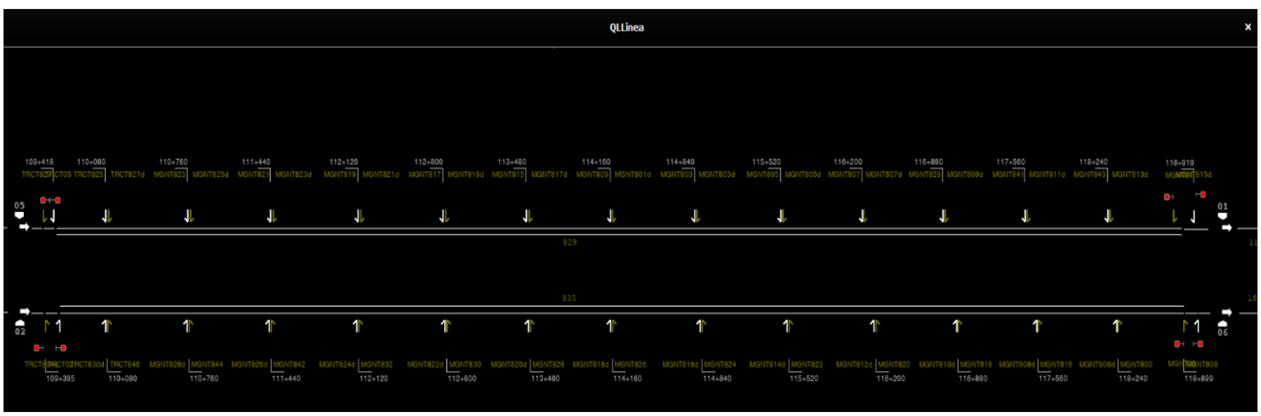


**Figure 11: Sample prototype view from the Dispatcher Control Panel**

#### 2.4.2.3 Architecture

Figure 12 shows the architecture of the prototype:

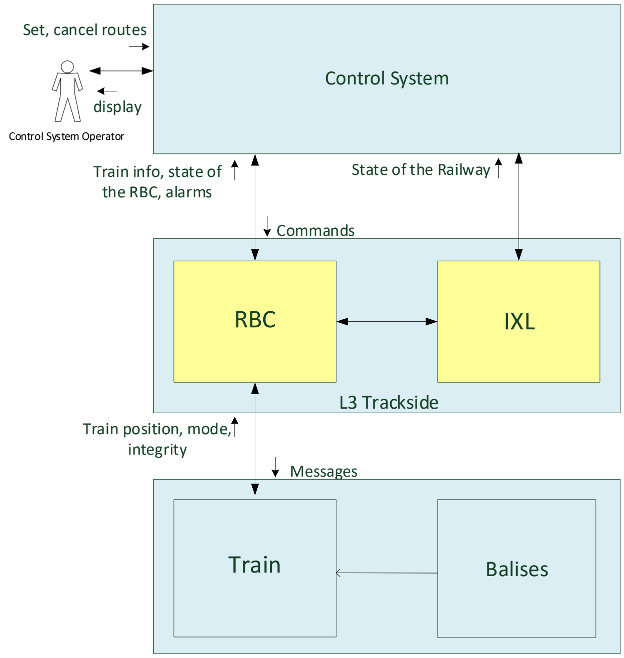


**Figure 12: Overall Low Traffic /Freight Prototype System Architecture (logical scheme)**

This architecture has been set up in a laboratory system, with the following composition and functional role:

- L3 Trackside, which is composed by:
  - hosted software implementing the ERTMS/ETCS RBC based on D5.1 and D5.2, which includes the interfaces with the IXL, with the Trackside Operator and with the train. This RBC implements FVB status evolution by combining Position Reports/Train Integrity information received from the on-board with the TTD status received from the IXL. This RBC also computes the availability of the line based on the state of its FVBs.
  - balises: ERTMS/ETCS balise database included within the RBC line configuration data.
  - IXL: ERTMS/ETCS L2-based Italian IXL simulator transmitting TTD status (both of station TTDs and of the inter-station TTD) and line direction to the RBC, as well as the status of any other physical or logical in-station object.
- Train: ERTMS/ETCS L2 on-board simulator transmitting Train Integrity information according to the UNISIG CR940.

The Test environment implementing this system has the following composition:

- Operator desk with monitors showing the Line and the Train display Panels and a few basic commands to the RBC, such as RBC Initialisation.

- RBC Safety Nucleus interface: software interface by which it is possible to interact with the RBC software for start-up and reset operations.
- GTB (Gateway Terra Bordo): software “gateway” providing information transfer from the on-board to the IXL simulator. This gateway, configured with the same line database of the RBC, receives train position information from the on-board simulator and provides the IXL simulator with the occupied TTDs associated with this position.
- On-board simulator: software interface from which it is possible to monitor communication with the RBC (communication status, message exchange) and to set several Position Report parameters and degraded conditions such as loss of communication and loss of integrity.
- IXL simulator: software interface from which it is possible to set station path and line direction. This simulator interfaces with the GTB and with the RBC.

#### 2.4.2.4 Functions Included

The functions implemented are those associated with the scenarios in Table 6. As it is visible from that table, there are scenarios not taken into account for this prototype. This is due to the following reasons, also impacting on the selected line chosen for prototype:

- Handover and transitions: requirements have been deemed not different from Level2, especially considering that some topics further discussed during X2Rail-3 where pending at the end of X2Rail-1 project .

- Joining, Splitting, generally in-station procedures: Stations have not been re-engineered, such as explained in section 2.4.2.2, therefore it has been deemed that this kind of operations would have not shown better performance than the original line.

### 2.4.3 Outcome

#### 2.4.3.1 Result from tests

A short summary of the testing of functions is in the next subsections.

The tests have proven the feasibility of the Level 3 Low Traffic/Freight Technical Demonstrator in the normal and degraded situations mentioned in the subsections below.

The tests are based on X2Rail-1, [X2R1-D52] and [X2R1-D51] respectively.

All tests passed as expected, however some situations have generated the observations and suggestions reported in sections 2.4.3.2 and 2.4.3.3, respectively.

##### *2.4.3.1.1 Normal Train Movement*

An integer train performs Start of Mission from a station track section and sends an MA request message to the RBC. The RBC sends an MA message to this train and it starts moving. As the train moves, the state of the FVBs involved in this passage transitions from free to occupied and from occupied to free. As the first FVB of the line becomes free, the line is available for a chasing train. A second integer train performs start of mission from the same station, sends the RBC an MA request message and receives an MA message up to the last FVB released by the first train.

As this latter releases an FVB with its CRE, an extended MA message covering the same FVB is sent to the chasing train.

#### *2.4.3.1.2 End of Mission*

An integer train performs Start of Mission from a station track section and sends an MA request message to the RBC. The RBC sends an MA message to this train and it starts moving. As the train moves, the state of the FVBs involved in this passage transitions from free to occupied and from occupied to free. The train performs End of Mission within the line. The state of the FVBs on which the train is located transitions from occupied to unknown and remain in this state until swept or cleaned-up by means of a command from the operator.

#### *2.4.3.1.3 Start of Mission*

A train with a known position establishes a safe connection with the RBC, sends Train Data Message and receives the validated train data message. The train sends a Position Report including Train integrity information and all the FVBs associated with the train location (from the one including the train front end to the one including its CRE) becomes occupied.

#### *2.4.3.1.4 Loss of Communications*

An integer train performs Start of Mission from a station track section and sends an MA request message to the RBC. The RBC sends an MA message to this train and it starts moving. As the train moves, the state of the FVBs involved in this passage transitions from free to occupied and from occupied to free. A loss of communication with the train is detected from the RBC, and all the FVBs from the one including its CRE and the one ending at the End of Authority of its MA transitions to the unknown state. This state remains as the train moves. The train regains communication with the RBC and sends a new Position Report with train integrity information. The state of the unknown FVBs transition to free or to occupied depending on the latest reported position.

#### *2.4.3.1.5 Initialisation of Trackside*

Trackside Startup with no trains: all the FVBs of the line have unknown status, the RBC is not able to detect information from the XL and the inter-station TTD state is set to the safe state (occupied). The RBC is able to detect information from the IXL and the inter-station TTD transitions to free. The Operator sends the Initialisation Command to the RBC with which confirms that the startup process is finished and the FVBs of the line transition to free.

#### *2.4.3.1.6 Loss of Train Integrity*

An integer train performs Start of Mission from a station track section and sends an MA request message to the RBC. The RBC sends an MA message to this train and it starts moving. As the train moves, the state of the FVBs involved in this passage transitions from free to occupied and from occupied to free. The train sends a Position Report to the RBC with train integrity lost, the

RBC receives it and all the FVBs from the one including its CRE and the one including its front transitions to the unknown state. This state remains as the train moves, and the FVBs associated with each further Position Report received transition from free to unknown as well. The train sends a new Position Report with train integrity confirmed. The state of the unknown FVBs transition to free or to occupied depending on the latest reported position (current CRE and front end).

##### *2.4.3.1.7 Sweeping*

An integer train performs Start of Mission from a station track section and sends an MA request message to the RBC. The RBC sends an MA message to this train and it starts moving. As the train moves, the state of the FVBs involved in this passage transitions from free to occupied and from occupied to free. The train sends a Position Report to the RBC with train integrity lost, the RBC receives it and all the FVBs from the one including its CRE and the one including its front transitions to the unknown state. This state remains as the train moves, and the FVBs associated with each further Position Report received transition from free to unknown as well. A second integer train performs start of mission from the same station, sends the RBC an MA request message and receives an MA message automatically extended over those unknown FVBs in rear of the one currently including the latest min safe rear end of the train ahead, based on the latest Position Report received from this latter. As the second train releases with its CRE the unknown FVBs included in its MA, the state of these FVBs transitions to free.

##### *2.4.3.1.8 TTDs*

In all the above scenarios TTD status (received form the IXL) is taken into account by the RBC to determine the state of the FVBs of the line, together with the position information coming from the train via Position Report.

#### 2.4.3.2 Observations

The inter-station axle counter impacts on the status of the whole line selected, it is like to say that the whole line is associated with a single TTD. That being stated, it has been experienced that D5.1 requirements REQ-TTD-1 does not properly cover this particular configuration, but only the typical overlay configuration having several TTDs. In fact, if a train performs EoM as per section 2.4.3.1.2, only the FVBs associated with the train location become unknown, while those released or never occupied by that train remains free. This is in line with the EoM requirements within D5.1 and with REQ-TTD-2, but apparently contradicts REQ-TTD-1 and its Rationale, according to which all parts (FVBs) of a TTD should become unknown after a latency timer is expired without the RBC having received a Position Report from the train.

Another Observation regards Scenario 2.4.3.1.7. If the train with lost integrity regains integrity information (this could happen in case of temporary TIMS failure), the RBC cleans-up the unknown FVBs still not swept by the chasing train but already covered by an MA with on-sight profile for that train, however, in the absence of specific requirements within D5.1, it has been project-specific choice that the on-sight profile already sent to the chasing train is not upgraded according to the new state of the cleaned-up FVBs. This behaviour has been deemed safer for the chasing train.

The first MA assigned to any train always includes an on-sight profile over the FVB under the train front end. Such degraded profile comes from a project-specific implementation for the “Novara Padova” Project, where it was implemented on the TTD under the train front end.

From the performance perspective, it is relevant that the original portion of line selected from the “Novara-Padova” line has track sections long about 2000m, therefore, in addition to the overall saving of TTDs, configuring FVBs of 700m has reduced the headway by around a third, with the same trains (type and length).

#### 2.4.3.3 Suggestions

If on one hand the guidance of REQ-TTD-1 has pointed out the typical scenario originating this requirement,(that is train entering a track section before the RBC receiving any updated Position Report from that location) on the other hand it is suggested that the main text of REQ-TTD-1 is slightly reworded so that it is clear that a TTD still occupied by a train no longer connected because of an EoM carried out or because not yet re-connected after a system restart does not require a latency timer to be managed (i.e. latency timer should be activated only in case a TTD were occupied without neither any current nor stored event associable to this occupation).

# 3 Conclusions

This Deliverable contains descriptions of the four Moving Block Technical Demonstrators created within X2Rail-3 Task 4.6, and the results of the testing of the Technical Demonstrators.

Most of the tests in the four Moving Block Technical Demonstrators have passed successfully. However, there are some Observations and Suggestions from each of the Technical Demonstrators.

These Observations and Suggestions will be processed as part of the work on the specification update which will take place within X2Rail-5.

# 4 References


[X2R3-D42] X2Rail-3 WP4 Moving Block Deliverable
D4.2 Moving Block Specifications

[X2R1-D51] X2Rail-1 WP5 Moving Block Deliverable
D5.1 Moving Block System Specification

[X2R1-D52] X2Rail-1 WP5 Moving Block Deliverable
D5.2 Moving Block Operational and Engineering Rules

[X2R3-D41] X2Rail-3 WP4 Moving Block Deliverable
D4.1 Report on Testing of Moving Block Signaling Systems

[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.

# Appendix A - Ownership of results

The following Table 7 lists the ownership of results for this deliverable.

| Ownership of results | | | |
|---|---|---|---|
| **Company** | **Percentage** | **Short Description of share/ of delivered input** | **Concrete Result (where applicable)** |
| SIE | | | |
| BTSE | | | |
| STS | | | |
| TD | | | |

**Table 7: Ownership of results**

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