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VB Train Positioning Specification

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1 Executive Summary

This document reports the activity related to subtask 5.2.1 “Fail-Safe Train Positioning based on Virtual Balise (VB) – Specification and Solution enhancement” as part of Task 5.2 “Train Positioning Specification” of WP5 “Fail-Safe Train Positioning Specification”.

2 Table of Contents

2.1 Table of Figures

2.2 Tables

3 Abbreviations and acronyms

The following table provides definitions for terms, acronyms and abbreviations relevant to this document.

Abbreviation / Acronyms	Description
ATO	Automatic Train Operation
BG	Balise Group
BTM	Balise Transmission System
CENELEC	Comité Européen de Normalisation Électrotechnique
CCS	Control-Command and Signalling
DM	Digital Map
EGNOS	European Geostationary Navigation Overlay Service
EM	Electro Magnetic
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FSTP	Fail-Safe Train Positioning
GA	GNSS Augmentation
GNSS	Global Navigation Satellite System
IXL	Interlocking
KPI	Key Performance Indicator
MOPS	Minimum Operational Performance Standards
PVT	Position Velocity Time
RAMS	Reliability, Availability, Maintainability and Safety
RBC	Radio Block Centre
SBAS	Satellite-Based Augmentation Systems
SF	System Failure
SIL	Safety Integrity Level
SiS	Signal in Space
SoL	Safety of Life
TSI	Technical Specification for Interoperability
VB	Virtual Balise
VBR	Virtual Balise Reader
VBTS	Virtual Balise Transmission System

4 Background

The present document constitutes WP5's Deliverable D5.1 "VB Train Positioning Specification".

The Deliverable is part of the framework of the Project titled "Completion of activities for Adaptable Communication, Moving Block, Fail safe Train Localisation (including satellite), Zero on site Testing, Formal Methods and Cyber Security"(Project Acronym: X2Rail-5; Grant Agreement No 101014520).

5 Objective/Aim

Starting from the results and findings obtained in X2RAIL-2 regarding the development of the Fail-Safe Train Positioning **(FSTP)** based on the approach proposed in Stream 1 (The reader is referred to the following deliverables [1]-[6]), this document aims to advance in specifying the solution, by integrating the latest efforts made both in the WP5 context towards standardization and in the WP6 context in the demonstration phase. As direct result, this document represents the most updated version of Virtual Balise based solution specification.

6 Introduction

This document provides the set of specifications and requirements aimed at easing the use of Satellite technology (GNSS) in the ERTMS ETCS L2/L3 safe train positioning by introducing the Virtual Balise (VB) concept.

Therefore, using satellite-based functionality refers to the use of satellite technology to provide safe train positioning through the virtualization of balises, known as VB. Building on the activities developed in other tasks within WP5, namely those related to standardization of augmentation information necessary to use EGNOS and Digital Map (DM), and taking into account the feedback received from WP6 demonstrators, this document further consolidates the functional architecture already specified in X2R2 [2], detailing the input/output features and resulting functional and non-functional requirements.

Section 5 of this document states the objectives and aims of the document along with any relevant dependencies.

Section 6 (i.e. this section) provides an introduction and overview of the system needed to understand the rationale for specifications stated in the remaining sections.

Section 7 contains the VBTS system description, with details on its inputs and outputs, going down to interfaces specification.

Section 8 lists the functional and non-functional requirements.

Section 9 provides details about RAMS analysis.

Section 10 investigates the feedback that the demonstrative phase provided from field experiences to WP5 activities.

Section 11 provides the conclusions.

7 Fail-Safe Train Positioning (FSTP) based on Virtual Balise (VB): System Functional Specification

In this section the functional specification of the FSTP system based on VB will be first provided, identifying the interfaces that interact with the subsystems; then, for each of the presented interfaces the expected information is described. To be noted that, at this level, the document shall only refer to functional interfaces.

7.1 System Description

The reference architecture of the system described in this chapter was designed and finalized in the activities carried out in the X2Rail-2 project [2], and here it is shown in Figure 1 for sake of clarity.

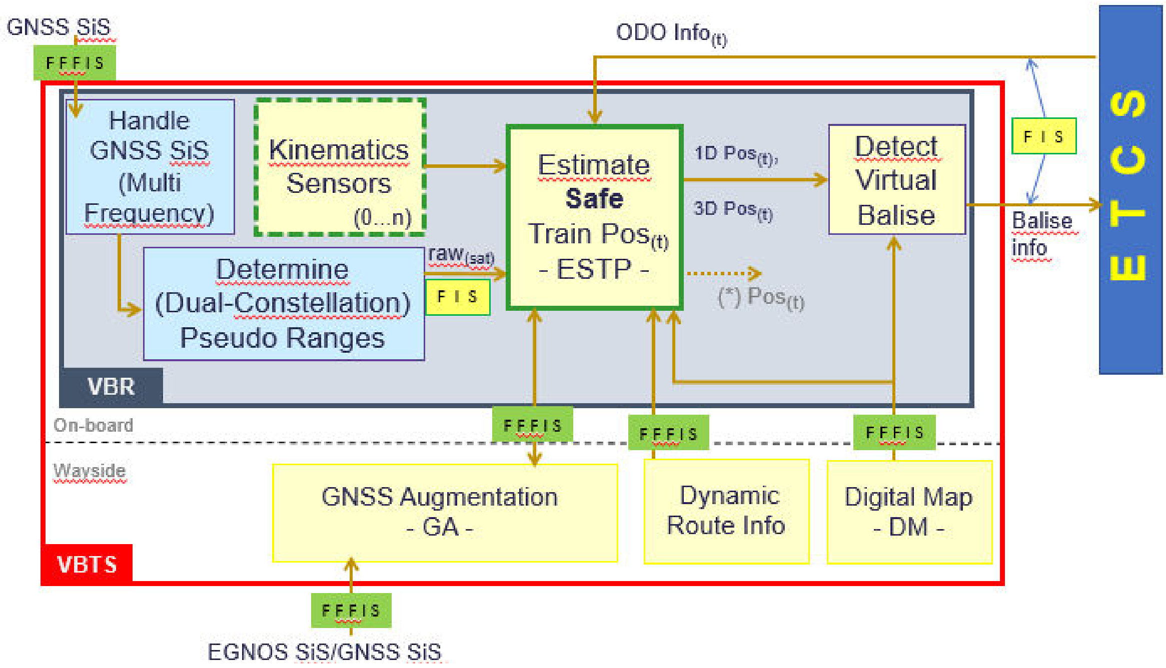

Figure 1: Architecture of VB-based FSTP

The FSTP solution already proposed in X2Rail-2 WP3 Stream 1 is based on the concept of the virtualization of the physical balise, therefore it is referred to as Fail-Safe Train Positioning based on Virtual Balise (**VB**).

The whole system is indicated as **VBTS**, namely Virtual Balise Transmission System, that includes both the on-board (i.e. Virtual Balise Reader, **VBR**) and the trackside part (**VBTS wayside**). The system is designed to be integrated into existing ERTMS/ETCS system structure with minimal level of intrusiveness, so as to ensure the VB detection function without changing the on-board

ERTMS/ETCS location determination functions. More specifically, VBTS works in cooperation with ETCS and does not implement ETCS functions; besides, it uses the location principles - leaving them unchanged - of the current ETCS system described in Subset-026 §3.6 [7] (e.g., Train Position Confidence Interval and Relocation, Position Reporting to the RBC, etc.), complementing the BTM with the management of the *Virtual Balise*.

The VB detection is performed by *Detect Virtual Balise* block displayed in Figure 1: it is the main function of Stream 1 FSTP that utilizes the safe train position (provided by the *Estimated Safe Train Position –ESTP-* functional block) to evaluate a condition of "matching" between such position and the known VB Location. When a matching event occurs, namely a VB detection, the VBTS executes the same actions as the real BTM: provides information suitable for detecting and evaluating the location reference of the (Virtual) Balise, making this information available to the ERTMS/ETCS Kernel as a Real Balise Transmission Module function would. (as stated into §4.4.6.2.4 section of Subset-036 [8]).

It provides the GNSS-based position together with its confidence interval, unconstrained (referred to as *3D Pos(t)* in the Figure 1) or constrained (i.e. matched to the track on the map, referred to as *1D Pos(t)* in the Figure 1). This feature should be considered for easing the FSTP employment for other on-board applications (e.g. ATO, enhanced positioning), once their user needs are specified.

The ESTP functional block can optionally utilize additional kinematic sensors (on top of that what is already part of ETCS Odometry). Indeed, in the case the odometry information already provided by ETCS Odometry enables the FSTP based on VB to compute the continuous position estimation in accordance with the expected performance and safety, the additional kinematic sensors are not required for VB detection. Anyway, due to the fact that each supplier has its own odometry, it remains a choice of the supplier if, which and how many kinematic sensors to add for achieving the performance and safety targets.

In the following section, the description of functional inputs and outputs is provided.

7.1.1 Functional Inputs

In this section, an input is classified as:

- Mandatory input, if it must be used by FSTP for obtaining the expected results.

- Safety related input, if it guarantees by itself safety integrity to some extent. Note that, as extracted from [7] <<*a function, component, product, system or procedure is called safety-related if at least one of its properties is used in the safety argument for the system in which it is applied. These properties can be of functional or non-functional nature. The requirements attributed to the function can be systematic or random integrity requirements*>>.

- Optional input, if it can be optionally used by FSTP for obtaining the expected results.

7.1.1.1 GNSS-SiS - FFFIS (IS GPS-200, Galileo OS SIS ICD, etc.) (Mandatory Input)

The acquisition of the GNSS signals (broadcasted by space segment) takes place at the trackside (for navigation data) and by the on-board (for raw observation data). The ability of optionally acquiring navigation data by on-board is also covered in the solution.

7.1.1.2 GNSS Augmentation (GA) Information (Safety Related Mandatory Inputs)

The VBR also takes advantage of the SBAS data (i.e. corrections and integrity information) coming from VBTS wayside for the calculation of the train position. In particular, EGNOS SiS (w.r.t. RTCA Do229E – ED-259) is acquired by wayside to make available GA information to the on-board unit; it is expected that this information ensures the safety, with a given THR, of GNSS system against global threats.

To be noted that GNSS SiS by itself does not have associated safety integrity requirements, while safety of the service is guaranteed by GNSS Augmentation information.

7.1.1.3 Digital Map – DM (Safety Related Mandatory Input)

DM represents the complete set of trackside related information (e.g. track geometry, objects locations etc.), used for FSTP functionality (please refer to [21] for the description of the state of the art of DM for LOCalization). Starting from this complete set, specific views can be obtained to suit different needs (e.g. by VBR and VBTS wayside), namely:

- Wayside views shall be formatted so that they can be logically linked to the usual representation of the line used by the signalling equipment (RBC).

- On-board views shall be formatted (see §9.3 of [2]) so that they can:
  - represent the geometry of the track and the VBs positions;
  - be easily and safely used by the VBR.

The DM Data shall be available on-board before the train enters in an area where FSTP is supposed to be active. It shall include also the Virtual Balise representation (e.g., Balise User Bits, Virtual location along the track) that is necessary for VBR to perform the VB detection (see §6.1.1.3 of [2] for more details).

The DM Data can also contain the auxiliary information relevant to particular technologies employed in ESTP. An “a priori reception information” describing the obstacles along the track preventing or attenuating GNSS signal reception can be given as an example. However, since not all solutions utilize this DM Data it is a matter of further evaluation in the next projects.

7.1.1.4 Dynamic Route Information (Safety Related Mandatory Input)

This information represents the dynamic information necessary to identify, within the DM, the track portion that the train is actually travelling. It is mainly related to constrained position computation performed by ESTP block (w.r.t. Figure 1).

Dynamic Route Information shall be updated in the FSTP by means of a Radio Communication Channel before the train enters into the track section.

The Dynamic Route Information includes:

a) Route information, including the status of the switches;

b) initial train position and

c) initial train orientation.

The initial train position and orientation is defined from ETCS Position Report (including validated SoM PR), IXL info about track occupancy, and eventually other inputs from specific applications managed by the ETCS On-Board.

7.1.1.5 Odometry (Safety Related Mandatory Input)

The FSTP receives from On-Board ERTMS/ETCS kernel continuous information related to train kinematics,, namely the odometer information or Odometer Data (i.e. Travelled Distance, Speed and Time, see § 9.6 of [2]). The Odometry Data are computed by On-Board constituent and they are based on the information coming from the “Odometry Sensors” (e.g. Wheel Sensors mounted on the train’s bogies, Radars, Accelerometers, IMUs, etc.).

This type of information (in particular, Time and Distance with related uncertainties) is useful to assign to the 1D Pos(t) an appropriate tag or time stamp. By means of such tag/stamp, the “Detect Virtual Balise” Block shall be able to refer the Balise Info in the same Odometric Coordinates System used by ETCS Kernel.

With integrated FSTP the Performances of the Odometry Subsystem in the ETCS reference architecture shall be compliant (i.e., better or equal) to the Subset-041 Requirements [9].

7.1.1.6 Independent (from ETCS Odometry) Kinematic Sensors (Optional Input)

Further kinematic sensors are not required if the Odometry Information already provided by ETCS Odometry enables the FSTP to compute the continuous position estimation in accordance with the expected performance and safety.

The independence shall be guaranteed by each supplier at a level of kinematic physical measures. The demonstration of this is supplier-dependent because the set of physical measures employed by ETCS Odometry is chosen differently by each supplier.

To be noted that kinematic sensors can be used to further improve FSTP only if they are independent from ETCS Odometry, otherwise common cause failures might be possible and can affect consistency checks.

7.1.2 Functional Outputs

7.1.2.1 Output to ETCS Kernel

In a short/medium time perspective of using the FSTP into the ETCS architecture as it is, the only functionally valid output generated by FSTP – in the sense that it is the only actually processable new[1] information for localization aims – is towards ETCS kernel for Balises detection functionality.

In this case, the 1D position (*1D Pos(t)*), constrained to the track, computed by ESTP block with the corresponding Along the Track Protection Level (ATPL) is given in input to Detect Virtual Balise block, for triggering the detection of VB. When this event occurs, it is announced to ETCS Kernel in an equivalent manner respect to what is actually done by BTM, namely through the message representing the "**output to ETCS Kernel**"; this message includes (see §4.4.6.2.4 section of Subset-036 [8]):

- Time and odometer stamp of the detected virtual balise centre,
- The detection error associated with the virtual balise detection accuracy,
- Balise information (user bits) for the detected virtual balise.

7.1.2.2 Outputs for future uses

All location-related information currently elaborated by Stream 1 FSTP, namely 1D/3D position (i.e. track constrained/unconstrained to the map) are auxiliary information potentially available for other on-board applications.

At the time of writing this document, outside of immediate use for ETCS positioning, this is considered as future use of FSTP, due to the lack of agreed and consolidated operational needs.

7.2 System Interfaces Specification

For each interface identified in Figure 1, the type of interface specification is indicated: more specifically, the level of the information is equivalent to FIS (Functional Interface Specification) if interoperability is not required; otherwise, the level of FFFIS is required to allow interoperability.

The 6.1.4 section of [2] provides a complete list of interfaces involved in Stream1 FSTP, together with their definition and related documentation. Besides, Appendix 9 of [2] completes the interfaces specification with the description of related functions and data.

[1] Odometry is an existing functional block of the ETCS system.

8 SYSTEM REQUIREMENTS FOR VBTS

The requirements specification activity carried out in WP5 started from the analysis on the requirements done in the context of WP3 of X2R2; they were subsequently refined during the course of WP5, basing on the feedback received from demonstrative phases carried out in WP6.

The resulting consolidation and specification effort is reported in the following sections, where functional and non-functional requirements are formalized.

Hereafter, the term “shall” is used to indicate mandatory requirements, while the term “must” is used to identify features that are important, but are out of the scope of this document.

8.1 FUNCTIONAL REQUIREMENTS

8.1.1 General Requirements

According to the architecture displayed in Figure 1, the functional requirements of the main constituents of VBTS are specified.

8.1.1.1

The VBTS shall consist of:

a) VBR that, in analogy with the BTM Function, is part of the components of the ETCS on-board subsystem. It is responsible for the safe detection of train position, based on GNSS data, and provides virtual balises, when detected, to the ERTMS/ETCS Kernel.

b) a wayside function that has the task of providing augmentation and route information (by GA and Dynamic Route Info), based on a pre-configured DM, to all VBRs of connected vehicles.

8.1.1.2

A train equipped with the VBR shall ensure interoperability with all lines compliant with CCS TSIs specification [10], also in case they are not equipped with wayside VBTS and Virtual Balises.

Note: The VBR is an additional function that complements current ETCS on-board functions (e.g., BTM).

8.1.1.3

The VBTS shall allow the use of the VB functionality only as a result of safe discrimination (i.e. unambiguous and certain discrimination in accordance with SIL4) of the track on which the train is located.

Note: If necessary, the VBR can use the information from the physical balises to discriminate the track on which the train is located (e.g. when the train starts to run, announcing itself with a position different form valid).

8.1.1.4

The interoperability-relevant messages, packets and variables exchanged over the interface between GA and VBR shall be compliant with [12].

8.1.1.5

Each virtual balise shall have a unique identifier and shall contain information encoded according to ERTMS/ETCS rules for balise telegrams (see section 8.4.2 of [7]).

Note: This is for minimizing the impact on ERTMS/ETCS kernel.

8.1.2 VBR-related Requirements

8.1.2.1

The ERTMS on-board subsystem based on GNSS localization functionality shall be equipped with the VBR function to detect the VB telegram.

8.1.2.2

The VBR shall be equipped with a set of GNSS antennas placed on the train roof, suitable amplifiers and connection cables. They shall be compliant to the railway MOPS as well as with the railway standards (e.g. EN 50155 [13], EN 50125-3 [14], EN 50121-3-2 [15] and EN 50126 [16]).

Note: Preliminary railway MOPS could be found in X2R2 D3.6 deliverable [5].

8.1.2.3

The VBR shall determine the position of the train on the track (constrained position) using:

a) GNSS signals, navigation data and augmentation information;

b) information on the railway track described by DM;

c) information provided by odometry and optionally from additional kinematic sensors;

d) any dynamic route information, corresponding to the status of the switches, enabling the determination of a unique route.

8.1.2.4

The VBR shall determine the odometric time and space when a VB is encountered by comparing the estimated safe train position with the VB locations stored on the DM.

8.1.2.5

When a VB is encountered, the VBR shall transmit to the ERTMS/ETCS Kernel the contents of the virtual balises (i.e. user bits), in a similar way to what the BTM does for physical balises.

8.1.2.6

The VBR shall use position/odometry information to transmit VB time and odometer stamping information to the ERTMS/ETCS kernel in a similar manner as done by BTM with physical balises.

8.1.2.7

The VBR shall transmit to the ERTMS/ETCS Kernel the accuracy information of the VB position taking into account the contributions of all uncertainties which affect the position estimate (coming from satellite positioning, DM together with Dynamic Route Information, odometry and optionally from additional kinematic sensors).

Note: Therefore, the confidence interval calculated by the ERTMS/ETCS Kernel and based on VB shall take into account the contribution of overall uncertainty transmitted by the VBR.

8.1.2.8

The VBR shall ensure that VB information is delivered to the ERTMS/ETCS Kernel in sequence, in the correct order, according to the train movement direction.

8.1.2.9

At startup the VBR shall run self-tests for checking its nominal behavior.

8.1.2.10

If the VBR self-tests fail, any anomaly shall be reported to the ERTMS/ETCS Kernel (and the driver) and the VB function shall be suspended.

8.1.2.11

The VBR shall perform run-time tests and any anomaly shall be reported to the ERTMS/ETCS Kernel (and the driver), and the VB function shall be suspended (without braking the train).

Note: The suspension of the VB function means that the ERTMS kernel will no longer receive the contents of VBs, and the system will continue to operate in accordance with ERTMS rules.

Note: As VBs are not expected to be used to provide safety related ETCS packets (e.g., Stop if in SR/SH, TSR, …), a less restrictive reaction than SF is expected. In general, while BTM shall guarantee balise detectability, VBR may not, especially at SoM or in case route cannot be safely determined.

8.1.3 VBTS Wayside-related Requirements (GA, Dynamic Route Information and DM)

8.1.3.1

The VBTS wayside (namely, the ERTMS wayside subsystem based on GNSS localization) shall be equipped with GA, Dynamic Route Information and DM-related functions.

8.1.3.2

The GA shall perform the following functions:

a) acquires GNSS SISs for navigation data demodulation;

b) interfaces with a public augmentation network (e.g., EGNOS) to acquire the augmentation data (i.e., differential correction and integrity data);

c) disseminates GNSS-related data (i.e., navigation data and augmentation information) to each connected train, namely to each connected VBR, to allow GNSS-based train position performing the VB detection function.

NOTE: It is expected that the augmentation information ensures the safety of GNSS system against global threats. For example, the augmentation data provided by EGNOS covers corrections and integrity for satellite position errors, satellite clock/time errors and errors induced by the estimation of the delay of the signal while crossing the ionosphere.

8.1.3.3

The Dynamic Route Info shall provide the route information (dynamic route) necessary for each connected VBR to determine the (constrained) position of the train on the track. This is ensured by:

a) acquiring route information (e.g., switches/points positions from interlocking, initial train position from ETCS, …);

b) acquiring DM data;

c) mapping on the DM the valid route information for each connected - and equipped with VBR- ERTMS train.

8.1.3.4

The VBTS wayside shall use exiting ERTMS Radio interface (currently GSM-R interface, in the future FRMCS) to implement the communication with all connected VBRs by means of ERTMS Safe Communication Session.

8.1.3.5

The VBTS wayside shall manage DM data representing:

a) Geometry of the railways track axis;

b) Virtual Balises representation. “To install” a Virtual Balise means to define a list of mandatory parameters: VBs Locations and VBs Balise Information (i.e. Balise User Bits).

Note: The information of the DM to be shared between VBTS wayside and VBR and how to access them are currently under discussion.

8.1.3.6

The VBR shall use the VB function only after the success of the consistency checks (compatibility) of the DM data used by the VBR and VBTS wayside. This consistency checks shall be carried out once the communication session is established between VBR and VBTS wayside.

8.1.3.7

If the consistency check fails, the VBR shall report the error to the ERTMS/ETCS Kernel and the driver and it shall attempt to load the update of the DM data automatically via the radio channel.

8.1.3.8

As long as the consistency checks (compatibility between VBR and VBTS wayside) of the DM have not been successful, the VB function shall be suspended.

Note: The suspension of the VB function means that the ERTMS kernel will no longer receive the contents of VBs, and the system will continue to operate in accordance with ERTMS rules.

8.2 NOT FUNCTIONAL REQUIREMENTS

In the following sections, the non-functional requirements are reported, taking into account that VBTS has to operate in a Railway Environment.

8.2.1 Installation Criteria of Virtual Balises

8.2.1.1

In the framework of the assessment of the specific applications, the areas where the VB concept is applicable (i.e. where the VB shall be virtually installed) shall be identified through dedicated tools (e.g., performance simulator) taking a Track Survey as one of their inputs.

8.2.1.2

The installation constraints for virtual BG (e.g. minimum distance between balises) shall not be more restrictive than the equivalent constraints for Eurobalises.

8.2.1.3

The criteria for determining which BGs can be "virtualized" must be defined in the Hazard Analysis process, based on their contents (ETCS packets), location and overall function in the specific application.

8.2.2 Performance Requirements

8.2.2.1

The VBR function shall never allow an increase of current train position confidence interval computed by the ERTMS/ETCS on-board kernel when a virtual BG is detected.

Note: The VBR may discard a GNSS-based position whose poor accuracy may affect the detection error associated with a virtual balise, to avoid the increase of current train position confidence interval computed by the ERTMS/ETCS on-board kernel.

8.2.3 Monitoring Requirements for VB function

8.2.3.1

The VBTS must be equipped with tools capable of performing automatic offline monitoring of data collected during operation, through the use of predefined KPIs (e.g. position accuracy, delivery of established VBs, correct sequence of provided VBs, train position confidence interval) and producing alarms if the VB function may be compromised (e.g. predictive diagnostics of GNSS signal quality).

Note: A proposal of possible KPIs is elaborated and defined in [17].

8.2.4 Safety Requirements

8.2.4.1

The design, development, implementation, and maintenance of VBTS functions must comply with CENELEC standards for the railway industry [16], [18], [19] for SIL4 applications.

8.2.4.2

The VBTS must ensure a Tolerable Hazard Rate of at least the one specified in European standards [10]; in particular, the safety target of $1.0 \cdot 10^{-9}$/h for the onboard ETCS subsystem and 10^{-9}/h for the ETCS ground subsystem as specified in Subset-091 [11] must be guaranteed at the system level.

8.2.4.3

The design, implementation, and maintenance process of the digital track map must comply with CENELEC standards for the railway industry [16], [18], [19] for SIL4 applications.

8.2.4.4

The ERTMS/ETCS L2 system, which includes the VBTS, must provide a confidence interval of the train position based on VB in compliance with SIL4, regardless of the position and any changing environmental conditions (including global phenomena mitigated by the augmentation function and local events such as EM interference and multipath).

9 RAMS ANALYSIS

The RAMS analysis conducted in X2R2 identified RAMS-related requirements; more specifically, into section 6.4 of D3.2 [2], the top-level functionalities of the VBTS constituents in terms of basic functions are defined and then the related hazards are found. To be noted that intentionally the same functions are referred to and analyzed by Subset-036 [8] and a similar approach has been followed for top level hazards.

10 Feedback from technological and operational experiences

Considering the functional architecture shown in Figure 1, in X2Rail-5-WP6 the technological demonstrators are developed, with the aim to evaluate the feasibility of Virtual Balise detection by mixing the state-of-the-art technologies for the GNSS-based positioning, augmentation network and kinematic sensor technologies. More specifically, WP6 focused on three different demonstrators. For sake of completeness, following a brief description is taken from [17]: the reader is referred to [17] for more details.

The AZD's demonstrator represents an implementation of Virtual Balise resulting from both X2Rail-2 and X2Rail-5 research activities. The aim of the demonstrator is to confirm the feasibility of the concept and also to assess the performance of the implementation in the real railway environment; coping with this idea, the logic behind the test bench design is to be simple and minimalistic but still providing sufficient capability to support development of AZD's Virtual Balise demonstrator. The authenticity of the railway environment is solely ensured by the real data which were collected during the measurement campaign in the railway environment. The test bench therefore does not simulate any environmental impacts on GNSS signals, only those already recorded in the input dataset are used during laboratory testing.

Goal of Hitachi Rail STS demonstrator developed within the X2R5 WP6 is to prove the effectiveness of the FSTP applying the Virtual Balise concept on an existing ERTMS environment. It is just the complete integration with ERTMS the key feature of HSTS demonstrator be aimed at demonstrating the feasibility of a new technology such as the satellite-based positioning on a well-established operational context like the ERTMS one is. The pilot line is a currently working ERTMS commercial line, with a tight scheduled rail traffic and therefore not freely to be used for all the tests needed especially for the development and tuning phases. For this purpose, the Hitachi Laboratory has been set up with Hardware and Software instruments which constitute the Demonstrator Testbed aimed at including the capability to perform testing of equipment under both nominal and extreme conditions, including support for fault-injection testing. The testbed complements field testing, allowing conditions that are statistically unlikely to be observed in the field to be simulated in a highly controlled and repeatable environment.

The demonstrator develops by MERMEC for X2Rail 5 WP6 implements a Virtual Balise solution as a result of what was done during the X2Rail-2 project and the activities carry out in X2Rail-5 project. It is fed with real data from real acquisitions. The entire demonstrator will be tested in the laboratory, the receiver will be installed also on the vehicle even when the test runs are performed.

The receiver outputs are collected during real trips. The activities in the laboratory will be used to evaluate the deviation from an independent and very precise Ground Truth.

The [20] provides comprehensive test specifications and test scenarios for the above-mentioned demonstrators. On the basis of these testbeds, an evaluation of Stream 1 FSTP performances and main system requirements becomes feasible. As result, the use of a set of Key Performance Indicators (KPIs), supplemented by related figures of merit (i.e., graphs and diagrams), provided valuable feedback to specification-related WP5 task, namely T5.2.1 task.

11 Conclusions

This document describes the updated system specification for Stream 1 FSTP.

The results of the testbeds and the consequent qualitative analysis conducted between WP6 and WP5, in fact, have allowed progress in the process of specifying the requirements that, started in X2R2, have been further consolidated in X2R5 WP5.

This specification gives also evidence that the VBTS ensures a new function which complements the BTM one, preserving the same principles and relation to the ETCS kernel. Due to this fact, in the near future, Stream 1 FSTP can be integrated into the ETCS architecture smoothly since the expected amount of specification changes seems to be limited.

12 References

[1] X2R2 D3.1 System Requirement Specification of the Fail-Safe Train Positioning Functional Block V 09
[2] X2R2 D3.2 System Architecture Specification and System Functional Hazard Analysis of the Fail-Safe Train Positioning subsystem V09.
[3] X2R2 D3.3 Business Model Impact Analysis associated with the Introduction of the Fail-Safe Train Positioning subsystem V 03
[4] X2R2 D3.5 – Internal Report Technical solutions for Fail Safe train positioning, advantages and disadvantages V 04
[5] X2R2 D3.6 Minimum Operational Performance Requirements of the multi-sensor devices required for the Fail-Safe Train Positioning subsystem Guidelines for Virtual Balise Transmission System V03
[6] X2R2 D3.7 V&V Process Definition and Functional-Non Functional Test Specification for the Fail-Safe Train Positioning Subsystem V 00
[7] ERTMS/ETCS System Requirements Specification Subset-026 issue 3.6.0
[8] ERTMS/ETCS FFFIS for Eurobalise Subset-036 issue 3.1.0
[9] ERTMS/ETCS Performance Requirements for Interoperability Subset-041 issue 3.2.0
[10] Set of Specifications 3 (ETCS B3 R2 GSM-R B1) of Technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union, Control Command and Signalling TSI | European Union Agency for Railways (europa.eu)
[11] ERTMS/ETCS Safety Requirements for the Technical Interoperability of ETCS in Levels 1 and 2 Subset-091 issue 3.3.0
[12] GNSS Augmentation for ERTMS/ETCS Interface Control Document for GA-OB/GA-TS (Airgap), Ref 20E087, version 0f, 31/05/2022
[13] CENELEC, "EN 50155 - Railway applications - Electronic equipment used on rolling stock", version May 2008
[14] CENELEC, "EN 50125-3 - Railway applications - Environmental conditions for equipment Part 3: Equipment for signalling and telecommunications", version Jan 2003
[15] CENELEC, "EN 50121-3-2 - Railway applications - Electromagnetic compatibility Part 3-2: Rolling stock – Apparatus", version July 2006
[16] CENELEC, "EN 50126 - Railway applications, The specification and demonstration of Reliability Availability Maintainability and Safety", version 2006
[17] X2Rail-5 D6.1 – VB Train positioning prototypes test bench. Version 03, 2022-09-08. X2R5-T6_2-D-HRI-002-02
[18] CENELEC, "EN 50128 - Railway Applications: Software for Railway Control and Protection Systems", version 2011
[19] CENELEC, "EN 50129 - Railways Applications – Safety-related Electronic Systems for Signalling", version 2018
[20] X2Rail-5 D6.2 – VB Train Positioning Updated Test Scenarios GA 101014520. Version 02, 2023-06-19
[21] X2Rail-5 D5.3 - Contribution to the standardisation activities GA 101014520. Version 01

Appendix A: Ownership of results

The following Table 12-1 lists the ownership of results for this deliverable.

Ownership of results			
Company	**Percentage**	**Short Description of share/ of delivered input**	**Concrete Result (where applicable)**
All beneficiaries contributing to WP5	-	The ownership of the WP5 results is shared between the X2Rail-5 beneficiary members of WP5. STS led the WP5 work and the WP5 members contributed to this work. STS, MER MEC and AZD are the authors of this deliverable D5.1 “VB Train Positioning Specification”.	VB Train Positioning Specification

Table 12-1 Ownership of results

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