Ref. Ares(2025)9208125 - 28/10/2025

Grant Agreement Number: 101101962
Project Acronym: FP6 - FutuRe
Project Title: Future of Regional Rail

DELIVERABLE D3.4
USE CASES AND SCENARIOS FOR ABSOLUTE SAFE TRAIN POSITIONING DEMOS ON G1 REGIONAL LINES

Project acronym:	FP6 - FutuRe
Starting date:	01/12/2022
Duration (in months):	48
Call (part) identifier:	Call: EU-RAIL JU Call Proposals 2022-01 (HORIZON-ER-JU-2022-01) Topic HORIZON-ER-JU-2022-FA6-01
Grant agreement no:	101101962
Grant Amendments:	AMD-101101962-15
Due date of deliverable:	30-09-2024
Actual submission date:	28-10-2025
Coordinator:	Michal Matowicki, AZD
Lead Beneficiary:	AZD
Version:	V4
Type:	Report
Sensitivity or Dissemination level[1]:	Public
Taxonomy/keywords:	Localisation, ASTP, regional railways

This project has received funding from the Europe's Rail Joint Undertaking (JU) under grant agreement 101101962. The JU receives support from the European Union's Horizon Europe research and innovation programme and the Europe's Rail JU members other than the Union.

[1] PU: Public; SEN: Sensitive, only for members of the consortium (including Commission Services)

Document history

Date	Name	Affiliation	Position/Project Role	Action/Short Description
03.10.2023	Michal Matowicki	AZD	Task Leader (Task 3.4)	v1 – Creation.
19.03.2024	Michal Matowicki	AZD	Task Leader (Task 3.4)	Consolidation of changes from initial review process
10.05.2024	Michal Matowicki	AZD	Task Leader (Task 3.4)	Cleaning of comments, remarks and requirement unification
29.05.2024	Michal Matowicki	AZD	Task Leader (Task 3.4)	Editor changes for M18
20.09.2024	Rui Eirinha João Mira	GTSP	Reviewers	Overall document review
30.09.2024	Michal Matowicki	AZD	Task Leader (Task 3.4)	Document update based on revision
02.10.2024	Fabrizio Burro	FT	WP1 Leader	Quality Check
02.10.2024	Fabrizio Burro	FT	WP1 Leader	Steering Committee Review
23.04.2025	Michal Matowicki	AZD	Task Leader (Task 3.4)	FP2 review updates
10.07.2025	Fabrizio Burro	FT	WP1 Leader	Quality Check
27.10.2025	Michal Matowicki	AZD	Task Leader (Task 3.4)	Improved description and clarified position of NTNU/NRD demonstrator
28.10.2025	Fabrizio Burro	FT	WP1 Leader	Quality Check

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Executive Summary

The present document represents the deliverable D3.4 with the title "Use Cases and Scenarios for Absolute Safe Train Positioning Systems (ASTP) demos on G1 Regional Lines".

This deliverable aims to provide a set of Use Cases and Scenarios that reflect the operational behaviour of a Regional Line, in relation to some ASTP functions.

The concept of a Use Case or Scenario is broadly defined in the industry, but in the context of this document it must be understood as a "sequence of steps or actions that defines the interaction between different actors (being those humans or technical systems) in a given situation".

Following that description, this document gathers a list of potential uses of an ASTP system in a Regional Line environment.

The main actors involved in the Use Cases or Scenarios described here are the ETCS system (its trackside or on-board part), and the Digital register (Map Data). In the scope of this deliverable, ASTP is a system under consideration which is put into the regional lines context using the defined Use Cases and Scenarios.

Once this deliverable is released, a selected subset of Use Cases and Scenarios shall be verified by demonstrators; this verification is the objective of the subsequent FP6 WP8 Task 8.5.

This later step shall serve to demonstrate that the technology developed in other Flagship Projects (e.g., FP1, FP2) is applicable and fits the customer needs when it is applied to the Regional Lines, by using the demonstrators created in FP6.

The present version of this document is the final version of D3.4 released under FP6 WP3 Task 3.4.

List of Abbreviations, Acronyms and Definitions

Abbreviation / Acronym	Definition
ATO	Automatic Train Operation
ATO-TS	ATO Trackside
ATP	Automated Train Protection
ASTP	Absolute Safe Train Positioning
BG	Balise Group
CCS	Control, Command and Signalling
DMI	Driver Machine Interface
ETCS	European Train Control System
EVC	European Vital Computer
FA2	Flagship Area 2 – R2DATO (used indistinctively with FP2)
FA6	Flagship Area 6 – FutuRe (used indistinctively with FP6)
FP2	Flagship Project 2 – R2DATO (used indistinctively with FA2)
FP2 WP21	Flagship Project 2 – R2DATO Work Package 21 Absolute Safe Train Positioning (ASTP)- operational needs
FP2 WP22	Flagship Project 2 – R2DATO Work Package 22 Absolute Safe Train Positioning - System Architecture, Design & RAMS
FP6	Flagship Project 6 – FutuRe (used indistinctively with FA6)
FP6 D3.4	Use cases and scenarios for cost effective fail-safe highly accurate train positioning demos on G1 regional lines – Collaborative Deliverable
FP6 Task 3.4 (belonging to FP6 -WP3)	Task 3.4 – Preparatory Activities for the Absolute Safe Train Positioning Systems demos on G1 Regional Lines
FP6 Task 8.5 (belonging to FP6 -WP8)	Task 8.5 – Development of individual demonstrator for cost-effective fail-safe highly accurate train positioning on G1 lines
FP6 WP2 (belonging to FP6)	Work Package 2 – Regional Rail System Solutions/Architecture
FP6 WP3 (belonging to FP6)	Work Package 3 – Regional Rail CCS & Operations for G1 Requirements & Specifications
FP6 WP8 (belonging to FP6)	Regional Rail CCS & Operations for G1 Demonstrations
FutuRe	Future of Regional
G1	Group 1 Regional Lines – those that are connected with the mainline railway system, forming together the Single European Railway Area (SERA) (see GA for further details)
G2	Group 2 Regional Lines – those that are not

Abbreviation / Acronym	Definition
	functionally/operationally connected with the mainline railway network (see GA for further details)
GA	Grant Agreement
GoA	Grade of Automation
MA	Movement Authority
MoM	Minutes of Meeting
MXX	Month (number) XX
NA	Not Applicable
OB	Onboard
RBC	Radio Block Center
SoM	Start of Mission
SSP	Static Speed Profile
TBC	To Be Completed
TBU	To Be Updated
TE	Technical Enabler
TPR	Train Position Report

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N/A

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1. Introduction

The present document constitutes the final version of the deliverable D3.4 (Use cases and scenarios for cost-effective fail-safe highly accurate train positioning demos on G1 regional lines – Collaborative Deliverable).

Chapter 1 provides a high-level background and the lists of inputs and outputs involved.

Chapter 2 explains the objective of the task T3.4 and of its associated deliverable, D3.4.

Chapter 3 depicts the scope of the content of this deliverable.

Chapter 4 gathers the list of Uses Cases, grouped by functionalities and by owner.

Chapter 5 gathers general requirement for regional lines

Chapter 6 describes connection of T3.4 findings with KPI's

Chapter 7 introduces tips and needs to be considered prior to performing the demonstration (during WP8 lifetime).

Chapter 8 closes the document, with the most relevant conclusions.

1.1. Background

The D3.4 is located within the Task 3.4 (belonging to the WP3).

According to the GA, the mentioned task will be performed, based on the specifications, guidelines and any other deliverables (regarding ASTP functionalities) existing and/or coming from FP6 WP2, FP2 WP21 and WP22, and the System Pillar. Additionally, Shift2Rail projects may also be considered as inputs for consultation.

1.2. Inputs

As mentioned above, different sources are used to create this deliverable. The next two sections identify the main inputs, both external to this FP and internal to this FP, which have been evaluated.

1.3. External Inputs

- FP2: In particular, the deliverables coming from WP21 and WP22. [2]
- System Pillar, as consultation [2].
- Shift2Rail deliverables.
- EUG Localisation Working Group, as consultation [3].
- D2.2 Regional Lines Operational and Functional Requirements [4]

[2] **DISCLAIMER**: Although stated as input to Deliverable 3.4 in Grant Agreement, the outputs from FA2 R2DATO WP21 and WP22 were not made available for the contributors of the Task 3.4 FP6. Due to this fact, information about their inclusion is based only on GA and not factual state of FP2.

1.4. Internal Inputs

The main internal provider of inputs to the WP3 is the FP6 WP2. From this WP, two deliverables are used as reference:

- D2.1 “Regional Lines Architecture” (see [3]).
  The Annex 1, at the end of this document, describes the traceability between the D2.1 and this deliverable D3.4.
- D2.2 “Regional Lines Operational and Functional Requirements” (see [4]).
  The Annex 2, at the end of this document, describes the traceability between the D2.2 and this deliverable D3.4.

1.5. Outputs

According to the GA, the present deliverable, which will be finalized the latest by M22, will provide:

- Compendium of Use Cases and Scenarios (…) to provide a consolidated and complete list of unique use cases/scenarios, which allow the performance of the demonstrators.

That list of Use Cases is duly reported in Chapter 4. Additionally, and to satisfy the objectives of the Task 3.4 (summarised in the next Chapter), this deliverable also contains information about the demonstrator setup (see Chapter 7), to be developed in further tasks within this FP6.

Thus, this deliverable is intended to be used as one of the inputs to support Task 8.5 (within WP8), with title "Development of individual demonstrator for cost-effective fail-safe highly accurate train positioning on G1 lines".

2. Objective

Starting by the context of this deliverable, it is worth mentioning that the main goal of the WP3 is to "find suitable, already existing and interoperable CCS solutions which can be applied to G1 lines, to ensure their long-term viability and decrease their total costs" (as stated in the GA).

Although the starting point is to "find (…) already existing and interoperable CCS solutions", it is true that this European initiative must bring innovation and new approaches to the solutions; in the case of ASTP functions, such innovations are described in the FP2, and not in the FP6, which specifically aims at demonstrating these innovations.

Examples of these innovations include the use of advanced localisation systems and their application in regional railway systems (see chapter 3).

Considering the main goal of the WP3, the innovation added by the collaborative FP2, and the information stated in the GA, it can be extrapolated that the objective of the Task 3.4 is divided into:

- consolidate a unique and comprehensive list of Use Cases and Demonstration Scenarios of ASTP functions, and
- define the most suitable demonstrator setup for demonstrating the capabilities of TE in a regional line setup.

For the Task 3.4 purpose and therefore of deliverable D3.4, the terms Use Case and Use Case Scenario are defined in the following manner:

Use Case:	A list of actions or event steps typically defining the interactions between an actor (or actors) and a system under consideration (ASTP in the context of this deliverable) to achieve the goal or measurable value to actor(s).
Use Case Scenario:	A list of characteristics and setup for specific variation of the Use Case.

3. Target Operational Environment and benefits

This chapter aims to depict the scope of the content of this deliverable.

The word "content" refers to two topics:

- the ASTP functions selected to perform the further demonstration, and
- the basic characteristics and identification of G1 lines in light of this deliverable.

The functionalities and Use Cases in this deliverable are closely connected to the activities of WP21 and WP22 of FP2 R2DATO and to the baseline exercise for train positioning system [2]. For the purpose of this deliverable, the definition of ASTP system is accepted as stated in the System Pillar baseline exercise:

> *"ASTP is an independent (fully defined functional boundary and interfaces) ONBOARD subsystem, making use of different inputs, coming from other onboard and trackside subsystems, responsible for providing the position and the orientation of the safe train front end along the track, speed, acceleration and possible other relevant data (e.g. pitch, roll), with the relevant uncertainties, over standardised interfaces to multiple users."*

Moreover, according to SP definition:

> *"ASTP is able to correlate the detected train position with reference to a physical ETCS balise group and also with a reference location included into a standardised track Digital Map (DM) based on a reference system different from the balise groups reference system (this in order to avoid circular reference)."*

In Deliverable 3.4, we are focusing solely on the specificities and unique applications of ASTP considering the stated operational environment. The envelope for the Operational Environment is under the umbrella of the G1 regional lines. G2 lines are out of the scope (refer to the GA to find more details about these two-line categories).

About the ASTP main goals, in coordination with the beneficiaries and participants of the Task 3.4, the following have been identified in nominal conditions:

- Make estimated position more accurate and keeping train confidence interval as short as possible when needed for operational reasons (e.g. approach to the beginning/end of a location where a variation of the speed profile occurs or an action is required to the driver/vehicle). Estimated position accuracy and confidence interval are not always to be consider as combined needs: for example, good accuracy of the estimated position is necessary for several ATO applications without the need of a small confident interval if danger points are "far away".
- Introduce the possibility to make use of alternative virtual/physical reference points different from physical eurobalises.

- Reduce the distance to be run in a non-protected mode (e.g. SR) after SoM with non-valid position or after a failure (failure understood as a shut down of on-board ETCS which allows a subsequent power on).

4. Use Cases

This chapter presents the Use Cases.

There is a first section, with the complete list of Use Cases, followed by the section elaborating each UC in detail and finally concluded by a table listing all proposed UCs with their identified requirements for the Technical Enablers.

Furthermore, to unify understanding and development process in Task 3.4, the following assumptions and definitions regarding described Use Cases were made:

- Since this deliverable concerns only Use Cases that are performed by ASTP system, the assumption in this chapter is that the ASTP system itself is not an actor in any of the elaborated UC's, but rather it is a main performer in the environment in which UC is taking place. Therefore, ASTP system is not treated as a Main or other actor in any of the presented Use Cases.
- Assumptions in the UC are general conditions always valid to make specific UC possible (e.g. presence and vitality of certain systems). As general assumption, regional application is considered having sustainability (asset reduction) as the main target rather than increase of capacity.
- Preconditions are conditions which must be set or present before particular UC is performed (e.g. request received from certain system, malfunction of certain system etc).

4.1. Use Cases List

This section gathers the complete list of Use Cases.

This list is fully consolidated, meaning there is no repetition, and each scenario has only one author.

Each Use Case has a unique ID, which follows the next pattern:

UC_01_4_XX

XX refer to number of UC

01 refer to WP3

4 refer to T3.4

The list is presented in a table shape, with 5 columns, each of them with the next meaning:

- ID: Use Case Identifier.
- Title: Use Case Title.
- Author: Contributor company who has proposed the Use Case, and it is responsible for its maintenance.
- Status: Draft / Completed.
- Comments: Additional information to help with the understanding of the Use Case.

Table 1. Use Cases List

UC ID	Title	Author	Status	Comments
UC_01_4_1	Provision of safe position and speed for train supervision	AZD	Completed	
UC_01_4_2	Triggering Provision of fixed ETCS information	ADIF	Completed	
UC_01_4_3	Passing a Radio Hole	ADIF	Completed	
UC_01_4_4	Provision of safe position for the distance limit supervision	AZD	Completed	
UC_01_4_5	Releasing of the passed track sections	AZD	Completed	
UC_01_4_6	ASTP initialization without track selectivity capability	AZD	Completed	
UC_01_4_7	Minimising the distance to be run in a ETCS non-protected mode after SoM	RFI	Completed	
UC_01_4_8	Reduce railway track maintenance cost by providing accurate faulty track locations.	NRD	Completed	
UC_01_4_9	Provide accurate geo-positions of the train under challenging conditions.	NRD	Completed	
UC_01_4_10	Ensure continuous and precise geo-positioning of the train during periods of GNSS signal unavailability.	NRD	Completed	
UC_01_4_11	Facilitate the approach to the location where a variation of the speed profile occurs or an action is required to the driver/vehicle)	RFI	Completed	
UC_01_4_12	Continuous train position determination	MERMEC	Completed	**Disclaimer** *Use Cases 01_4_12 through 01_04_16 have been developed by MERMEC and are not product of general consensus among all the partners in T3.4 in a sense, that their potential overlap, inconsistency with remaining Use Cases and form cannot be affirmed by all consortium members in Task 3.4 of FP6 WP3.*
UC_01_4_13	ASTP at SoM send a Special Virtual Balise message.	MERMEC	Completed	
UC_01_4_14	Start of Mission in Station with Q_STATUS “KNOWN”.	MERMEC	Completed	

UC ID	Title	Author	Status	Comments
UC_01_4_15	ETCS Start of Mission in Station with Q_STATUS "UNKNOWN" OR "INVALID".	MERMEC	Completed	
UC_01_4_16	ETCS Start of Mission in Line with Q_STATUS "UNKNOWN" OR "INVALID".	MERMEC	Completed	

4.2. Developed Use Cases

This chapter contains a detailed elaboration of Use Cases identified in chapter 4.1. For the purpose of Use Cases definition, a following concept was adopted. Since the analysed system for which Use Cases and requirements are being identified and developed here is ASTP, the term ACTORS for the purpose of D3.4 is reserved for entities (systems, devices and persons) outside of the analysed system. Therefore, in developed Use Cases, ASTP is never considered as an actor, although it is a main action providing system in developed Use Cases. The reporting of the TPR to Trackside is in charge of ETCS OBU (and not to ASTP); however, it can be used to monitor/measure the accuracy of the ASTP.

UC_01_4_1. Provision of safe position and speed for train supervision

Use Case Group	WP3 – Task 3.4
Use Case	Provision of safe position and speed for train supervision
UC ID	UC_01_4_1
Main actor	ETCS-OB
Other actors	ETCS-TS, digital register (track map), driver
Main goal	ASTP provides the safe position and speed of a vehicle to be used in ETCS-OB for continuous speed supervision. On regional lines, more frequent changes in the speed profile are expected compared to main lines. Typically, regional lines have a large number of level crossings, often without warning devices, resulting in drops in the speed profile. Similarly, there is a need to limit speed in curves and transition sections, which are also more common on regional lines. Position and speed are provided by a new interoperable constituent ASTP operating in regional line conditions, where the trackside may be in a simplified configuration and therefore not provide all the supporting information for the ASTP (either via radio link or as a consequence of a reduced number of balise installations). However, it will always be the responsibility of the infrastructure manager to choose the right balance between simplification on the track side and the relaxation of ASTP localisation performance as a consequence of such simplification. The driving motivation is the cost reduction (by simplifying the track side), while still ensuring sufficient performance of ASTP from an operational point of view. Specific scenario:

	When possible, this UC can be performed under the nominal scenario (normal rail adhesion conditions) and and under the possible “rail environmental conditions”.Rail environmental conditions have to be meant as: - weather conditions (rain, snow, ice...) - line conditions (tunnels, long downhill, presence of big metal masses, …) - vehicle constraints (availability of unpowered axles, availability of anti-slip/slide device, …) The challenge is how to reproduce such conditions with the demonstrators.
Assumptions	• ASTP is installed and capable of providing continuous safe position and speed of the train. • ETCS-OB can intervene in train traction and train braking system in case of speed limit exceeding. • The speed profile is kept up to date based on the track status ahead (including the status of level crossing warning devices). • Actual trackside configuration may impact the ASTP performance (e.g. longer confidence intervals due to reduced installation of balises).
Precondition	• ASTP is powered on and in the nominal mode of operation (i.e. ASTP is providing a full set of output information complying with respective requirements). • Actual train position and speed are within respective confidence intervals provided by ASTP • The train is moving under the issued MA. • The speed profile along track sections ahead is provided to the ETCS-OB.
Flow of events	The following step is performed repeatedly during the entire move under MA: 1. ASTP issues the train’s safe position and safe speed (both expressed with confidence intervals). To have a complete view on this UC, note that the following steps (not strictly related to ASTP) are performed too: I. The speed profile may be updated based on the status of level crossing warning devices ahead. II. The driver controls the actual train speed using the information provided via ETCS display (DMI). III. ETCS-OB assures that the train speed doesn’t exceed the speed limit (if the speed limit is exceeded, ETCS-OB intervenes with the traction and braking system).
Postcondition	ASTP issues the train’s safe position and safe speed (both expressed with confidence intervals), as it did during the UC. Regarding the train itself (ETCS-OB), one of the following states can be reached at the UC end: Either: • The train is moving under the issued MA (as at the beginning of the use case) or: • The train came to a standstill as a consequence of exceeding the speed limit (emergency brake intervention).
Safety relation	Speed and distance provided by ASTP to be used in the train protection system, i.e. in ETCS-OB, are both safety relevant-information.

Open topics / consideration	• If the applied position technology has relaxed performance (with respect to the usual localisation performance of Eurobalises) the consequence is inflated low-speed sections in the actual train move. • The current speed profile can be dynamically adjusted based on the status of a level crossing warning device ahead (after the positive confirmation from the warning device the respective speed drop can be removed from the speed profile).

UC_01_4_2. Triggering Provision of fixed ETCS information

Use Case Group	WP3 – Task 3.4
Use Case	Triggering Provision of fixed ETCS information
UC ID	UC_01_4_2.
Main actor	ETCS-OB
Other actors	Digital Register OB (DR-OB, Map Data), Digital Register TS (DR-TS), ETCS TS, IXL, ABS.
Main goal	Using track georeferenced information provided to the on-board as support, this UC aims to confirm the added value of using both virtual balise (VB) concept as a valid reference and (potentially) fixed ETCS information linked to virtual ETCS transmission media as well, in ETCS L1 / L2 trackside engineering implementations. This is especially intended (but not limited) to low-density regional lines, where long single-path block sections (i.e., without intermediate switches) are typical, and radio communication is intentionally not deployed (L1) or cannot provide optimum coverage to update the ETCS data exchanged between OB and TS (i.e. radio-hole). In such conditions, provision of ETCS virtual references as well as support of redundant, granular and available (fixed) ETCS messages, meaning univocal information once the train has entered the block section (unique path), could be relevant. It could provide interesting flexible capabilities to improve the operation. These capabilities could consist of providing more detailed track description along the track that could not be stored in a Balise Group at the beginning of the section. For example, different packets 21 (Gradient Profile), 27 (Speed Profile), 5 (linking information) and 68 (Track Conditions) could be stored in the DR-OB and be triggered in specific locations. This more detailed information provides better accuracy on the supervision of the resulting braking curves when approaching to critical points. To spread this UC into several applications, different scenarios in nominal / degraded conditions will be proposed, a variety of information packets (empty telegrams or with track description, linking information, track conditions, etc.) will be linked to the virtual ETCS transmission media and the corresponding functional behaviour as well as the operational impact would be analysed. This UC is intended to be covered under the interoperability umbrella. Consequently, the progress in the integration of these new functionalities (ASTP, Digital Register, Map Data…) into the global CCS+ architecture needs to be monitored through FP interactions in the way that it fits in with G1 regional line needs.
Assumptions	• The absolute position of the train front-end is provided by the ASTP to the on-board in a safe and accurate way as long as the QoS of the ASTP system is guaranteed. • To ensure an adequate level of integrity to optimize the train position accuracy, its confidence interval behaviour (odometry improvement)

	redundancy of hybrid sensors as GNSS and inertial sensors could be required. • Digital map transmission and versioning check, dynamic route information and other necessary inputs transferred from TRK to OB shall be sent prior to the train entering the concerned / georeferenced area. • The validation and maintenance of the Map Data content relies on an overall safe data configuration process (SIL 4) jointly managed by both on-board and trackside subsystem. • The existing IXL and ABS safely control and command the route status to the trackside signals as well as guarantee the entrance of a train into the single-path block section (i.e., without intermediate switches). The applicable operational rules allow the driver to enter the route following the signal status. • This kind of block sections will have a relevant length for the application of this use case. • The ASTP provides position information together with the correct track edge id, i.e., the position will be projected to the correct track edge id.
Precondition	• The onboard of a train located in front of an exit signal at some status has received an update of the Digital Map thanks to the radio coverage existing at the station. • The on-board, having performed a SoM or being in an ongoing mission, has entered the route operating in ETCS L1/L2. The train is running in long single-path block sections (i.e., without intermediate switches) under the first issued MA + track description. • Suitable georeferenced information along the single-path section is provided by ASTP to the ETCS on-board.
Flow of events	The following steps are performed in each selected georeferenced point located at the long single-path block section between stations or signals during the entire movement covered by the MA provided at the exit signal: 1. The train reaches a location where the onboard receives from the ASTP a georeferenced position projected to the correct track edge id. 2. The ETCS part of the on-board, acting as a user of the DR-OB, triggers (does not trigger) the transmission of VB reference (LRBG) as well as the associated ETCS fixed information. This ETCS information is conducted through the corresponding transmission media according to the current ETCS operational level. *NOTE: This ETCS part could be any related building block, like some Virtual ETCS transponder Service or the ETCS On-board itself.* 3. The ETCS OB (does not) processes and updates the ETCS information.
Postcondition	Odometrical uncertainty and its confidence interval has been updated by the ETCS-OB. Besides, LRBG and ETCS fixed information have been processed by the ETCS-OB.
Safety relation	The function “Triggering Provision of fixed ETCS information” is safety relevant as this is an information to be managed by the ETCS OB. However, fixed ETCS information does not depend on the signalling / route status once the train has entered the long block section (redundancy, granularity and availability purposes).

Open topics / consideration	• Related KPIs such as impact on time schedule delays and cost – benefit analysis regarding ETCS L1/L2 solution, where investment of physical signalling assets is minimized, should also be considered.

UC_01_4_3. Passing a Radio Hole

Use Case Group	WP3 – Task 3.4
Use Case	Passing a Radio Hole
UC ID	UC_01_4_3
Main actor	ETCS-OB
Other actors	ATP-TS, Digital Map OB, FRMCS/GSM-R/MNO Radio Communication System, GNSS+Augmentation, Dynamic Route Information Subsystem.
Main goal	Verify if the 1D positioning provided by the ASTP with digital map support allows the ATP-OB system to correctly manage a defined radio hole approaching, passing, and leaving within the expected positioning accuracy and safety (confidence interval) level.
Assumptions	• ASTP is a hybrid positioning system based on several sensors, for example: GNSS, augmentation, inertial sensors, rotational sensors, radar-based sensors and optical sensor. • Augmentation data increases accuracy to GNSS positioning. Augmentation info can be provided through radio or SIS. • Reception of ASTP support information, as digital map updates, clock time, route info or GNSS data may be interrupted while the train is passing the radio hole area. • ASTP might receive augmentation data from space or via radio. • There are no specific requirements (accuracy or distance) related to front end location for announcing a radio hole (refer to SS-026 5.18.5 and SS-093 Section 6.5).
Precondition	• Train is running along the track and ASTP is providing Safe Train Front End 1D position and speed. • Train is approaching a Radio Hole. • Track-train radio communication session is active, and support info is available for ASTP.
Flow of events	1. ASTP provides Safe Train Front End 1D position and Safe Train speed to the ATP-OB while the train approaches a radio hole. (Safe means within the confident interval (CI)). 2. Once the train enters the radio hole, ATP-OB stops supervising radio safe connection. Radio connection is lost. 3. Digital map onboard cannot request for a map update. 4. All the way through the radio hole, ASTP must keep providing safe and accurate positioning and speed to the ATP-OB without radio connection. That is, within the expected maximum CI. 5. Train exits the radio hole and returns to normal conditions.
Postcondition	Nominal operational conditions are recovered.
Safety relation	This use case is safety relevant.
Open topics / consideration	• Confidence Interval model proposed in R2DATO WP21 D21.1, either the fixed value uncertainty model or the speed dependent model. • ASTP integrity/accuracy KPIs definition. • Depending on the results provided by the demonstrators in the following phases of the project, GNSS augmentation may be implemented to improve positioning accuracy.

UC 403 scenarios

Previous UC contemplates entry and exit a radio hole. It is considered next additional scenario:

- Approaching a critical location within a Radio hole.

In case there are critical locations within a radio hole, for example a level crossing, ASTP in conjunction with ATP must allow a safety approach to it, considering that neither ASTP support information (i.e. augmentation data) nor RBC messages (i.e. RBC message with level crossing information, RBC MA update, ...) will be available onboard.

UC_01_4_4. Provision of safe position for the distance limit supervision

Use Case Group	WP3 – Task 3.4
Use Case	Provision of safe position for the distance limit supervision
UC ID	UC_01_4_4
Main actor	ETCS-OB
Other actors	ETCS-TS, Digital Register (track map), driver
Main goal	ASTP provides the current safe position of a vehicle to ETCS-OB to supervise the distance to the issued End of Authority. Distance supervision and stopping at the exact position of (close to) End of Authority is important on regional lines due to the usually short platforms in regional line stations (short parallel track sections in the stations). Exact stopping can therefore be crucial to allow a train from the opposite direction to pass in a station on single track lines. Position and speed are provided by a new interoperable constituent ASTP operating in regional line conditions, where the trackside may be in a simplified configuration and therefore not provide all the supporting information for the ASTP (either via radio link or as a consequence of a reduced number of balise installations). However, it will always be the responsibility of the infrastructure manager to choose the right balance between simplification on the track side and the relaxation of ASTP localisation performance as a consequence of such simplification. The driving motivation is the cost reduction (by simplifying the track side), while still ensuring sufficient performance of ASTP from an operational point of view. Specific scenario: Low adhesion conditions When possible, this UC can be performed under the nominal scenario (normal rail adhesion conditions) and the low adhesion scenario (low adhesion conditions can be determined in a natural, e.g. rainy day, or artificial way, e.g. making rails more slippery by adding soapy water) in order to test the robustness of the algorithm.
Assumptions	• ASTP is installed and capable of providing continuous safe position and speed of the train. • ETCS-OB can intervene in train traction and train braking system if the distance and speed limits are exceeded with respect to the location of EoA. • Actual trackside configuration may impact the ASTP performance (e.g. longer confidence intervals due to reduced installation of balises).
Precondition	• ASTP is powered on and in the nominal mode of operation (i.e. ASTP is providing a full set of output information complying with respective requirements). • Actual train position and speed are within respective confidence intervals provided by ASTP. • The train is moving under the issued MA (with the zero-target speed at the end of MA).

	• The speed profile along track sections ahead is provided to the ETCS-OB.
Flow of events	The following step is performed repeatedly during the entire move under MA: 1. ASTP issues the train's safe position and safe speed (both expressed with confidence intervals). To have a complete view on this UC, note that the following steps (not strictly related to ASTP) are performed too: I. The driver controls the actual train speed using the information provided via ETCS display (DMI) to reach zero speed at the EoA location. II. ETCS-OB assures that the train position and speed don't exceed the limits (if exceeded ETCS-OB intervenes with the traction and braking system).
Postcondition	ASTP issues the train's safe position and safe speed (both expressed with confidence intervals), as it did during the UC. Regarding the train itself (ETCS-OB), one of the following states can be reached at the UC end: Either: • The train stopped at the EoA location as a result of the correct driver's control of the train. or: • The train came to a standstill (however did not reach the EoA location) as a consequence of exceeding the speed limit (emergency brake intervention).
Safety relation	Speed and distance provided by ASTP to be used in the train protection system, i.e. in ETCS-OB, are both safety-relevant information.
Open topics / consideration	

UC_01_4_5. Releasing of the passed track sections

Use Case Group	WP3 – Task 3.4
Use Case	Releasing of the passed track sections
UC ID	UC_01_4_5
Main actor	ETCS-TS
Other actors	ETCS-OB, digital register (track map), TIMS
Main goal	The UC is pertinent for Regional lines considering the trains crossing scenario. ASTP provides the safe position of a vehicle for ETCS-OB, where the rear end of the train is determined. The rear end of the train is then reported to the trackside, allowing the release of track sections (a fraction of a track section) that have been passed. The train is either equipped with TIMS or the train is an inseparable train unit and operating on lines with virtual sections. The typical motivation for using virtual sections is to increase line capacity to accommodate more trains, which is not a typical need on regional lines. However, regional lines are typically operated with multiple-unit trains (DMU, EMU) which, being inseparable, have intrinsic train integrity status. This UC can be easily implemented and can bring some benefits if multiple-unit trains comprise most of the line operation. If the fleet is comprised of inseparable units and/or trains equipped with TIMS only, there is a further benefit of reducing track-side assets. The position and speed are provided by a new interoperable constituent ASTP operating in regional line conditions, where the trackside may be in a simplified configuration and therefore not provide all the supporting information for the ASTP (either via radio link or as a consequence of a reduced number of balise installations). However, it will always be the responsibility of the infrastructure manager to choose the right balance between simplification on the track side and the relaxation of ASTP localisation performance as a consequence of such simplification. The driving motivation is the cost reduction (by simplifying the track side), while still ensuring sufficient performance of ASTP from an operational point of view.
Assumptions	• ASTP is installed and capable of providing a continuous safe position of the train front end. Either: • TIMS is installed and capable of providing continuous confirmation of train integrity. Or: • The train is an inseparable unit (multiple-unit train) with a known fixed length.
Precondition	• ASTP is powered on and in the nominal mode of operation (i.e. ASTP is providing a full set of output information complying with respective requirements). • Actual train position and speed are within respective confidence intervals provided by ASTP • The train is moving under the issued MA • TIMS is powered on and provides integrity confirmation (for a train with separable carriages)

	• The train length is known on board (as dynamic train configuration data).
Flow of events	The following step is performed repeatedly during the entire move under MA: 1. ASTP issues the train's safe position (expressed as a confidence interval). To have a complete view on this UC, note that the following steps (not strictly related to ASTP) are performed too: I. TIMS provides a confirmation of the train integrity (for a train with separable carriages) II. The estimated rear end of the train is computed using the estimated front end and the train length (respecting the confidence interval). III. The position report including the rear end of the train is sent to the trackside IV. The trackside releases the virtual track section based on the reported min safe rear end of the train from received position report.
Postcondition	ASTP issues the train's safe position and safe speed (both expressed with confidence intervals), as it did during the UC. Regarding the train and the trackside, the following status are reached: • The train is moving under the issued MA (as at the beginning of the use case). • Passed virtual track sections behind the last reported min safe rear end of the train is released.
Safety relation	Position provided by ASTP to be used for (min/max) safe front end and (min/max) safe rear end is safety-relevant information.
Open topics / consideration	

UC_01_4_6. ASTP initialization without track selectivity capability

Use Case Group	WP3 – Task 3.4
Use Case	ASTP initialization without track selectivity capability
UC ID	UC_01_4_6
Main actor	ETCS-OB
Other actors	ETCS-TS, Digital Register (track map), Driver
Main goal	The ASTP initialisation is a procedure that takes place after the ASTP is switched on until the first train position and speed are issued (this procedure runs in parallel with the SoM of ETCS-OB). If the ETCS-OB position is unknown or invalid and the track section has no balises installed, it could be difficult (or impossible) for the ASTP to provide a unique train position (i.e. the position cannot be uniquely related to the single-track section). The described situation may occur during SoM on regional lines where no balises are installed in stations for cost reasons. After the ASTP initialization, the ASTP provides an ambiguous safe position in a station with parallel tracks to ETCS-OB (i.e. corresponding confidence intervals occupy track sections that are not connected and are on parallel tracks), which in turn generates an ambiguous position report provided to the trackside. It is supposed that the ambiguous position report will use a new “enhanced” position report package containing a set of position alternatives. Based on the actual track layout and the current operational situation, the track side (RBC) can issue the permission to move (e.g. under SR) even if the position is ambiguous (assuming that the train moving from any possible track section in the ambiguous position will not collide with any other trains in the stations). Also consider the fact that the train will be unambiguously positioned as soon as it moves out of the station and it reaches the single-track section of the line. The provided ambiguous safe position is therefore sufficient for granting the permission for the train move in the described situation.
Assumptions	• ASTP is installed and capable of continuously providing safe position and speed of the train. • The railway line is a single-track line with stations with parallel tracks • Stations are equipped with self-restoring switches, allowing operation in both directions without local or remote control (in case of facing-point movement, the straight or diverging track is determined with the pre-configuration of the switch). • Trackside is without Eurobalises installation. • Trackside provides a valid Map Data. The Map Data containing (among others) geolocated Reference Points to be used as coordination system origins instead of Balises. • Trackside is not capable of providing unique route information for the given train.
Precondition	• ASTP is powered on and is able to provide ambiguous position only since route information is not provided by the trackside and balises are not installed. • Actual train position is within one of the confidence intervals provided by ASTP as an ambiguous position.

	• The train is at a standstill in a station with parallel tracks, the ETCS-OB position is unknown or invalid.
Flow of events	1. ASTP provides a train position with confidence intervals occupying multiple parallel tracks in a station (ambiguous position). 2. The driver initiates the SoM procedure as usual, however, the position report sent to ETCS-TS is based on the set of confidence intervals estimated by ASTP 3. ETCS-TS checks there is no conflict in the current track occupancy and the reported set of confidence intervals about the intended train move. If no conflict is detected, the permission to move is granted. 4. The train leaves the station (with parallel tracks). When the train reaches a single-track section outside the station the ASTP unambiguously provides safe train position and speed. 5. When the train reaches the next station (with parallel tracks) the unambiguous provision of position and speed with ASTP is preserved since the station track is uniquely defined with the pre-configuration of self-restoring switches.
Postcondition	• The ASTP provides unambiguous position (i.e. provides safe train position and speed with single continuous confidence interval projected to the single track). • The train moves under the issued MA, the distance and speed are fully supervised under the issued MA.
Safety relation	The ambiguous position provided by ASTP to be used in the train protection system, i.e. in ETCS-OB, for the ambiguous position report, is safety-relevant information.
Open topics / consideration	

UC_01_4_7. Minimising the distance to be run in a ETCS non-protected mode after SoM

Use Case Group	WP3 – Task 3.4
Use Case	Minimising the distance to be run in a ETCS non-protected mode after SoM
UC ID	UC_01_4_7
Main actor	ASTP, ETCS-OB
Other actors	ETCS-TS, Driver
Main goal	Providing positioning information (track selective in the case of parallel tracks in the station) after SOM with initial ETCS train position different from valid.
Assumptions	• ETCS-OB and TS are installed. • ASTP is installed and capable of providing continuous safe position and speed of the train. • The railway line is a single-track line with stations that have parallel tracks. • Trackside is with a minimum number of Eurobalises installation. • Trackside provides a valid Map Data. The Map Data containing (among others) geolocated Reference Points to be used as coordination system origins instead of Balises.

Precondition	• ETCS-OB and TS are working properly
	• ASTP is powered on.
	• The train is at a standstill; the ETCS train position is unknown or invalid:
	  • Scenario 1: in a station with parallel tracks.
	  • Scenario 2: in line with single track.

Flow of events	1. The usual SoM procedure takes place and ETCS-OB provides a SoM TPR with a position different from valid. 2. ETCS-TS authorises the train to move in SR. 3. ASTP provides a train position with accuracy and integrity to enable ETCS-OB to provide a TPR against a geolocated Reference Point (before reading any physical balises). 4. ETCS-TS provides the MA according to available conditions.
Postcondition	• The train moves under the issued MA. Both the distance and speed are fully supervised under the issued MA.
Safety relation	This function is safety related.

UC_01_4_8. Reduce railway track maintenance cost by providing accurate faulty track locations.

Use Case Group	WP3 – Task 3.4
Use Case	Reduce railway track maintenance cost by providing accurate faulty track locations.
UC ID	UC_01_4_8
Main actor	ETCS-OB
Other actors	ASTP, ETCS-TS, Digital Track Map, On-Board Fault Detection System
Main goal	Provide accurate (±50cm) faulty location on the railway track for the maintenance team to reduce maintenance cost. Scenarios: 1. During regular inspections, the fault detection system detects irregularities in track alignment while the ASTP pinpoints the exact locations for maintenance teams. 2. After a severe weather event, the fault detection system and ASTP are used to quickly assess damage to tracks in different areas and prioritize repair work based on severity and location.
Assumptions	ASTP should contain the following components: • GNSS is available • Odometer is available • IMU is available • Cameras are available • A digital twin of the railway track is available (equivalent to CityGML)
Precondition	The following ASTP components should be able to: • GNSS should provide real-time accurate positions • Odometers can provide speed data once per second • IMU should provide accurate orientation, acceleration, and angular velocity data • Cameras can provide image data of the surrounding environment of the train (front, back, and two sides) in at least 5 frames per second • The digital twin should contain accurate geometric and semantic information of the railway environment ASTP should achieve a localisation accuracy of ±50 cm.
Flow of events	The following step is performed repeatedly during the entire move under MA: 1. ASTP utilizes various data sources, including GNSS positions, odometer readings, camera images and a pre-recorded digital environment to continuously triangulate and correct the vehicle's position. To have a complete view on this UC, note that the following steps (not strictly related to ASTP) are performed too: 2. At the moment of identifying a track fault, the train's accurate (±50cm) position provided by ASTP is recorded and send to maintenance teams for inspections.

	3. Upon arriving the scene, maintenance teams can locate faults with minimal search effort, reducing operational downtime.
Postcondition	The recorded information along with a warning, will be transmitted to the maintenance team such that they are able to directly find the precise fault location utilizing the data provided by ASTP, without “wandering” along the track
Safety relation	This function is not safety related.
Open topics / consideration	NA

UC_01_4_9. Provide accurate geo-positions of the train under challenging conditions.

<table>
<tr><td>Use Case Group</td><td>WP3 – Task 3.4</td></tr>
<tr><td>Use Case</td><td>Provide accurate geo-positions of the train under challenging conditions.</td></tr>
<tr><td>UC ID</td><td>UC_01_4_9</td></tr>
<tr><td>Main actor</td><td>ETCS-OB</td></tr>
<tr><td>Other actors</td><td>ASTP, ETCS-TS, and Digital Track Map</td></tr>
<tr><td>Main goal</td><td>Provide accurate geo-positions of the train in challenging regional conditions such as in tunnels or valleys with weakened GNSS signals.

Scenarios:
1. In urban areas where buildings cause signal reflection and blockage, ASTP still accurately determines the train's position.
2. In remote areas with poor GNSS coverage, like tunnels or valleys, ASTP can still maintain accurate positioning.
3. During bad weather conditions, such as heavy rain or storm, where the GNSS signal strength becomes weak and less reliable, ASTP can still accurately determine the train's position.</td></tr>
<tr><td>Assumptions</td><td>ASTP should contain the following components:
• GNSS is available (with significant uncertainty)
• Odometer is available
• IMU is available
• Cameras are available
• A digital twin of the railway track is available (equivalent to CityGML)</td></tr>
<tr><td>Precondition</td><td>The following ASTP components should be able to:
• GNSS should provide real-time positions, although accuracy does not need to be high.
• Odometers can provide speed data once per second.
• IMU should provide accurate orientation, acceleration, and angular velocity data
• Cameras can provide image data of the surrounding environment of the train (front, back, and two sides) in at least 5 frames per second.
• The digital twin should contain accurate geometric and semantic information of the railway environment.</td></tr>
<tr><td>Flow of events</td><td>The following step is performed repeatedly during the entire move under MA:
1. ASTP utilizes various data sources, including GNSS positions, odometer readings, camera images and a pre-recorded digital environment to continuously triangulate and correct the vehicle's position.

To have a complete view on this UC, note that the following steps (not strictly related to ASTP) are performed too:
I. When the train passes through tunnels and valleys where GNSS signals are significantly weakened, the ASTP can still effectively utilize image</td></tr>
</table>

	and speed data, in combination with the digital twin, to obtain accurate real-time train positions.
Postcondition	ASTP provides accurate real-time positions of the train under significantly weakened GNSS signals, utilizing image and speed data, inaccurate GNSS position data, and the digital twin.
Safety relation	Yes, it is safety-relevant, as ASTP must provide safe positions during challenging conditions with GNSS signals are weakened.
Open topics / consideration	NA

UC_01_4_10. Ensure continuous and precise geo-positioning of the train during periods of GNSS signal unavailability.

Use Case Group	WP3 – Task 3.4
Use Case	Ensure continuous and precise geo-positioning of the train during periods of GNSS signal unavailability.
UC ID	UC_01_4_10
Main actor	ETCS-OB
Other actors	ASTP, ETCS-TS, and Digital Track Map
Main goal	Provide consistently accurate real-time geo-positions of the train in emergency cases where GNSS signal is completely unavailable (e.g., complete signal blockages caused by severe weather conditions or dense surrounding materials) Scenarios: 1. During a GNSS blackout caused by electronic interference, the system still maintains accurate train positions. 2. In a long tunnel where GNSS signals are lost, the system still maintains accurate train positions. 3. In the event of severe weather conditions, like a solar storm or heavy snowfall, which cause complete GNSS signal unavailability, the system still maintains accurate train positions.
Assumptions	ASTP should contain the following components: • GNSS is not available • Odometer is available • IMU is available • Cameras are available • A digital twin of the railway track is available (equivalent to CityGML)
Precondition	The following ASTP components should be able to: • GNSS Signal is completely not available. • Odometers can provide speed data once per second. • IMU should provide accurate orientation, acceleration, and angular velocity data • Cameras can provide image data of the surrounding environment of the train (front, back, and two sides) in at least 5 frames per second. • The digital twin should contain accurate geometric and semantic information of the railway environment.
Flow of events	The following step is performed repeatedly during the entire move under MA: 1. ASTP utilizes various data sources, including GNSS positions, odometer readings, camera images and a pre-recorded digital environment to continuously triangulate and correct the vehicle's position. To have a complete view on this UC, note that the following steps (not strictly related to ASTP) are performed too: I. When the train experiences complete signal blockages in emergency cases such as severe weather conditions or dense surrounding materials, the ASTP can effectively utilize only image and speed data, in

	combination with the digital twin, to obtain accurate real-time train positions.
Postcondition	The system provides accurate real-time positions of the train under complete GNSS signal blockages, purely utilizing image and speed data, and the digital twin
Safety relation	Yes, it is safety relevant as ASTP must provide safe positions in emergency cases where GNSS signal is completely unavailable
Open topics / consideration	NA

UC_01_4_11. Facilitate the approach to the location where a variation of the speed profile occurs or an action is required to the driver/vehicle)

Use Case Group	WP3 – Task 3.4
Use Case	Facilitate the approach to the BEGINNING of a location where a variation of the speed profile occurs or an action is required to the driver/vehicle)
UC ID	UC_01_4_11a
Main actor	ASTP, ETCS-OB (odometer)
Other actors	ETCS-TS
Main goal	The goal is to improve operation performances and drivability (shortening of the ETCS confidence interval) when approaching the beginning of a location where a variation of the speed profile occurs or an action is required to the driver/vehicle (e.g. EoA, TSR, SSP reduction, track condition) by providing safe position and speed data with the required level of accuracy and integrity in order to allow the ETCS-OB to build the train confidence interval and the position report according to the ERTMS specification. Even in regional lines where increase of accuracy performances can be considered as an enabler for cost reduction.
Assumptions	• Radio ETCS-OB and TS are installed and working properly. • ASTP is installed and capable of providing continuous safe position and speed of the train. • All necessary inputs (e.g., Map Data, possible GNSS augmentation info, etc.) of ASTP are available. • Trackside is a regional line characterised by low-density traffic.
Precondition	• ASTP is powered on and in the nominal mode of operation (i.e. ASTP is providing a full set of output information complying with respective requirements) • The train is moving in FS under the issued MA • No relocation physical BGs are provided trackside since X km (for the definition of X, see the Open topics section) • ASTP has to ensure an adequate level of integrity (TBD).
Flow of events	1. The train is approaching a speed restriction (e.g., TSR, SSP restriction or EoA) or a location where the driver/vehicle is expected to perform an action (track condition). 2. ASTP provides, during the motion, the train position with an uncertainty within the thresholds according to the established requirements. 3. Thanks to this “small” uncertainty, ETCS-OB can approach the location where a speed restriction or the driver/vehicle is expected to perform an action in an effective way. 4. In case of violation of integrity restriction according to the track characterization, the ASTP will inform the ATP on-board.
Postcondition	• The ASTP operates in nominal mode with adequate safety integrity and performances. • Achieving sufficient performances to operate in a regional line.

Safety relation	Yes, it is safety relevant as ASTP must provide safe position and speed to the ETCS-OB.
Open topics / consideration	- Integrity: It is necessary to clarify that, in this context, the term integrity is defined as: *the measure of the trust that can be placed in the correctness of the information supplied by a navigation/positioning system. Integrity includes the ability of the system to provide timely warnings to users when the system should not be used for navigation/positioning.* Integrity, in terms of performance, is a complex concept that has to be defined based on its relationship with other ad-hoc KPIs, such as accuracy, availability or train operation continuity, which shall be evaluated and defined. Thresholds could be dependent on the different scenarios that are defined. This concept of integrity or any other analogous term (e.g., reliability) is contemplated to be aligned with the explicit or implicit definitions according to the progress of WP21&22 of FP2 to cover and ensure the established safety levels. - 2,5 Km constraint: in the current ETCS specification, there is a constraint related to the maximum distance between 2 consecutive balise groups. One of the goals of ASTP should be to remove or relax this constraint. In order to achieve this goal, testing must be performed having the distance between 2 BGs larger than 2.5 Km. Anyway, the 2.5km constraint is not directly related to odometry issues and a larger analysis needs to be done before proposing to release such requirement. This use case can only confirm that ETCS odometry (ASTP) does not export conditions impeding the removal of this requirement. - Accuracy: requirements to be fixed. Values from R2DATO WP21 can be taken.

Use Case Group	WP3 – Task 3.4
Use Case	Facilitate the approach to the END of a location where a variation of the speed profile occurs or an action is required to the driver/vehicle
UC ID	UC_01_4_11b
Main actor	ASTP, ETCS-OB (odometer)
Other actors	ETCS-TS
Main goal	The goal is to improve operation performances (shortening of the ETCS confidence interval) when leaving the end of a location where a variation of the speed profile occurs or an action is required to the driver/vehicle (e.g. EoA, TSR, SSP reduction, track condition) by providing safe position and speed data with the required level of accuracy and integrity in order to allow the ETCS-OB to build the train confidence interval and the position report according to the ERTMS specification. Even in regional lines where increase of accuracy performances can be considered as an enabler for cost reduction. We expect ASTP to improve operational performance by releasing track devices more efficiently, even in case of regional lines with less TTDs.
Assumptions	• Radio ETCS-OB and TS are installed and working properly • ASTP is installed and capable of providing continuous safe position and speed of the train.

	• All necessary inputs (e.g. Map Data, possible GNSS augmentation info …) of ASTP are available. • Trackside is a regional line characterised by low-density traffic.
Precondition	• ASTP is powered on and in the nominal mode of operation (i.e. ASTP is providing a full set of output information complying with respective requirements) • The train is moving in FS under the issued MA • No relocation physical BGs are provided trackside since X km (for the definition of X, see the Open topics section) • ASTP has to ensure an adequate level of integrity (TBD).
Flow of events	1. The train is approaching a location where speed increases (e.g. end of TSR or SSP increase) or where the driver/vehicle is expected to perform an action (e.g. end of track condition neutral section) independently if the speed/action needs to be increased/performed, considering or not the entire train length. 2. ASTP provides, during the motion, the train position with an uncertainty within the thresholds according to the established requirements. 3. Thanks to this "small" uncertainty, ETCS-OB can approach the location where a speed increase or the driver/vehicle is expected to perform an action in an effective way. 4. In case of violation of integrity restriction according to the track characterization, the ASTP will inform the ATP on-board.
Postcondition	• The ASTP operates in nominal mode with a highly accurate value of position. • Achieving sufficient performances to operate in a regional line.
Safety relation	Yes, it is safety relevant as ASTP must provide safe position and speed to the ETCS-OB.
Open topics / consideration	- Integrity: It is necessary to clarify that, in this context, the term integrity is defined as: *the measure of the trust that can be placed in the correctness of the information supplied by a navigation/positioning system. Integrity includes the ability of the system to provide timely warnings to users when the system should not be used for navigation/positioning.* Integrity, in terms of performance, is a complex concept that has to be defined based on its relationship with other ad-hoc KPIs,such as accuracy, availability or train operation continuity, which shall be evaluated and defined. Thresholds could be dependent on the different scenarios that are defined. This concept of integrity or any other analogous term (e.g., reliability) is contemplated to be aligned with the explicit or implicit definitions according to the progress of WP21&22 of FP2 to cover and ensure the established safety levels. - 2,5 Km constraint: in the current ETCS specification there is a constraint related to the maximum distance between 2 consecutive balise groups. One of the goal of ASTP should be to remove or relax this constraint. In order to achieve this goal testing must be performed having the distance between 2 BGs larger than 2.5 Km. - Accuracy: requirements to be fixed. Values from R2DATO WP21 can be taken.

Disclaimer

Use Cases 01_4_12 through 01_04_16 are developed by MERMEC and are not product of general consensus among all the partners in T3.4 in a sense, that their potential overlap, inconsistency with remaining Use Cases and form cannot be affirmed by all consortium members in Task 3.4 of FP6 WP3.

UC_01_4_12. Continuous train position determination

This USE CASE reports the activities that are carried out within the ASTP.

Use Case Group	WP3 – Task 3.4
Use Case	Continuous train position determination
UC ID	UC_01_4_12
Main actor	ASTP On-Board
Other actors	Trackside, Track Map
Main goal	Continuous computation of the Train Position and its confidence interval
Assumptions	All necessary data is available on board
Precondition	All necessary data are available on board MERMEC in R2DATO WP21 & WP22 is working for having a double use of its ASTP. Provide Virtual Balise or in alternative Provide Odometrical Info. In this contest the MERMEC ASTP is providing Virtual Balises. In the MM ASTP there is also the option that ETCS can provide its Odometry.
Flow of events	1. Switch on the ASTP system. 2. ASTP performs internal check. 3. ASTP checks the availability of a digital map. 4. ASTP checks the availability of the GNSS augmentation information. 5. ASTP checks the availability of dynamic route data information. 6. ASTP checks the availability of the ETCS odometry. 7. ASTP starts the internal first step computation. 8. ASTP starts the fusion algorithm. 9. ASTP provides internally the position of the train and its confidence interval. 10. ASTP sends virtual balise when triggered in the map.
Postcondition	
Safety relation	It is safety relevant
Open topics / consideration	The accuracy of the position and its confidence interval depends on the availability of the input data and their accuracy.

UC_01_4_13. ASTP at SoM send a Special Virtual Balise message.

This UC shows the function of updating the position of the train within the line based on the digital map.

Use Case Group	WP3 – Task 3.4
Use Case	ASTP at SoM send a Special Virtual Balise message.
UC ID	UC_01_4_13
Main actor	ASTP
Other actors	ETCS Trackside, Track Map ASTP On-Board
Main goal	Perform a Start the Mission

Assumptions	All necessary data are available on board MERMEC in R2DATO WP21 & WP22 is working for having a double use of its ASTP. Provide Virtual Balise or in alternative Provide Odometrical Info. In this contest the MERMEC ASTP is providing Virtual Balises. In the MM ASTP there is also the option that ETCS can provide its Odometry.
Precondition	No fault in the ASTP system included sensors. Availability of digital map with a sufficient level of accuracy. Availability of GNSS Augmentation service Availability of the dynamic route information provide by trackside. Availability of the ETCS odometry. Train is stopped but powered
Flow of events	UC_01_401. ASTP computes the train position based on its inputs. UC_01_402. ASTP receives from EVC a command to send the Special Virtual Balise. UC_01_403. ASTP identifies the train position on the digital maps. UC_01_404. ASTP sends a Special Virtual Balise, this isn't in the list of Virtual Balises stored on board. The telegram of this balise has a special packet that contains an indication whether the location provided is reliable and elaborate from the digital maps the closest balise on the track. UC_01_405. EVC can use this information for providing the Position report.
Postcondition	
Safety relation	It is safety relevant
Open topics / consideration	The information contained in the new package sent by ASTP indicates which balise contained in the digital map is closest to the train's position. If the train direction and the confidence interval are compatible with the position of the identified balise then the ASTP system will send the information regarding the balise. The EVC has to manage the new packet about the Special Virtual Balise.

UC_01_4_14. Start of Mission in Station with Q_STATUS "KNOWN".

This UC shows the SoM of the EVC in the station when all the information allows the position of the train to be identified.

The ASTP system is the object of the development of the FP6 WP3 task 3.4. But, at the same time, the stand alone ASTP system would have no reason to exist. The information produced by ASTP is used by the ETCS board for its operation. For this Use Case, and contrary to the normal rules adopted for the Use Cases, we focus on the functionality of the board that uses the information produced by the ASTP system.

This UC is present to underline that the Start of Mission by the EVC with Q_STATUS "KNOWN" does not require any particular use of the ASTP system.

Use Case Group	WP3 – Task 3.4
Use Case	ETCS Start of Mission in Station with Q_STATUS "KNOWN"
UC ID	UC_01_4_14
Main actor	ETCS EVC
Other actors	Trackside, Track Nap ASTP On-Board
Main goal	Start the mission and move the train from the station

Assumptions	all necessary data are available on board. Each platform, belonging to a Terminal Railway Station, is equipped with two physical BGs, i) One BG aligned with the starting signal. ii) One BG placed near, and in rear, of the starting signal. This is a typical Italian station configuration.
Precondition	The EVC and trackside have established a communication session. The conditions of freedom of the Route in advance of the train position are satisfied. The ASTP is working correctly
Flow of events	1. The EVC has a valid position on board and doesn't command to ASTP for special Balise. 2. The EVC sends the Start of Mission Position Report message, including the information on the stored position (Q_STATUS = 1). 3. RBC receives the SOM Position Report message 4. RBC determines that the reference BG of the Position Report received is located in advance of the Min Safe Front End of the train. regards the SoM TPR as valid, and the train as localized. 5. EVC sends the Validated Train Data message to RBC. 6. RBC receives the Validated Train Data message and perform the acknowledgement handshake 7. The START button is enabled on DMI (The Driver waits to receive from the Dispatcher the authorization to press it). Driver enters the Train running number, if it is not valid yet. 8. EVC sends a Position Report message including the Train running number packet. 9. The Driver presses the START button (Once authorized by the Dispatcher). 10. The EVC sends the MA Request message and waits for the authorization to move. 11. RBC sends the MA message to EVC.
Postcondition	The Train can move with MA
Safety relation	It is safety relevant
Open topics / consideration	This scenario is not affected by the operation of ASTP.

UC_01_4_15. ETCS Start of Mission in Station with Q_STATUS "UNKNOWN" OR "INVALID".

This UC shows the SoM of the EVC in the station when it isn't possible from EVC know the train position.

Two scenarios of this Use Case are provided: Scenario 1 and Scenario 2.

The ASTP system is the object of the development of the FP6 WP3 task 3.4. But, at the same time, the stand alone ASTP system would have no reason to exist. The information produced by ASTP is used by the ETCS board for its operation. For this Use Case, and contrary to the normal rules adopted for the Use Cases, we focus on the functionality of the board that uses the information produced by the ASTP system.

The reason for reporting the actions of the EVC system and ETCS in general highlights the positive effect of a properly functioning ASTP system.

Unlike the previous case, in this case the presence of the ASTP participates in the Start of Mission procedure and demonstrates its usefulness.

Scenario a: ASTP is not able to provide a valid position at SoM

In this case, since the ASTP information is not sufficiently capable of providing a correct position, it does not produce an objective advantage. In the Scenario a the ASTP doesn't affect the behaviour.

Use Case Group	WP3 – Task 3.4
Use Case	ETCS Start of Mission in Station with Q_STATUS "UNKNOWN" OR "INVALID"
UC ID	UC_01_4_15a
Main actor	ETCS EVC
Other actors	ETCS RBC, Trackside, Track Map ASTP On-Board
Main goal	Start the mission and move the train from the station
Assumptions	All necessary data are available on board. Each platform, belonging to a Terminal Railway Station, is equipped with two physical BGs, i) One BG aligned with the starting signal. ii) One BG placed near, and in rear, of the starting signal. This is a typical Italian station configuration.
Precondition	The EVC and trackside have established a communication session. The conditions of freedom of the Route in advance of the train position are satisfied. The ASTP is working correctly.

Flow of events	1. The EVC does not have a valid position on board 2. The EVC command to ASTP for special Balise 3. The ASTP provides the special VB to the EVC, but the quality of the position provided is low. The EVC is not able to identify the distance against the LRBG. 4. The EVC sends the Start of Mission Position Report message, including the information Q_STATUS = 0/2. 5. RBC considers the SoM TPR Invalid/unknown, and then RBC considers the train Not Localized. 6. RBC starts the handshake to inform to EVC that the train has been accepted. EVC answers. 7. EVC sends the Validated Train Data message to RBC. 8. RBC receives the Validated Train Data message and perform the acknowledgement handshake. 9. The START button is enabled on DMI (The Driver waits to receive from the Dispatcher the authorization to press it). Driver enters the Train running number, if it is not valid yet. 10. EVC sends a Position Report message including the Train running number packet. 11. The Driver presses the START button (Once authorized by the Dispatcher). 12. The EVC sends the MA Request message and waits for the authorization to move. 13. RBC sends the SR Authorization message to EVC with D_SR=infinite and including the List of Balises in SR Authority packet including Balise of the current RBS plus the Balise of the RBS in advance. 14. The train starts to move with the EVC in SR Mode, and detect the first BG. 15. RBC regards the EVC as localized and commands the visualization of the train icon on the RBC HMI. 16. RBC sends the Movement Authority message to EVC.
Postcondition	The Train can move with MA
Safety relation	It is safety relevant
Open topics / consideration	This scenario is not affected by the operation of ASTP.

Scenario b: ASTP is able to provide a valid position at SoM

In this case, the advantage in global procedures is highlighted, of having brought back a special virtual balise as a reference during the Star of Mission phase.

Use Case Group	WP3 – Task 3.4
Use Case	ETCS Start of Mission in Station with Q_STATUS “UNKNOWN” OR “INVALID”
UC ID	UC_01_4_15b
Main actor	ETCS EVC
Other actors	ETCS RBC, Trackside, track map ASTP on-board
Main goal	Start the mission and move the train from the station
Assumptions	all necessary data are available on board. Each platform, belonging to a Terminal Railway Station, is equipped with two physical BGs, i) One BG aligned with the starting signal. ii) One BG placed near, and in rear, of the starting signal

Precondition	The EVC and trackside have established a communication session. The conditions of freedom of the Route in advance of the train position are satisfied. The ASTP is working correctly
Flow of events	1. The EVC does not have a valid position on board 2. The EVC command to ASTP for special Balise 3. The ASTP provide the special VB to EVC with high quality of the position. Thanks to this, the EVC is able to identify the distance respect the LRBG. 4. The EVC sends the Start of Mission Position Report message, including the information on the stored position (Q_STATUS = 1). 5. RBC receives the SOM Position Report message. 6. RBC determines that the distance from the LRBG of the Position Report received is located in advance of the Min Safe Front End of the train. Regards the SoM TPR as valid, and the train as localized. 7. EVC sends the Validated Train Data message to RBC. 8. RBC receives the Validated Train Data message and perform the acknowledgement handshake 9. The START button is enabled on DMI (The Driver waits to receive from the Dispatcher the authorization to press it). Driver enters the Train running number, if it is not valid yet. 10. EVC sends a Position Report message including the Train running number packet. 11. The Driver presses the START button (Once authorized by the Dispatcher). 12. The EVC sends the MA Request message and waits for the authorization to move. 13. RBC sends the MA message to EVC.
Postcondition	The Train can move with MA
Safety relation	It is safety relevant
Open topics / consideration	This scenario is upgraded by the operation of ASTP.

UC_01_4_16. ETCS Start of Mission in Line with Q_STATUS "UNKNOWN" OR "INVALID".

This UC shows the SoM of the EVC in the line when it is not possible for EVC to know the train position.

The ASTP system is the object of the development of the FP6 WP3 task 3.4. But, at the same time, the stand alone ASTP system would have no reason to exist. The information produced by ASTP is used by the ETCS board for its operation. For this Use Case, and contrary to the normal rules adopted for the Use Cases, we focus on the functionality of the board that uses the information produced by the ASTP system.

The reason for reporting the actions of the EVC system and ETCS in general highlights the positive effect of a properly functioning ASTP system.

Similarly to the previous case in the station, the presence of the ASTP participates in the Start of Mission procedure in le line and demonstrates its usefulness.

Scenario a: ASTP is not able to provide a valid position at SoM

In this case, since the ASTP information is not sufficiently capable of providing a correct position, it does not produce an objective advantage. In the Scenario 1 the ASTP doesn't affect the behaviour.

Use Case Group	WP3 – Task 3.4
Use Case	ETCS Start of Mission in Line with Q_STATUS "UNKNOWN" OR "INVALID"
UC ID	UC_01_4_16a
Main actor	ETCS EVC
Other actors	ETCS RBC, Trackside, Track Map ASTP On-Board
Main goal	Start the mission and move the train in the line
Assumptions	This scenario represents a degraded case, assuming it is executed due to a failure. All necessary data is available on board. The train is on single track line. The ASTP, on request from EVC only during the SoM, can provide a special balise message that contains the current train position.
Precondition	The EVC and trackside have established a communication session. The ASTP is working correctly, and it is able to identify the position of the train along the line.
Flow of events	1. The EVC does not have a valid position on board 2. The EVC command to ASTP for special Balise 3. The ASTP provides the special VB to the EVC, but the quality of the position provided is low. The EVC is not able to identify the the LRBG to refer to. 4. The EVC sends the Start of Mission Position Report message, including the information Q_STATUS = 0/2. 5. RBC considers the SoM TPR Invalid/unknown, and then RBC considers the train Not Localized. 6. RBC starts the handshake to inform to EVC that the train has been accepted. EVC answers. 7. EVC sends the Validated Train Data message to RBC. 8. RBC receives the Validated Train Data message and perform the acknowledgement handshake. 9. The START button is enabled on DMI (The Driver waits to receive from the Dispatcher the authorization to press it). Driver enters the Train running number, if it is not valid yet. 10. EVC sends a Position Report message including the Train running number packet.

	11. The Driver presses the START button (Once authorized by the Dispatcher). 12. The EVC sends the MA Request message and waits for the authorization to move. 13. RBC sends the SR Authorization message to EVC with D_SR=infinite and including the List of Balises in SR Authority packet including Balise of the current RBS plus the Balise of the RBS in advance. 14. The train starts to move with the EVC in SR Mode and detect the first VBG. 15. RBC regards the EVC as localized and commands the visualization of the train icon on the RBC HMI. 16. RBC sends the Movement Authority message to EVC.
Postcondition	The Train can move with MA
Safety relation	It is safety relevant
Open topics / consideration	This scenario is not affected by the operation of ASTP.

Scenario b: ASTP is able to provide a valid position at SoM

In this case, the advantage in global procedures is highlighted, of having brought back a special virtual balise as a reference during the Star of Mission phase.

Use Case Group	WP3 – Task 3.4
Use Case	ETCS Start of Mission in Line with Q_STATUS “UNKNOWN” OR “INVALID”
UC ID	UC_01_416b
Main actor	ETCS EVC
Other actors	ETCS RBC, Trackside, track map ASTP on-board
Main goal	Start the mission and move the train in the line
Assumptions	This scenario represents a degraded case is assuming to execute it due to a failure. all necessary data is available on board. The train is on single track line. The ASTP, on request from EVC only during the SoM, can provide a special balise message that contains the current train position.
Precondition	The EVC and trackside have established a communication session. The ASTP is working correctly, and it is able to identify the position of the train along the line.
Flow of events	1. The EVC does not have a valid position on board 2. The EVC command to ASTP for special Balise 3. The ASTP provide the special VB to EVC with high quality of the position. The EVC is able to identify the train position against the VB. 4. The EVC sends the Start of Mission Position Report message, including the information on the stored position (Q_STATUS = 1). 5. RBC receives the SOM Position Report message. 6. RBC determines that the reference BG of the Position Report received is located in advance of the Min Safe Front End of the train. Regards the SoM TPR as valid, and the train as localized. 7. EVC sends the Validated Train Data message to RBC. 8. RBC receives the Validated Train Data message and perform the acknowledgement handshake.

	9. The START button is enabled on DMI (The Driver waits to receive from the Dispatcher the authorization to press it). Driver enters the Train running number, if it is not valid yet. 10. EVC sends a Position Report message including the Train running number packet. 11. The Driver presses the START button (Once authorized by the Dispatcher). 12. The EVC sends the MA Request message and waits for the authorization to move. 13. RBC sends the MA message to EVC.
Postcondition	The Train can move with MA
Safety relation	It is safety relevant
Open topics / consideration	This scenario is upgraded by the operation of ASTP.

5. General Requirements for Regional Lines

This section contains a list of ASTP requirements that are generic, i.e. not strictly related to the specific UC (or group of UCs). The list therefore represents the view of the representatives of this task on an ASTP on-board constituent. However, it was agreed that the list is not an exhaustive list of ASTP requirements (as this is not the scope of this task). Rather, it is a selected subset of the essential ASTP requirements (to highlight what the task representatives expect from an ASTP constituent) and/or those requirements that are relevant to regional lines (in which case the relevance to regional lines is explained in the last column).

Other input used as a basis to define the list of Use Cases in the present document is the "Regional Lines Operational and Functional Requirements" provided by the FP6 WP2. These requirements (Operational and Functional), when applicable, are traced to the specific ASTP related requirements in tables 2 and 3.

Table 2 The list of generic requirements for ASTP system

Consumer	**Req. ID**	**Description**	**Req. type**	Tracing to other WP
All	R_01_4_01	ASTP shall operate under all "normal" external conditions (GNSS signal shadowed or completely blocked, GNSS signal distorted by heavy multipath, slip and slide conditions for wheel sensors, etc.).	Non-functional	-

Consumer	Req. ID	Description	Req. type	Tracing to other WP
All	R_01_4_02	ASTP shall detect all “abnormal” external conditions and if the impact of such condition cannot be excluded the ASTP output (position and speed) shall not be provided. The status of detected “abnormal” conditions is reported. The “abnormal” external conditions cover situations such as heavy RF interference, cyberattacks (GNSS spoofing), etc.	Functional	
All	R_01_4_03	ASTP shall operate under the standard environmental conditions (temperature range, humidity, altitude, vibration and shock, etc.) as requested for on-board constituents. The conditions and constituent testing are described in the CENELEC EN 50 155.	Non-functional	
All	R_01_4_04	ASTP shall be sustainable and shall contribute to the overall cost reduction.	Non-functional	
ETCS-OB, ATO	R_01_4_05	ASTP shall be interoperable, which requires fully defined trackside / on-board interfaces, functions, performance, engineering and operational rules.	Non-functional	
ETCS-OB, ATO	R_01_4_06	ASTP shall be an “exchangeable” on-board constituent, which means that the ASTP of one supplier can be replaced by the ASTP of another supplier but with the cooperation (support) of the ETCS-OB supplier to which the ASTP is connected.	Non-functional	
All	R_01_4_07	ASTP shall provide continuous position and speed information of a vehicle. This information is provided after ASTP initialisation. The meaning of “continuous” is that the ASTP output is updated regularly with a small update period.	Functional	
ETCS-OB	R_01_4_08	ASTP shall provide safe (SIL4) position and speed for ATP (ETCS-OB). This means that position and speed are each associated with a confidence interval (the occurrence of the actual train position and speed outside the confidence interval shall not be higher than the defined THR).	Functional	

Consumer	Req. ID	Description	Req. type	Tracing to other WP
ETCS-OB	R_01_4_09	ASTP shall be able to express 1D position as a distance from any reference spot defined in the digital map (thus known by trackside and on-board). It means, that the origin of 1D positions is not limited to LRBG only.	Functional	
ATO-OB	R_01_4_10	ASTP shall provide safe (SIL2) position and speed for ATO-OB. This means that position and speed are each associated with a confidence interval (the occurrence of the actual train position and speed outside the confidence interval shall not be higher than the defined THR).	Functional	
Maintenance	R_01_4_11	ASTP shall provide position and speed with basic integrity (SIL0). The position and speed are provided as point estimates accompanied by corresponding standard deviations (sigmas).	Functional	
All	R_01_4_12	ASTP shall ensure that the position accuracy (i.e. difference of estimated position and true position) and speed accuracy (estimated speed and true speed) fulfil defined statistical property defined with 95% quantile (2-sigma accuracy).	Non-functional	
All	R_01_4_13	ASTP shall be able to self-diagnose and report to the consumer(s) when the expected performance (maximal limit for the confidence interval, 2-sigma accuracy) cannot not be fulfilled.	Functional	
All	R_01_4_14	ASTP shall be able to self-diagnose and report to the consumer(s) ASTP own malfunctions preventing correct operation (e.g. HW failures including sensors, SW exceptions, incorrect configurations, etc.).	Functional	

5.1. Use Case Specific Requirements

This section provides a list of ASTP requirements that are specific to specific UCs. The list therefore complements the generic list in Sec. 5, where requirements applicable to all proposed UCs are given. The list thus highlights specific functions or features of ASTP that are necessary to make ASTP (reasonably) usable in the specific UC. Note that some of the non-functional requirements are described qualitatively (no specific values are given), with the aim of being specified later.

Table 3 The list of Use Case specific requirements for ASTP system

UC ID	Req. ID	Req. spec.	Req. type	Tracing to other WP
UC_01_4_4 UC_01_4_11	R_01_4_4_1 R_01_4_11_2	ASTP shall be able to keep the train confidence interval short when approaching to the "specific points" of the line (e.g. EoA, LoA, track conditions, speed profile variation, start/end of LX). In particular, the performance of ASTP shall allow an approach to the EoA without the application of release speed (if technologies in ASTP allow this). This requirement assumes that the shorter confidence interval is required only in the vicinity of these “specific points” leaving the relaxed requirement in the other track sections.	Non-Functional	
UC_01_4_8 UC_01_4_9 UC_01_4_10	R_01_4_8_3 R_01_4_9_4 R_01_4_10_5	ASTP shall ensure the position uncertainty (i.e. difference of estimated position and true position) is less than 1m with 95% percentile (two sigma accuracy is 1m). This performance requirement is fulfilled even in the GNSS challenging environment (terrain or urban canyons, tunnels, stations with platform roofs, etc.).	Non-functional	
UC_01_4_3	R_01_4_4_6	ASTP shall guarantee the performance characteristics (accuracy and maximum allowed length of confidence interval) even within radio holes, i.e. under the conditions of no augmentation data due to the lack of communications.	Non-Functional	

UC ID	Req. ID	Req. spec.	Req. type	Tracing to other WP
UC_01_4_1 UC_01_4_3 UC_01_4_4 UC_01_4_5 UC_01_4_6 UC_01_4_7	R_01_4_1_13 R_01_4_5_14 R_01_4_6_15 R_01_4_7_16 R_01_4_4_17 R_01_4_3_18	ASTP shall also work in a simplified trackside configuration, i.e. in conditions where some supporting information is not available, or at least not for all track sections (it could be: reduced number of balise installations, radio holes –i.e. no augmentation (EGNOS) data are delivered, route info/switch status info). This may lead to worse performance (in terms of longer confidence interval) however, the availability and safety are preserved.	Functional	
UC_01_4_6	R_01_4_6_19	ASTP shall be able to generate an ambiguous position if the unique position cannot be provided due to simplified trackside. This is applicable for the first position after ASTP initialisation (ETCS-OB position is invalid or unknown). An ambiguous position contains confidence intervals covering several parallel tracks. An ambiguous position is generated by ASTP when no route information is provided by the track side and the track itself has no balises to generate a unique position.	Functional	
UC_01_4_6	R_01_4_6_20	exported constraint: ETCS-OB and trackside (RBC) shall be able to process the position report with an ambiguous position.	Functional	
UC_01_4_6	R_01_4_6_21	exported constraint: trackside (RBC) shall be able to issue an MA for a train providing the position report with an ambiguous position if all routes starting from confidence intervals in the ambiguous position have no collision with other train routes.	Functional	
UC_01_4_2	R_01_4_2_22	Exported constraint: ETCS-OB shall be able to process the information given by the ASTP to manage the triggering of the ETCS location reference (potential LRBG), as well as the linked fixed ETCS message if any. This last message shall be conducted through the corresponding transmission media interface to be accepted according to the current ETCS operational level (L1/L2).	Functional	

UC ID	Req. ID	Req. spec.	Req. type	Tracing to other WP
UC_01_4_2	R_01_4_2_23	Exported constraint: DR-OB must have ETCS information associated to each necessary location.	Functional	
UC_01_4_3	R_01_4_3_24	Exported constraint: the ETCS-OB shall be able to use the DR-OB in areas where no ETCS radio (GSM-R or FRMCS) is available.	Functional	
UC_01_4_2	R_01_4_2_25	Exported constraint: the ETCS-OB shall be able to use the DR-OB in L1	Functional	

6. Link of ASTP in D3.4 with KPI's

Each task of FP6 FUTURE, WP3 has been linked to set of specific Key Performance Indicators (KPI). In this chapter, identification of each associated KPI is provided with brief justification of ASTP contribution to those KPI's in regional railway conditions.

Table 4. Link of ASTP functions with KPI's

KPI	Description	ASTP contribution
SE01	Overall reduction of the Total Cost of Ownership (CAPEX and OPEX) of the CCS system, while maintaining or increasing the present safety level.	The ASTP systems brings potential in reduction of total number of assets installed on track by reduction of number of balises needed for continuous train positioning while preserving (or even improving) the localisation performance.
SE03	Increased system availability due to reduced trackside asset failure and more reliable CCS (Average delay minutes per assets and signalling failures).	The ASTP systems brings potential in reduction of total number of assets installed on track by reduction of number of balises needed and thus potentially increasing the RAMS parameters of trackside assets.
SE04	Reliable cost-effective fail-safe on-board train integrity, train length detection and train positioning.	ASTP is essential for determining the safe rear end of the train (together with the integrity confirmation from TIMS), which can then be provided to the trackside and used to release the section(s) of track passed. SEO4 is related to the increase of reliability therefore ASTP is expected to contribute to this goal (together with Train integrity) by reducing TTD and specifically those TTD used to set switches and LXs free.
SE05	Overall reduction of OPEX and CAPEX.	Thanks to the installation and exploitation of on-board ASTP system, less immovable trackside equipment will be allocated on regional and remote railways which reduces OPEX and CAPEX in such railways. In addition, the on-board ASTP system utilizes cost-effective sensors, such as cameras, odometers, and GNSS to minimize OPEX and CAPEX.

KPI	Description	ASTP contribution
SE08	Reduced OPEX costs/km for trackside railway assets.	Thanks to the installation and exploitation of on-board ASTP system, less immovable trackside equipment will be allocated on regional and remote railways which reduces OPEX and CAPEX in such railways.

7. Demonstration Setup

In this section planned demonstrators to be realized in Task 8.5 are introduced. The section is structured into subsections containing individual demonstrators with their description in tables for each demonstrator planned. Detailed description and plan for realisation of the demonstrators will be provided through T8.5 efforts based on Use Cases and demonstrator requirements elaborated in this Deliverable.

7.1. AZD Demonstrator setup

This section provides a list of ASTP requirements that are

Demonstration group	WP3 – Task 3.4	Lead demonstrating company	AZD
Demonstration Name	Verify operation with regional lines equipment		
UC ID	UC_01_4_3, UC_01_4_6		
Test site	Kopidlno – Dolni Bouzov Railway in the Czech Republic		
Set ups	Line setup will consist of: • Functioning ETCS L2 • Fully equipped ILX in station • Single track rail line • Station with multiple parallel tracks • Availability to induce radio hole conditions • Rail vehicle equipped in functioning ASTP system from AZD		
Evaluation method	• To evaluate operation of ASTP during passing of radio hole (UC_01_403), a situation with reduced or unavailable GNSS augmentation information will be constructed during which operation of ASTP will be assessed both during radio hole and during return to full communications. • To evaluate UC_01_406, an operation scenario for vehicle starting from platform in station with parallel tracks will begin journey without track selectivity information, for which ASTP system will compensate.		
Testing phase	• **Test 1**: The test vehicle with installed ASTP start at the station with parallel tracks. The first ASTP position is ambiguous, i.e. track cannot be discriminated (ETCS-OB starts with position invalid or unknown). The ambiguous position report is sent to the trackside. If this ambiguous position and all corresponding routes do not conflict with any trains (their routes) the MA is issued for the test vehicle. • **Test 2**: The test vehicle leaves the station with parallel tracks and reaches a line section with a single track. The ASTP position becomes unique and ETCS-OB generates unique position reports. • **Test 3**: The test vehicle reaches a single-track section where the radio hole is emulated. The conditions of radio holes for ASTP are enforced with a cut-off of the augmentation data stream, thus, ASTP has to generate its position and speed without this supporting information. When the end of this section is reached, the augmentation data channel is re-established and ASTP generates its position and speed as usual.		

7.2. NRD Demonstrator setup

This section provides a list of ASTP requirements that are

Demonstration group	WP3 – Task 3.4	Lead demonstrating company	NRD
Demonstration Name	Improve network operation and maintenance		
UC ID	UC_01_4_8, UC_01_4_9, UC_01_4_10		
Test site	1. Laboratory site: The Norwegian University of Science and Technology (NTNU) campus 2. Railway site: Namsos line, central Norway The lab test is a necessary supplement to the on-site testing, as the lab test site can simulate some regional line environments (e.g., tunnels, valleys, and various types of trackside objects) that may not be accessible at the railway test site. This supplementary testing allows for more comprehensive evaluations of the ASTP system's capabilities under more diversified challenging conditions.		
Set ups	The laboratory site is designed to replicate the complexities of a real-world railway environment, including: • closely positioned buildings to simulate valleys • an underpass to represent tunnels or enclosed spaces roadside objects including trees and poles to mimic objects adjacent to rail tracks The selected Railway site is at the boundary of mountain (covered by forests) and water body. The track passes through bridges and Viaducts. In both test site 1 and 2, an unmanned ground vehicle (UGV) is used to simulate a train's operations. It is equipped with: • a low-cost onboard GNSS • an odometer • an IMU • a set of five cameras around the UGV For evaluation purposes, a high-end ultra-precise GNSS system will also be used, which includes an onboard GNSS and a ground-based GNSS station. This system is capable of delivering highly accurate (±1cm) real-time positions of the UGV, even in areas where signal obstruction occurs.		
Evaluation method	• To evaluate the accuracy of the detected faulty locations, specific "faulty locations" will be manually marked along the UGV's route within the test environment. The precise coordinates of these locations, obtained from the ultra-precise GNSS, will be recorded. • To evaluate the positioning accuracy under weakened and absence of GNSS signals, the ultra-precise GNSS system will be used.		
Testing phase	• **Test 1**: In the laboratory site, the UGV's cameras will be navigated through its designated path, and scan for the predetermined faulty locations on the path. Whenever a faulty location is detected, the UGV's real-time location data will be cross-referenced with the pre-recorded coordinates of the faulty site to assess the system's location accuracy.		

	• **Test 2**: In the laboratory site, the UGV will navigate through designated routes, including sections that replicate "tunnels" and "valleys", where the GNSS signals will be significantly weakened. The accuracy of the UGV's real-time positions delivered by the ASTP will be evaluated by comparing it against the data obtained from the ultra-precise GNSS. • **Test 3**: In the laboratory site, the UGV will navigate through designated routes, including sections where the on-board GNSS will be shut down (GNSS signals will be completely unavailable). The accuracy of the UGV's real-time location data delivered by the ASTP will be evaluated by comparing it against the data obtained from the ultra-precise GNSS. • Test 4: In the railway site, the UGV will navigate through a designated track section. Tests 1-3 will be repeated on the track. For Test 2 and 3, GNSS signals will be manually weakened/shut down if a tunnel will not be accessible.

7.3. ATSA Demonstrator setup

This section provides a list of ASTP requirements that are

Demonstration group	WP3 – Task 3.4	Lead demonstrating company	ATSA
Demonstration Name	Increase the performances of train positioning system in G1 regional line		
UC ID	UC_01_4_7, UC_01_4_11		
Test site	Roccasecca – Avezzano RFI railway in Italy		
Set ups	• Train equipped with: ○ Alstom ERTMS/ETCS Onboard Compact Platform with ETCS odometry. ○ GPRS/LTE Radio Communication. ○ GNSS antenna Dual Frequency, installed on the roof of the train. ○ RF Interface, to adapt/condition the signal to receivers and provide power supply to the antenna. ○ GNSS receiver, Dual-Frequency, Multi-Constellation. ○ Ground Truth, composed by an Inertial Navigation System (3D Accelerometer, 3D Gyroscope…), and a GNSS Receiver. ○ PC to store the digital map of the line and pre-process GNSS/EGNOS/digital map data and feed the ASTP functions. ○ ASTP functions integrated in the ERTMS/ETCS Onboard Compact Platform to compute in real-time the train estimated position and the along track related interval. ○ Data logger to store the ETCS odometry and ASTP data. • Line with availability of: ○ GPRS/LTE (Public) Communication Network. ○ GNSS Augmentation, based on the current EGNOS SFSC service. ○ ETCS signalling system. ○ Physical balises in tunnels, trenches, stations, after divergences to allow track discrimination, and in all locations where there is poor satellite visibility. Minimum distance between physical BGs between stations with good satellite visibility: 2.5 km.		
Evaluation method	• To evaluate the effects of ASTP on the speed control function of the ERTMS/ETCS Onboard in a G1 regional line (UC_01_4_11), a scenario where the train is approaching a location where speed decreases/increases (e.g. due to TSR or SSP) at a distance > 2.5 km from the LRBG will be constructed during which the size of the safe confidence interval will be assessed. • To evaluate the capability of ASTP to minimise the distance to be run in a ETCS non-protected mode after SoM (UC_01_4_7), a scenario where the train starts its mission in line with ETCS train position unknown or invalid		

	will be constructed. It will be checked that, thanks to ASTP, ETCS provides a valid Position Report before the acquisition of the first Balise Group. • To check the safety of the confidence interval during all the test, it will be verified that the safe confidence interval includes the Ground Truth position at any time.
Testing phase	• **Test 1** (UC_01_4_11a): The train covers a route between two points and the ASTP continuously provides the estimated position and the related confidence interval. The train approaches a speed restriction (e.g. TSR or SSP restriction or EoA) at a distance > 2.5 km from the LRBG. The ETCS Onboard applies the speed limit decrease in an acceptable position from the operational point of view. The accuracy requirements of ASTP are met. The safe confidence interval includes always the Ground Truth position. • **Test 2** (UC_01_4_11b): The train covers a route between two points and the ASTP continuously provides the estimated position and the related confidence interval. The train approaches a location where speed increases (e.g. end of TSR or SSP increase) at a distance > 2.5 km from the LRBG. The ETCS Onboard applies the speed limit increase in an acceptable position from the operational point of view. The accuracy requirements of ASTP are met. The safe confidence interval includes always the Ground Truth position. • **Test 3** (UC_01_4_7 scenario 2): The train is at standstill in line with a single track. The ETCS train position is forced to unknown or invalid. The usual SoM procedure takes place. ETCS-OB provides a SoM TPR with a position different from valid. ETCS-TS authorises the train to move in SR. The train moves and, as soon as possible, ASTP computes a safe train position (without reading any physical balises). ASTP sends the position to ETCS-OB which provides to ETCS-TS a T • PR against a geolocated reference point. ETCS-TS provides the MA according to available conditions. The safe confidence interval provided by ASTP includes always the Ground Truth position.

7.4. MERMEC Demonstrator setup

This section provides a list of ASTP requirements that are

Demonstration group	WP3 – Task 3.4	Lead demonstrating company	MERMEC
Demonstration Name	Regional application for ASTP		
UC ID	UC_01_4_9, UC_01_4_10, UC_01_4_11, 0		
Test site	Reference line Avezzano Roccasecca Italy		
Set ups	Line and Laboratory • Single track rail line • Station with multiple parallel tracks • Vehicle equipped with ASTP system by MERMEC Collect the information from trips on the line		
Evaluation method	Checking the right sending of virtual balises		
Testing phase	• **Test 1.** The test vehicle performs trip on the regional line and collect all the data coming from all the possible operations conditions. The position of all the Virtual Balises are positioned along the rail maps. On the vehicles is present also a parallel system for accurate positioning and ground truth estimation. **Test 2**. Test 2 In laboratory the playback of all the trips are possible and the ASTP can provide its output. The check is done for compare the output of the ASTP elaboration with the expected ones. The virtual balises output are checked. It is also checked the position provided ASTP internally.		

8. Conclusions

As closure for this deliverable, this chapter recaps its key points, in a concise and synthetic manner.

<u>INTRODUCTION</u>

- ✓ This document constitutes the deliverable D3.4.
- ✓ It has been built consistently with some inputs coming from externals, as FP2 and System Pillar.
- ✓ It can be used as entry point to the definition and deployment of the demonstrator to be delivered by further Task 8.5.

<u>OBJECTIVE</u>

- ✓ This deliverable has two main objectives:
    - o to provide the definition of the demonstrator setup, and
    - o to provide the list of Use Cases to be exercised in that demonstrator.
- ✓ Both mentioned objectives with the final aim to satisfy the overall WP3 goal, which is to "*find suitable already existing and interoperable CCS solutions which can be applied for G1 lines, to ensure their long-term viability and decrease their total costs*" (as extracted from the GA).

<u>TARGET OPERATIONAL ENVIRONMENT</u>

- ✓ Contributors: AZD, OBB, ADIF, RFI, NRD, MERMEC, ATSA CEIT, FT, INDRA.
- ✓ Innovation: Use of Advanced positioning systems including EGNOS and GALILEO.
- ✓ Operational Area: G1 Regional lines.

<u>USE CASES</u>

- ✓ Compendium of Use Cases and Scenarios, provided in a unique list.

<u>ASTP REQUIREMENTS</u>

- ✓ Comprehensive list of general requirements for ASTP system is delivered.
- ✓ Additional list of Use Case specific requirements is specified

<u>DEMONSTRATION SETUP</u>

- ✓ The description of 4 distinctive demonstrators that are planned to be delivered as a part of WP8 were developed in this deliverable in the level of detail that was possible during T3.4 duration

References

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[2] Absolute Train Positioning including usage of EGNOS "baseline exercise", Version 1.0, 13.10.2023

[3] 18E112_TL-high-level-principles_2 VERSION 2 10/12/2019

[4] D2.2 Regional Lines Operational and Functional Requirements FP6-WP020D-MER-001-01, 21.07.2023