

Rail to Digital automated up to autonomous train operation

D46.1 – Testing scenarios and Regional line demonstrations planning

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Leader/Responsible of this Deliverable: Michal Novák (AZD)

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REPORT CONTRIBUTORS

Name	Company	Details of Contribution
Pierre-francois Jauquet	ATSA	Contributor, reviewer
Julien Plantard	ATSA	Contributor, reviewer
Musab Benayoune	ATSA	Reviewer
Matthieu Moussine-Pouchkine	ATSA	Contributor
Gavino Brundu	FT	Contributor, reviewer
Saro Thiyagarajan	FT	Reviewer
José Antonio Giménez Gómez	INDRA	Contributor, reviewer
Petr Stříteský	AZD	Contributor, reviewer
Michal Matowicki	AZD	Contributor, reviewer
Michal Pavlac	AZD	Contributor, reviewer
Peter Gurník	AZD	Contributor, reviewer
Michal Novák	AZD	Contributor, reviewer
Petr Kačmařík	AZD	Contributor, reviewer
Jakub Adámek	AZD	Contributor, reviewer
Dominik Kevický	AZD	Contributor, reviewer
Lubor Bažant	AZD	Contributor, reviewer

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EXECUTIVE SUMMARY

The deliverable contributes to the deployment and validation of advanced technologies targeted at autonomous train operation, aiming to provide operational and technical feedback on proposed architectures and specifications. While the demonstration is performed in a regional railway environment, the scope of this deliverable is strictly limited to activities carried out within the framework of the R2DATO project.

The work has been conducted by four R2DATO partners: AZD, ALSTOM, FAIVELEY, and INDRA. Each partner contributed by delivering technological components intended to be integrated into the autonomous train architecture. Additionally, AZD provided its testing line in Czechia and an experimental vehicle (EDITA). In cases where multiple suppliers provided technological components, the performed tests shall allow to check interchangeability feature, offering valuable feedback on the maturity of specifications and implementations. These tests are unique to the R2DATO project and represent a continuation of the initial SHIFT2RAIL X2RAIL tests of ATO up to GoA4 specifications, which were performed in late 2023.

The deliverable emphasizes the overall technological approach, alignment, preparation, and timely development of the testing and demonstration plan. The primary ambition of the organizations involved was to ensure a responsible and effective approach to demonstrating the solutions developed in the R2DATO project while adhering to specifications for autonomous train operation as closely as possible.

The official and unique system reference for the demonstrator technical development is "SRS ATO up to GoA3/4 v1.1.0," released by R2DATO WP6-Task 6.5 resulting from the R2DATO WP6-Task 5.3 consisting in review of existing (prior to EU-RAIL program) specification(s) for ATO GoA3-4 technology.

In case of missing or uncomplete SRS1.1.0 specifications to cover the outlined use cases, WP46 members proposed interim solutions to ensure progress. The proposed interim solutions prefigured as much as possible to the specifications that could be produced in future.

The same pragmatic approach was applied in situations where technological, operational, or regulatory limitations prevented full compliance with every aspect of the outlined Use Cases.

Key topics covered in the deliverable include:

Indetification of Technical Enabler: Identifying technologies and components for testing and demonstration, namely the Automatic Functions / ADM Module, Localisation Module, Perception Module, Digital Register/Repository and Remote Control.

Definition of Use Cases selected for Demonstration: Selecting Use Cases (UCs) from R2DATO deliverables D5.X, with detailed descriptions and assumptions for proper implementation. The selected UC set spans the key functional areas planned for the

demonstration — from train preparation and automatic mission start-up, through perception-supported behaviours such as obstacle reaction and signal recognition, up to remote-control operations including log-in, control transitions and routine driving.

Definition of Test Scenarios: Creating test scenarios for each UC, reflecting current specifications and ensuring feasibility. The scenarios were structured with defined preconditions, expected outcomes and step-by-step methodology, and aligned with the capabilities of the test vehicle and the regional test line. This provides a clear basis for demonstrating each UC during laboratory, integration and on-site testing.

Definition of the Testing Environment: The deliverable defines the testing environment by describing the regional test line Kopidlno–Dolní Bousov, its signalling and protection systems, operational constraints and communication infrastructure, as well as the configuration of the EDITA test locomotive and its required onboard interfaces.

Testing and Demonstration Plan: Developing a comprehensive plan covering component descriptions, timelines, and testing procedures. The plan defines the sequence of laboratory tests, integration steps and on-site validation activities, providing the structure for how the defined Use Cases and scenarios will be executed during the next phase of WP46.

The document marks the completion of the first major phase of Work Package 46 (Regional Line Demonstrations), covering activities from the first two tasks of this work package: **FP2-R2DATO Regional Line Testing Scenarios (Task 46.1)** and **Detailed Development and Demonstration Planning (Task 46.2)**. This forms a solid foundation for the next phase of the work package, focusing on practical adaptations, testing, preparatory activities, and final demonstrations (Tasks 46.3 and 46.4).

ABBREVIATIONS AND ACRONYMS

ADM	Automatic Driving Module
APM	Automatic Processing Module
ASTP	Absolute Safe Train Positioning
ATO	Automatic Train Operation
ATO-OB	Automatic Train Operation - Onboard
ATP	Automatic Train Protection
ATSA	Alstom
AZD	AŽD Praha
BTM	Balise Transmission Module
CAB	Cabin
CMD data	Command Data
DAC	Digital Automatic Coupler
DM	Digital Map
DMI	Driver Machine Interface
DR	Digital Register
DR-OB	Digital Register - Onboard
DR-TS	Digital Register - Trackside
DTO	Driverless Train Operation
Dx.x	Deliverable [WP number].[Deliverable in WP number], e.g. D46.1
EDITA	Experimental vehicle provided by AŽD Praha
EMU	Electric Multiple Unit
EOA	End Of Authority
ERA	European Union Agency for Railways
ERJU	Europe's Rail Joint Undertaking
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
ETCS-OB	European Train Control System – Onboard
EU	European Union

FAS	Fleet Automation System
FMS	Fleet Management System
FP	Flagship Project
GoA	Grade of Automation
HS	High-Speed
IM	Infrastructure Manager
IPM	Incident Prevention Module
ISM	Incident Solving Manager
JP	Journey Profile
JU	Joint Undertaking
K-DB track	Kopidlno - Dolní Bousov (AŽD Praha testing track)
LiDAR	Light Detection And Ranging
LOC	Localization
MA	Movement Authority
MD	Mission Data
MP	Mission Profile
OAS	Onboard Automation System
OB	Onboard
OE	Operational Execution
OM	Operations Manager
OS	On Sight
PAL	Protection Adaptation Layer
PER	Perception
PIS	Passenger Information System
PT	Post Trip
R2DATO	Rail to Digital automated up to Autonomous Train Operation
RC	Remote Control
RC-OB	Remote Control – Onboard
RC-TS	Remote Control - Trackside
RD	Remote Driver

REP	Repository
REP-OB	Repository - Onboard
RSC	Rail Service Center
RU	Railway Undertaking
RUS	Railway Undertaking Supervisor
SIL	Safety Integrity Level
SP	Segment Profile
SRRC	Situational Risk and Response Classification
SRS	System Requirements Specification
TAS	Trackside Automation System
TAURO	Technologies for the Autonomous Rail Operations
TCMS	Train Control Management System
TD	Train Data
TE	Technical Enabler
TMS	Traffic Management System
TRL	Technology Readiness Level
TS	Trackside
TSI	Technical Specification for Interoperability
UC	Use Case
UTO	Unattended Train Operation
X2R-X	Shift2Rail project X2Rail-[number]
WP	Work Package

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1 INTRODUCTION

This deliverable is part of the ERJU programme under Flagship Project 2 (FP2). It addresses several critical technology enablers, including Automatic Function (TE01), Absolute Safe Train Positioning (TE02), ATO Technology (TE04), Perception (TE06), and Remote Driving (TE07). As part of the demonstration cluster within the R2DATO project, it implements the objectives of two key tasks under WP46:

The first task, “FP2-R2DATO Regional Line Testing Scenarios” (Task 46.1), involves summarising the technical needs and properties that require validation within the scope of the regional test line. This includes identifying the necessary interfaces (high-level), functions relevant to interoperability.

The second task, “Detailed Development and Demonstration Planning” (Task 46.2), focuses on specifying the components needed for the test environment, locomotive, and technical enablers. It also provides a detailed plan for development and adaptation activities.

The primary aim of WP46 is thus to test and demonstrate technical enablers that facilitate fully automated train operations in regional railway environments. The testing process is based on SRS1.1.0 produced by the R2DATO WP6-Task 6.5 and, where possible, will evaluate the interchangeability of components supplied by different manufacturers.

This work contributes to the deployment and validation of advanced technologies in a target railway environment, and therefore provides operational and technical feedback on proposed architectures and specifications, and the return of experience to help shaping future advancements.

The document is structured to provide a clear and systematic basis for further work.

Chapter 2 defines the scope and lists key references.

Chapter 3 explains the methodology and working principles.

Chapter 4 details the technical enablers and technologies used.

Chapter 5 focuses on the use cases implemented within the project.

Chapter 6 outlines the testing scenarios

Chapter 7 describes the testing environment.

Finally, Chapter 8 presents the integration and demonstration plan.

By establishing this structure, the document forms a solid foundation for the demonstration preparation and adaptation activities required for WP46.

2 SCOPE

This work package focuses on testing and validation within the regional line environment, specifically addressing the use cases and requirements defined under FP2 – R2DATO. Only the scenarios and objectives outlined within this framework are considered within the scope of this deliverable.

The official system reference for demonstrator development is "SRS ATO up to GoA3/4 v1.1.0," which has been released by R2DATO WP6-Task 6.5 within R2DATO WP6.

The use cases selected for and to be covered by the WP46 demonstrator will be entirely covered by a strict and exclusive application of only the requirements listed in SRS1.1.0.

Requirements from WP6 regarding tested Use Cases will be applied if they are in line with SRS 1.1.0 and are feasible to be implemented by WP46 partners. In cases where it is possible, additional requirements from WP6, not present in SRS 1.1.0 might be considered for demonstration if agreed by all the partners.

In case of missing SRS1.1.0 specifications to cover the outlined use cases, WP46 members may propose interim solutions to maintain progress. These proposed interim solutions (if any) prefigured as much as possible to the specifications that could be produced in future.

Proceeding in such a way reflects the adaptability and forward-thinking of WP46 members to make as much progress as possible in order to bring a wealth of practical experience to the project

This approach ensures that the WP46 outcomes progresses and align with both current evolving specifications and requirements as much as possible.

3 METHODOLOGY AND WORKING PRINCIPLES

The methodology of WP46 assumes a systematic approach to the task of developing demonstration scenarios for multiple logical components and TE developed in R2DATO in order to verify their applicability, and possible shortcomings for use in regional lines. This has multiple objectives as defined in Chapter 1.

The methodology to achieve these objectives relies on applying a Use Case centric approach.

The principle of this Use Case centric approach is to ensure, on the basis of SRS1.1.0 as system reference specification, the verification of capability and possible limitations of the proposed solutions to perform Use Cases as defined in deliverables D5.X of R2DATO in regional railway conditions.

In this sense, the workflow of the WP46 is structured into following steps ensuring holistic approach to the task of demonstrating R2DATO benefits on regional railway:

- I. System (Technical Enabler) identification (to be tested in WP46)
- II. Identification of UC to be tested and their applicable scenarios
- III. Definition of testing scenarios
- IV. Description of testing environment
- V. Development of testing and demonstration plan.
- VI. Relevant documents and other sources

The abovementioned steps ensure responsible approach to the demonstration of TE capabilities, identification of their applicable scenarios in the testing environment and efficient planning of execution of the demonstration itself.

Moreover, initial focus on demonstration and Use Cases identification ensures level ground for all partners in firster adjustment of developed TE and preparation for the demonstrators.

- Identification of key Technical Enablers (TE) and technologies to be tested

Responsible: All partners

The first stage of WP46, focused on partners identifying TE and technologies which they plan to test during WP46 demonstration.

According to the development in WP6, the basic reference architecture for definition of components included in demonstrator shall be based on SRS ATO up to GoA3/4 v1.1.0, as a result of R2DATO WP6-Task 6.5.

The components defined here are to be analysed in context of available demonstration site as available in AZD Praha.

In addition, technologies and components that will be tested in frame of WP46 shall reflect the involvement of partners in development Work Packages and Use Cases to be tested in Regional line demonstrator by each partner.

- Identification of UC to be tested

Responsible: All partners

Following the definition of individual TE and components to be tested, the Use Cases need to be defined to verify implementation of individual components. At this stage, partners choose a list of Use Cases from the set of deliverables D5.X, to be verified in testing conditions of K-DB track. Together with Use Cases, their descriptions and specific assumptions (if any) were identified. This concerns mainly identifications of cooperating and necessary components and systems for proper realisation of all UC Specifically, each Use Case define systems and components involved in Use Case, a summary description of the Use Case, and demonstrator assumptions specific for given Use Case.

- Definition of testing scenarios

Responsible: All partners

After the final list of tested Use Cases and components to be delivered by each participant will be defined, demonstrating partners describe a specific testing scenario for Use Case. This shall reflect the Use Case scenarios as defined in D5.X , adapted for testing purposes, considering the aspects of practical feasibility, filling potential gaps/incoherences in specifications (work in progress) and limitations of technological developments. Only the scenarios and use cases delivered by R2DATO project are considered within the scope of this Work Package. The description of testing scenario should include identification of Use Cases tested, conditions of test, steps of the planned test and, where applicable, possible connection with other Use Cases/test scenarios. Besides mentioned, it is necessary to define success criteria for tests which will allow to evaluate and assess performed tests.

Planned outcomes of the testing are two folded. First and foremost, the goal of the testing is confirmation of the implementation of functionalities developed in R2DATO WP5 (as Use Cases) and further specified in WP6 (T6.5). Secondary benefit of WP46 demonstrator testing is feedback on requirements stated in T6.1, T6.3, T6.6 and T6.7 based on our testing. As such, for the purpose of testing verification of TE behaviour in WP46 we accepted SRS as the sole base in development and assessment of the testing results. Relation on individual tasks and block scheme of interdependencies of information and processes in WP46 testing is presented in Figure 1 below.

The workflow of WP46 was initiated by the identification of Use Cases to be tested as developed in D5.X within WP5 R2DATO. After the Use Cases to be demonstrated in WP46 were identified we moved to definition of prototype development conditions, requirements and specification. Since at the moment of these activities being taken (2nd and 3rd quarter of 2024) only SRS 1.1.0b were available as a deliverable, this was chosen as a common base for development of individual prototypes. This step was important as common, stable version of specifications and requirements was crucial to ensure viability of our work as well as interchangeability of developed prototypes. After carefully applied GAP analysis investigating SRS 1.0.0b coverage of Use Cases to be tested within WP46 by all partners, those involved in interchangeable prototypes testing begun bridging activities to cover grey spots and insufficient specifications in a way common for all demonstrators in WP46.

This will be done in form of sequence diagrams representing each step and interplay of individual logical components through execution of Use Cases and tests and filling gaps in interface specification. Upon finalization of sequence diagrams, activities in WP46 will be followed as prototype development, physical integration and adaptation of the demonstrator. Finally, in the final part of our work package we will execute demonstrators according to the prepared testing scenarios and evaluate its results in final report. In parallel, in order to provide additional feedback to Tasks T6.1, T6.3, T6.6 and T6.7 we prepared mapping of UC requirements to our Use Cases based on coverage analysis performed in T6.1. Based in this mapping, we will compare the results of our testing with available version of requirements coverage and provide our feedback on the results to WP6 R2DATO.

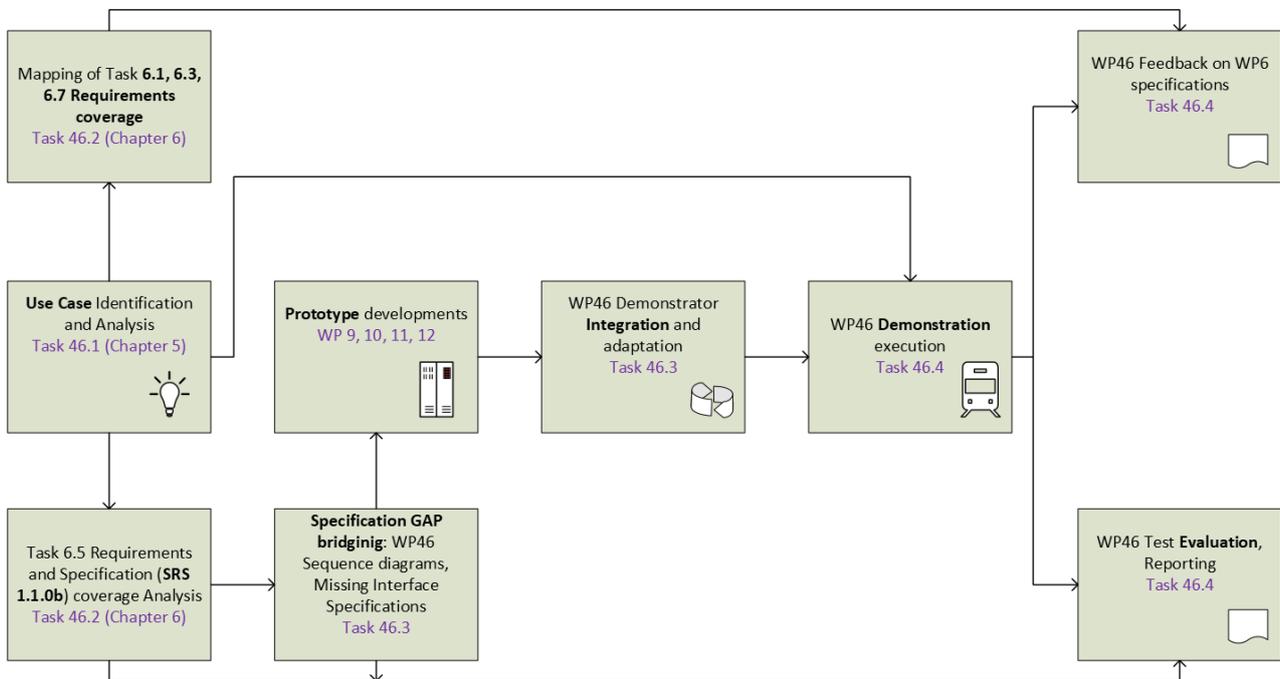


Figure 1: Workflow and contributions of WP46 demonstrator

- Testing environment

Responsible: AZD

In this stage, AZD will prepare description of the systems and equipment's deployed in the testing track. This considers both trackside and on-board, alongside with basic characterisation of the track at disposal for testing. The purpose of this activity is to present an overview of existing track/vehicle configurations and functional counterparts for elements to be tested by each demonstrating partner. This description will not include changes and systems to be implemented during test and for testing purpose only.

- Development and demonstration plan

Responsible: All partners

The final step of D46.1 development will include two stages. Firstly, the description of individual components, Technical Enablers and technologies to be tested within dedicated test side will be provided. This includes description of specificity (if identified as resulting from lack of SRS 1.1.0 specifications) and functionality implemented in tested components, as well as identification of possible complementing specifications and conditions from specifications of the components as defined in R2DATO WP6. Second stage is final preparation and description of timespan for preparatory activities and demonstration execution. Due to the dependencies on previous step this work is the last stage of demonstration preparation and will be performed after initial definition and description of the testing scope in terms of systems involved will be finished.

In order to ensure ongoing progress of the demonstrator development and preparation for final demonstrations, regular meeting with biweekly frequency were proposed among all partners prior to demonstration itself. As to development of individual demonstrators among partners, the activity of WP46 management is limited to periodical progress statement on the development and no detail briefings are provided by the partners. Coordination in this sense is limited to harmonizing and timely preparation of the common version of the requirements and specifications applicable as well as cooperation on development of testing and demonstration plan.

Additionally, to ensure common understanding of individual Use Case implementation, regular weekly meetings were organised in order to design in detail sequence diagrams and interfaces of the demonstrators to be developed. This allowed to clarify realisation of the demonstrations and technical cooperation between partners including possible combination of Use Cases withing individual test scenarios.

- Relevant documents and other sources

Responsible: All partners

During the development of D46, numerous documents were used as information and specifications source for the purpose of prototype development and testing definition. Most of these documents were used in the stage of draft status as their finalized versions were unfortunately unavailable at the time. Detailed list of all used references used to develop this deliverable is displayed in last section of this document together with brief explanation for documents and versions listed.

4 KEY TECHNICAL ENABLERS AND TECHNOLOGIES

Based on the ATO GoA3/4 architecture, the following technical enablers will be tested:

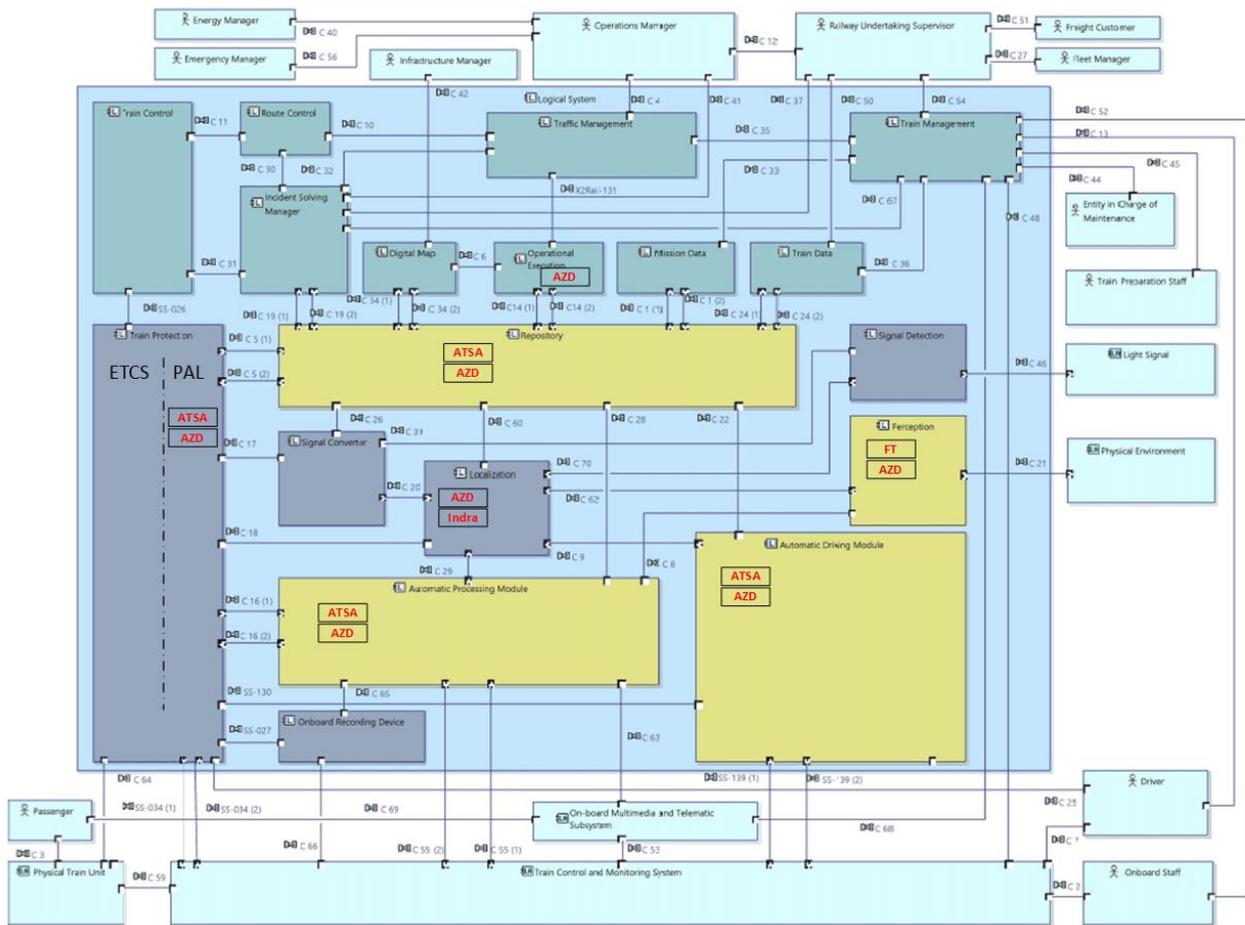


Figure 2: ATO up to GoA4 Architecture with WP46 partners involved

Diagram describes the intention of partners to develop module prototype to be tested and demonstrated in the scope of WP46.

Demonstration of trackside Operational Execution (OE), Mission Profile (MP) and Train Data (TD) and their connection to the train was initially considered as impossible and out of the scope of the demonstrator as there is no R2DATO work package dealing with this module.

The demonstrator was therefore initially decided to remain an (only) onboard demonstrator.

However, after further thought and deeper analysis, it was considered possible and (possibly) interesting for the REP-OB supplier(s) to rely on the existing “TSI-2023” compliant Operational Execution (OE) module so that the TMS could provide the train with all the data related to the / Journey(s) profiles supporting the test scenario(s).

Nevertheless, provided that any train movement required as part of a WP46 test scenario presupposes the prior setting of a static route (no change of route during the execution of a Mission

/ Journey), it was decided to let the REP-OB module supplier(s) free to define the way in which the ATO GoA4 data (Train Data, Mission profile, Journey profile, Segment profile, etc.) would be made available to the onboard demonstrator; i.e.

- Storage of TD/OE/DR/MD-related data in the REP-OB module
- Storage of TD/DR/MD-related data in the REP-OB and interface with the OE module to get the OE-related data from trackside
- Any other solution that should rely on the setting of a static route prior to any train movement required under a test scenario and that could ensure the availability on board of all the ATO GoA4 TD/OE/DR-related data

After carefully assessing the maturity of the Technical Enabler specifications, the overall needs of regional-line automation and the available development resources, the partners decided to implement only the Technical Enablers described in the following chapters.

4.1 AUTOMATIC FUNCTIONS, ADM MODULE

Generic Perspective

ADM module, historically referred as ATO -OB in TSI-2023, is the system responsible for train driving automation.

Depending on the implemented GoA (Grade of Automation) level, it executes either selected or all functions related to train driving.

Thus, it either must be supervised by a driver, who also performs the functions not covered by ATO (GoA2), or the train must be staffed by a train attendant, who closes the train doors and takes control in case of failure (GoA3), or the train can be fully unaccompanied, and ADM must be able to cover all situations that can arise, including most failures (GoA4).

By principle, the system architecture presented in Figure 2 is designed to support the threefold ATO GoA2, ATO GoA3 and ATO GoA4 train missions.

The ADM module shall be the result of an upgrade of the ATO GoA2 module as specified in the TSI-2023 simply because of the need to cover not only the ATO GoA2 functions as specified in the TSI-2023 but also, and above all, because of the necessity to cover the overall set of ATO GoA2 up to GoA4 functions and inter-modules interfaces as being defined in EU-RAIL SRS1.1.0 based on the system architecture shown in Figure 2.

Some of the needed change(s), if any, could already be described in the SRS1.1.0 chosen as the input system specification for our WP46 demonstrator.

In any case, for the sake of the WP46 demonstrator, the ADM module shall result from the diagram sequences that it will be possible to define, for each outlined Use Cases, on the basis of the strict application of SRS1.1.0 and of the specific features that it may be necessary to consider due to shortcomings in this SRS1.1.0

Those sequence diagrams shall allow a functional allocation per module and a precise definition of all the inter-modules interfaces listed below. This functional allocation per module and definition of

interfaces must be common to all WP46 partners to ensure the success of the interchangeability tests planned as part of the WP46 demonstrator

Applicable Interfaces

- **SS139** to TCMS
- **SS130** to ETCS
- **C9** to LOC
- **C22** to REP

Contributing WP46 Partners

Partners contributing to WP46 are **AZD** and **ALSTOM**.

Reference baseline for Prototype Development

- SRS ATO up to GoA3/4 v1.1.0 (output of D6.5)

Other possibly considered input(s) used for Prototype Definition

- Non-functional and functional requirement for automating functions (output of D6.1) only if all the partners can provide support to such additions.

4.2 LOCALISATION MODULE

Generic Perspective

The chapter contains the information related to outputs of WP21/22. WP21/22 has not yet solved GoA3/4 needs. Specific solution for WP46 will be provided below and in chapter 8.2

The aim of ASTP is to provide continuous train position and kinematic information (speed, acceleration) as well as train orientation (attitude, heading).

It is expected that modern (state-of-the-art) technologies will improve positioning performance and ensure an overall cost reduction (both compared to the current train localisation based on balise reading and distance measurement).

Utilizing the baseline documents, the ASTP can be specified using the following list:

- ASTP continuously provides the train position, and other kinematic information (velocity, acceleration). ASTP also provides train orientation (attitude).
- ASTP module shall compute those ASTP-related data based on ETCS-OB sensors or ASTP specific sensors. This could lead to necessity to define an ETCS-OB to ASTP interface providing the ability for the ETCS-OB to provide ASTP module with all the data related to the (historical) ETCS-odometry sensor(s)
- ASTP module shall be able to provide 1D (distance travelled from the beginning of the currently used Segment Profile) or 3D (projection of the Global Train position on the polyline related to the currently used Segment Profile) ASTP data. This leads to the necessity to define an REP-OB to ASTP interface providing the ability for the REP-OB module to provide ASTP module with all the Digital Map / Segment Profiles-related data required for ATO up to GoA4 driving mode.
- The information provided by ASTP should be suitable for different on-board consumers (ATP/ETCS, ADM, PER, PIS, etc.), considering that different consumers may require different safety targets (SIL4, SIL2, basic integrity [SIL0] are considered).
- The information computed by the ASTP (position, speed, etc.) is being provided with respect to the vehicle reference frame (preferably with the origin in the bogie pin) and not with respect to the front of the train.
- The information generated by the ASTP (position, speed, etc.) is provided via the ETCS-OB even if it is intended for other consumers (e.g. ATO). The reason is that ETCS may adjust position and speed information in certain cases, and these values used by ATP/ETCS would be different from those used by other consumers.

Current Generic Architecture (WP21/WP22)

The set of baseline documents that can be considered as a common specification for ASTP produced so far in WP21 and WP22 are listed below:

- **D21.1:** Operational needs and system capabilities of an ASTP system (Use Cases), ver. 12 (07/06/2024)

- **D21.2:** System requirements of ASTP system, ver. 05 (07/06/2024)
- **D22.1:** ASTP Report on Common Overall Design and Architecture, ver. 0.6 (15/01/2024)

While D21.1 performs a user needs analysis for train location and proposes constraints for the ASTP constituent, D21.2 formalises the list of requirements (functional, non-functional) resulting from the D21.1 analysis.

The D22.1 first analyses various ASTP demonstrators. This analysis is done from the perspective of the technologies used and perspective of the dependencies on external inputs. The document then proposes a common architecture that describes the interfacing of ASTP with other on-board constituents. The minimum set of internal sensors to be used by ASTP is also defined. The document also proposes several constraints (referred to as assumptions) aimed at ensuring the interoperability of ASTP.

The ASTP architecture in WP22 (D22.1) does not respect the ATO GoA3/4 architecture Figure 2.

The proposal to deal with this misalignment is described in the following list:

- All static data required by ASTP/LOC and originating from the trackside is provided by the on-board repository (REP), i.e. all the Segment Profiles related data describing the route to be used by the train, ... are provided by the REP-OB.
- If any data available within ATP / ETCS-OB module should have been shared with ASTP / LOC module, i.e. historical ETCS odometry-related sensors data, BTM data, CMD data, ..., ASTP module supplier(s) would be free to get those data directly from the ETCS-OB module via an ETCS-OB to ASTP interface or from the PAL through which this data would transit (ETCS-PB / PAL interfaces & PAL to ASTP interfaces)
- According to WP21/22 ASTP/LOC should provide all positioning and kinematic information exclusively via ATP/ETCS-OB. Regardless of the fact that there is no consensus on this within WP21/22, this cannot be achieved by simple mapping to the ATO GoA3/4 architecture.

It is therefore proposed that data / information (position, speed, acceleration, attitude, ...) computed by the ASTP module based on ETCS-related sensors, ATSP-specific sensors and Digital Map / Segment Profiles-related data are provided / broadcasted to relevant consumers (PER, ATO-AV, APM, ...) as expected by the ATO GoA3/4 architecture (see Figure 2).

This leads to the necessity to define an “ASTP to (any) OB-module consuming ASTP data” interface. This interface shall be of broadcast type and therefore common to all OB-module that should require consuming ASTP data.

Applicable Interfaces

The proposed architecture defines interoperable interfaces between ASTP and other onboard constituents. These are:

- ASTP / REP-OB
- ASTP / OB-module consumers
- ASTP / ETCS-OB for ETCS-OB to share odometry-related sensors data
- ASTP / PAL (if option implemented to get ETCS-OB data)

Note : As the alignment and interfacing between ASTP and other systems (consumers of localisation information) is ongoing, using ASTP within this demonstrator requires ad-hoc agreements to interface ASTP (and perform localisation function) and other components of ATO up to GoA4 architecture.

Contributing WP46 Partners

Partners contributing to WP46 are **AZD and INDRA**.

Common baseline for Prototype Development

- SRS ATO up to GoA3/4 v1.1.0 (output of D6.5)
- D22.2 – ASTP Design Report for each specific solution, ver. 0.2 (2024-12-23).

4.3 PERCEPTION MODULE

Generic Perspective

The Perception system is one of the main systems of the autonomous train in GoA3/4 operation. The Perception system is a complex set of sensors, computing units and software that allows the train to perceive and react to the physical environment in real time. The work of the perception system can be divided into successive stages.

1. Data acquisition

The Perception system collects data from the sensors. Sensors can be of different types (e.g., camera, LiDAR, radar, infrared camera, etc.). These sensors can have different locations, such as at the head of the train, inside the train to monitor passengers, on the sides of the train to monitor doors, or on the trackside to monitor risk areas such as platforms, etc.

2. Data processing

The real-time processing of the acquired data aims to ensure the identification of situations that may arise and need to be responded to. These situations are described by use cases developed in Task 5.2.

- Obstacle detection: Perception of the external environment **involves** detecting and recognizing static or dynamic objects of different types that can affect operation (road vehicle on an unprotected level crossing...).
- Signal reading that covers the need for ATO in areas without ERTMS/ETCS.
- Surveillance of locations associated with an increased risk of collision.
- Detection of infrastructure defects and anomalies.

3. Data storage

Storing the acquired data for the possibility of back-checking the behaviour of the autonomous train or as a black box record.

Current Considered Aspects Regarding the Perception

The development of the Perception system will be based primarily on the architecture proposed in Task 6.3.

In Task 6.3, the functions and requirements of the perception system were defined based on the use cases described in Task 5.2. The functions and requirements defined in the SHIFT2RAIL (X2Rail-X and TAURO) projects were used as input in Task 6.3 and new functions were added to cover all functionality required within the use cases from Task 5.2.

Applicable Interfaces

- **C8 Perception to APM (and vice versa)**

- **C62 Localisation to perception**
- **C21 Perception to physical environment**

List of Contributing WP46 Partners

Partners contributing to WP46 are **AZD** and **FAIVELEY**.

Common baseline for Prototype Development

The following table contains the documents that will be taken as a perception system baseline for demonstrator.

- SRS ATO up to GoA3/4 v1.1.0 (output of D6.5).
- Architecture and systems specification for perception system (output of D6.3).

4.4 DIGITAL REGISTER/REPOSITORY

Generic Perspective

The repository groups the communication needs of multiple applications into a single module, facilitating information exchange with trackside systems. This module plays a critical role in ensuring interoperability by standardizing communication between onboard and trackside equipment.

The repository module can be seen as an enhancement of Subset-126, specifically designed to address the requirements of GoA3/4 operations. It implements logical interfaces with trackside equipment, Infrastructure Managers (IM), and Railway Undertakings (RU).

From a broader perspective, the repository module is not merely a communication gateway. It also serves as a centralized hub for aggregating data from various sources, performing consistency checks to ensure reliability. These data sources come with differing constraints, such as timing, safety levels, and volume.

Additionally, the repository executes a universal mechanism based on a list of Segment Profile IDs. This mechanism allows the repository to collect, from a Trackside Digital Register (Transactor), only the data relevant to the current operation, ensuring it always operates with the latest version provided by the Infrastructure Manager. Among other functions, the repository distributes digital maps to various applications, guaranteeing that all data are consistently up-to-date.

The main goal of the Trackside Digital Register system is to establish a centralised static reliable infrastructure data management system to access and operate with reliable static infrastructure data.

Static infrastructure data refers to data that does not change during the validity period of a single version of infrastructure data.

The Digital Register as a complete system consists of trackside (DR-TS) and on-board (DR-OB) subsystems.

The data processed by the Digital Register originate from engineering processes or existing railway databases and are processed according to requirements within the Digital Register.

Current Considered Aspects Regarding REP-OB module

As shown in Figure 2, the Register/REP-OB module should interface with the :

- Trainside Train Transactor to get all the Train & (Train) Mission/Journey(s)-related data from the Train Management System owned / managed by the Railway Undertaker
- Trainside Traffic Transactor to get all the Journey(s)-related data, including the list of Segment Profiles composing the Journey(s), from the Traffic Management System owned /managed by the Infrastructure Manager
- The Digital Register (Transactor) to get all the Segment Profiles-related data as implemented within the Trainside Digital Register and required to be put at the disposal of the OB-modules – see Figure 3 below

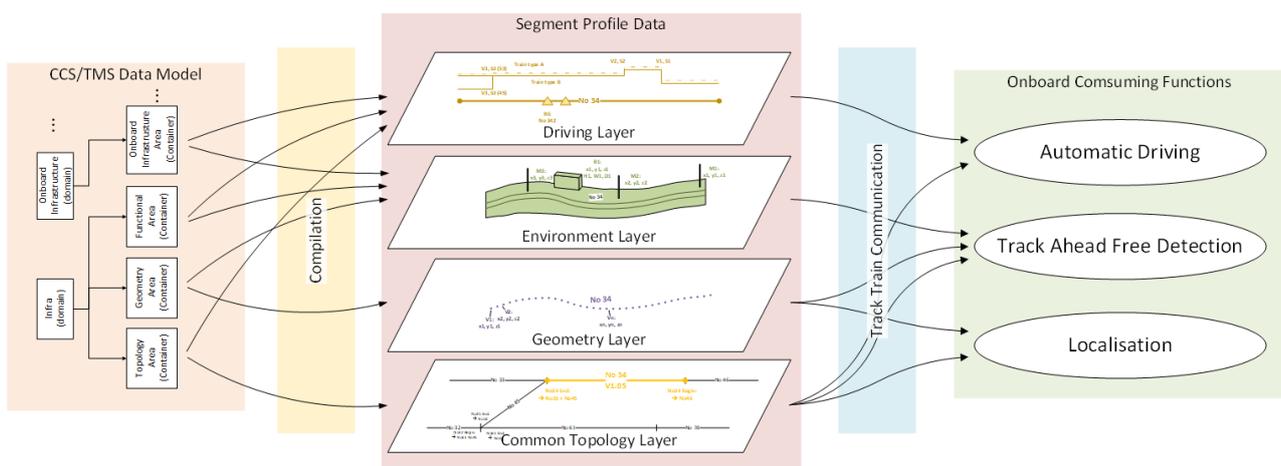


Figure 3: Data Model for Segment Profile Related Data

Thus, the REP-OB module should implement a functional sub-module called Digital Register-OB

As shown in Figure 4, the Digital Register-OB as part of the repository is indeed responsible for importing and standardizing Engineering Input Data, validating and aggregating it, transforming it into system-specific Domain Data, and distributing it to Consuming Systems while ensuring the correct version is active.

It does not handle dynamic Domain Data (e.g., Temporary Speed Restrictions), provide rolling stock data, or acquire data through methods like track recording or aerial surveys.

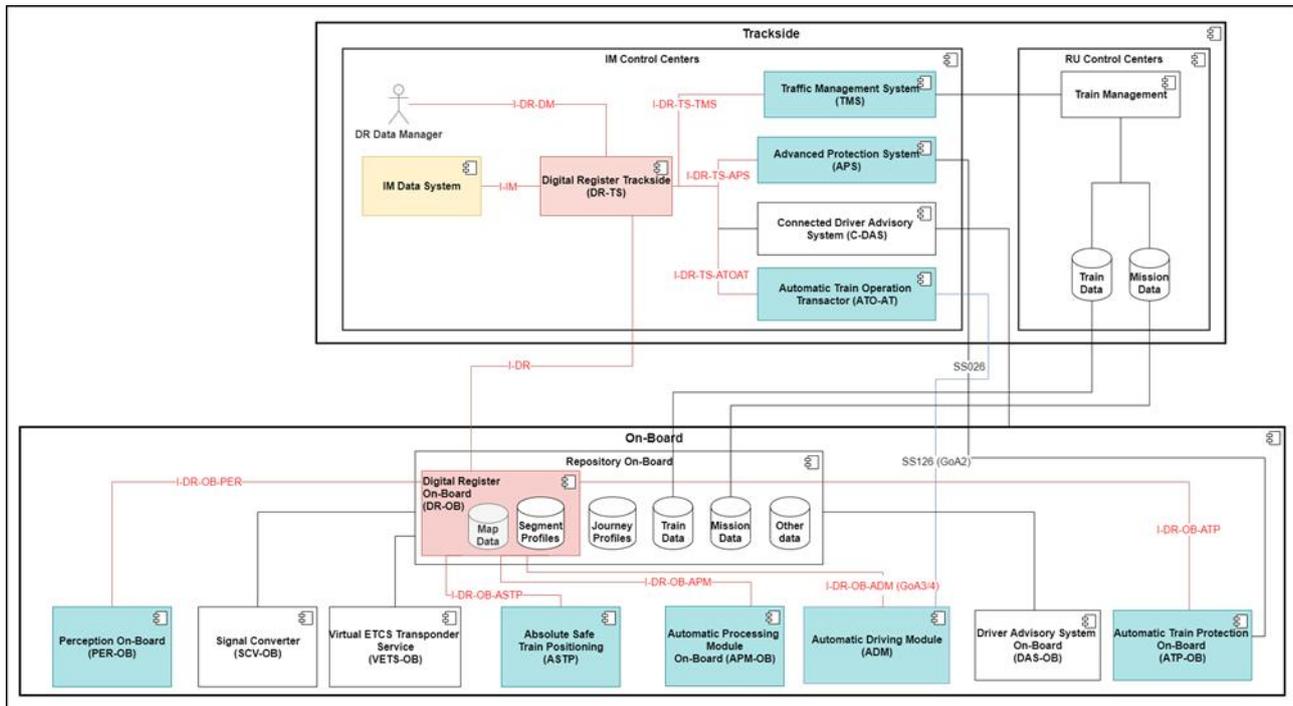


Figure 4: Scope of digital register within repository

The Trackside Digital Register is out of the scope of WP46 demonstrator. It is indeed being developed in the framework R2DATO WP27 and validate within the frame of the WP27.4 demonstrator to which ATSA contributes.

In addition, as explained in section 4, it was decided to let the REP-OB module supplier(s) free to define the way in which the ATO GoA4 data (Train Data, Mission profile, Journey profile, Segment profile, etc.) would be made available to the onboard demonstrator; i.e.

- Storage of TD/OE/DR-related data in the REP-OB module
- Storage of TD/DR-related data in the REP-OB and interface with the OE module to get the OE-related data
- Any other solution that should rely on the setting of a static route prior to any train movement required under a test scenario and that could ensure the availability on board of all the ATO GoA4 TD/OE/DR-related data

It remains that :

- All the Segment Profiles-related data making up the test track will have to be generated by and made available by AZD so that the REPOSITORY-OB can make them available to any on-board modules consuming those data (see Figure 4).
- As explained in section 4, this shall be made according to a solution specific to each REPOSITORY-OB supplier.

- As it is not within the scope of the WP46 demonstrator to comply with the data model currently being defined within WP27, an agreement on the format of the infrastructure / Segment Profiles-related data will have to be reached between REP-OB suppliers
- The REPOSITORY-OB will have to implement all the interfaces listed below so that all the BORD modules have the SP data they need.

Applicable Interfaces

- C5 REP-OB / ETCS-OB - PAL
- C28 REP-OB / APM
- C22 REP-OB / ADM (Subset 126)
- C60 REP-OB / ASTP

List of Contributing WP46 Partners

Partners contributing to WP46 are **AZD** and **ALSTOM**.

Common baseline for Prototype Development

- SRS ATO up to GoA3/4 v1.1.0 (output of D6.5).

4.5 REMOTE CONTROL

Generic Perspective

Remote control is used for remote control of the train, and the remote driver is able to control the train similarly to the on-board driver. There are also several situations where it is appropriate to use remote control.

Remote driving functions in this context refer to functions as a substitute for automation functions or perception functions performed by the system in GoA3/4 (DTO/UTO) operations to drive the train unit. This is mainly intended when GoA4 is not available as well as in case of degraded modes, and/or for specific restricted areas (shunting/depot, transfer from depot to station) without strong constraints on the trackside signalling system where operations are performed at lower speeds.

Currently, two types of remote driving are considered. In the first type, the remote driver will have the full control over the train. In the second type, the remote driver will control only part of the elements, while the rest will be controlled by the ATO.

The use of RC is assumed for classic driving but also for shunting in the perimeter of the station or depot. It follows that the control panel used by the remote driver to control the train can either be a standard console, like the one on the train, or, for example, a tablet.

Current Scope of Remote Control and Link to the Overall Architecture

In Task 6.7, a system boundary was defined for the remote system (Figure 5). With this, the remote driving system consists of two main parts:

1. Remote Control - Trackside (RC-TS):

This includes the components located in the remote control centre or in a mobile one. The RC-TS includes equipment such as track-side elements, the authorization server, and the authorization checker.

2. Remote Control - On-board (RC-OB):

These are the components installed on the train itself. The RC-OB communicates with other on-board systems to enable remote driving.

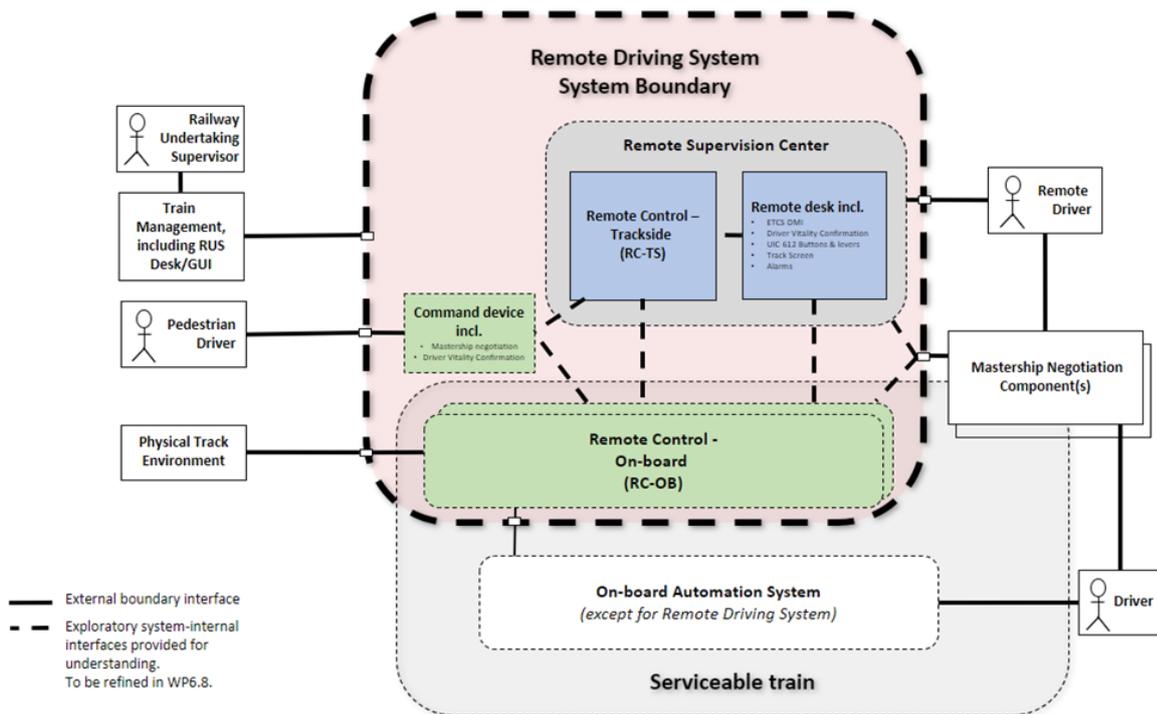


Figure 5: System Boundary of Remote Driving System

Applicable Interfaces

RC-TC – RC-OB

RC-OB – ADM

Note: Remote Control interfaces are not yet fully specified.

List of Contributing WP46 Partners

AZD is the only contributing partner for Remote control.

Common baseline for Prototype Development

In Task 6.7, the functions and requirements of the remote driving system were defined based on the use cases described in Task 5.4. The functions and requirements defined in TAURO projects were used as input in Task 6.7, and new functions were added to cover all functionality required within the use cases from Task 5.2. The following table contains the documents that will be taken as the remote driving system baseline for the demonstrator.

Project	Document	Description
FP2 D2DATO	D5.4 Use-cases for remote driving	Use cases described in Task 5.4
FP2 D2DATO	D6.7 Set of functional and non-functional requirements for remote driving	The functions and requirements defined in T6.7.

5 USE CASES TO BE DEMONSTRATED

Resources for this chapter is “D5.1 Documentation of use cases for automating functions - Annex 4 - Use cases for Automating Functions”.

Demonstrator assumptions in chapters 5.x.3 are filed by Precondition and are modified/enriched according to demo specific conditions.

It is important to note that the work presented in this section 0 has been done before the SRS1.1.0 is available while it has be decided and agreed by all WP46 stakeholders to use the SRS1.1.0 system specification as the only reference input system specifications for WP46 demonstrator.

As a result, the description of the Use Cases as presented below, i.e. the logical components involved, the activity summary and the demonstrator assumptions, does not presume any changes required from the sequence diagrams and intermodular interfaces currently being defined as a result of the strict application of SRS1.1.0, which has been adopted as the sole system reference specification for WP46 UCs.

The sequence diagrams defined for each of the Use Cases shall indeed highly depend on assumptions taken for and agreed on each UC.

5.1 UC5.1-003 **PREPARE TRAIN UNIT FOR A MISSION - CONFIGURE GOA AUTOMATICALLY**

5.1.1 Logical components involved

OAS

TAS (Optional)

5.1.2 Activity summary (from WP5)

After powering on the train, Trackside Automation System provides the Onboard Automation System with all mission and segment profiles needed for the mission.

There are three sources for GoA :

1. Static track plan data (static Segment Profile) – see Figure 3
2. Dynamic information from dynamic Segment Profile from IM (OE).
3. Dynamic information from Mission Profile from RU.

5.1.3 Demonstrator assumptions

Train is in one of the following modes:

- Service Retention mode
- Standby mode
- Energy Saving mode
- Shutdown mode

Train initial state will be Standby mode.

Communication with trackside is very limited as trackside modules are not part of this demo. Therefore: Segment profile(s) (for whole journey), Train data, DM and MP are prepared ahead and prestored in REP. Only JP will be either prestored in Repository or communicated with TS systems according to REP implementer decision.

As explained in section 4, the recourse to Train / Track communication to get the trackside traffic and train-related data, i.e. Mission profile, Journey profile, Segment profiles-related data (see Figure 3) is left to the discretion of the REP-OB module suppliers.

5.2 UC5.1-005 DETERMINE AND SELECT TRAVELLING DIRECTION

5.2.1 Logical components involved

OAS, FMS, RU

5.2.2 Activity summary (from WP5)

A change of the travelling direction can happen in two cases:

- Train preparation.
- A change in running direction requested by Mission Profile.

In both cases, it is necessary to enter the ATP data automatically (see 'UC5.1-006 Enter ATP data automatically').

Select the correct cab:

The change of cab is initiated by the On-board Automation System (OAS) using Mission Profile, Journey Profile and Segment Profile (Digital Map Information). The Serviceable train shall know its last orientation from last journey. Then it can select the correct cab based on the new Journey Profile and Segment Profile (Digital Map Information).

5.2.3 Demonstrator assumptions

Serviceable train is switched on.

OAS fully operational.

TAS fully operational

Train has to recall its orientation and position from last journey. In case the data will not be clearly defined in R2DATO specification, temporary solution will be discussed and chosen by partners of WP46 for demo implementation. The information will be prestored in REP in this case.

5.3 UC5.1-006 ENTER ATP DATA AUTOMATICALLY

5.3.1 Logical components involved

APM, ATP (PAL), REP

5.3.2 Activity summary (from WP5)

A change of the front end can happen in two cases:

- Train preparation.
- A change in running direction requested by Mission Profile.

In both cases, it is necessary to enter the ATP data automatically.

Enter the ATP data:

If the correct cab is selected, or if the TCMS is connected to the waggons by using the Digital Automatic Coupler (DAC) a system can enter the train data in ATP.

The train data is supplied by Fleet Automation System (FAS). OAS should check whether the input data from FAS has conflict with determined train local data. In EMUs this could be done by checking the inauguration data from TCMS. In freight trains it could be done by staff or by using the Digital Automatic Coupler (DAC).

5.3.3 Demonstrator assumptions

- Serviceable train is switched on.
- The On-board Automation System with subsystems like TCMS, ATO and ETCS is fully operational.
- The Trackside Automation System are emulated – data are prestored in REP – see bellow. Only OE data can be provided in some cases from TS to OB.
- The cab of Serviceable train is selected correctly.
- Demonstrator will use only one train possibly in two configurations – testing vehicle itself or testing vehicle with one wagon. So only 2 variants of “fixed” train data will be used.
- Data for train data will be prepared in Repository, no communication with trackside is foreseen as mechanism for dynamic data from trackside to repository is unclear at the moment.
- As the real ETCS will not allow automatic data entry for all data requested, the request for data entry will be sent to PAL, PAL will display the request for data entry on DMI to driver who will emulate ETCS automatic data entry.

5.4 UC5.1-010 REPORT END OF SHIFT/ASSIGNMENT

5.4.1 Logical components involved

ADM, REP, APM

5.4.2 Activity summary (from WP5)

This use case describes the operational scenario of “end of shift/assignment”.

The train arrives at the final destination, reports its end of shift, and sets the train in the mode (or state) specified by the mission profile.

The states of the train in parking includes:

- Train is parking with shutdown mode.
- Train is parking with service retention mode (or stand-by mode).
- Train in parking with energy saving mode.

Other train states are described in use case notes.

5.4.3 Demonstrator assumptions

- The On-board Automation System with subsystems like TCMS, ATO and ETCS are in operation.
- The Mission Profile has defined which state the train should have after the end of shift/assignment, (from, WP5 spec: such as shutdown mode, service retention mode or energy saving mode) – Leave train in ready mode will be used in the demo.
- In all these states the mobile communication is always on to guarantee the train can be waked up at any time. The state “Battery off” is therefore not a valid state for the train at the end of this use case.
- Communication with trackside is emulated as specification of this part is unclear at the moment.

5.5 UC5.1-012 LEAVE TRAIN IN READY MODE

5.5.1 Logical components involved

REP, APM, ADM

5.5.2 Activity summary (from WP5)

Process to take train out of operating mode and into standby/ready mode. In standby/ready mode, the pantographs remain up and continue to provide power to the train.

After 60 minutes of inactivity, the train automatically switches to sleep mode.

5.5.3 Demonstrator assumptions

- The train must be in operating mode/in service mode or in service retention mode (TCMS can emulate the state of “service retention/sleeping mode”)

5.6 UC5.1-014 PERFORM MISSION

5.6.1 Systems involved

all tested TEs: REP, APM, ADM, LOC, ATP

5.6.2 Activity summary (from WP5)

This use case describes the process of carrying out a mission that has been previously defined. This is a general umbrella use case that describes the assignment of mission segments (journeys and perform mission movement as well as stopping segments and tasks to be conducted if train is stopped). The mission is considered complete when all the segments have been completed. If necessary (due to disruptions, emergencies etc.), a mission can be modified (if conditions for modifying the current mission are met) or aborted before all segments have been completed.

5.6.3 Demonstrator assumptions

- Mission is defined (stop segments and move segments*).
- Mission is ready for execution.
- Current time \geq start time of first mission segment.
- Communication with trackside will be limited as specification of this part is unclear at the time. Therefore Mission (provided by RUS via FAS) will be prestored at REP.

Type of mission in this demonstration is limited for journey type

5.7 UC5.1-019 STOP AT PLATFORM FOR PASSENGER SERVICE

5.7.1 Systems involved

ADM, APM, PIS

5.7.2 Activity summary (from WP5)

The train approaches the scheduled passenger exchange position, where it stops precisely. Passenger doors are prepared for opening and passengers are informed in order to achieve an efficient passenger exchange.

5.7.3 Demonstrator assumptions

Train approaches platform. Braking effort is set according to track conditions.

There will be two modes for testing: without additional wagoon and with one.

In case of vehicle itself – information for passengers will be displayed at PC monitor in testing vehicle

In case of additional wagoon information will be displayed at PIS display on additional wagoon.
Doors are unlocked, to be opened manually.

5.8 UC5.1-070 APPLY TEMPORARY SPEED RESTRICTIONS FOR HIGH WINDS OR (APPROACHING AN UNPROTECTED LEVEL-CROSSING)

5.8.1 Logical components involved

5.8.2 Activity summary (from WP5)

This Use Case describes the needs and possible solutions for applying temporary speed restrictions owing to high winds and avoiding some incidents. The incidents that can occur are as follows: swaying overhead wires, derailment risk, or instability of sensitive wagons.

High winds TSRs are only applicable in areas where high-speed (HS) trains operate. Therefore, on lines equipped with Class B or L1 systems, where the speed limit is up to 200 km/h, they have no relevance or applicability.

5.8.3 Demonstrator assumptions

Train is performing the actual mission until a high wind event is detected.

Operations Manager has inputs from different sources for weather conditions such as sensors, staff reports, and weather forecasts.

OM must be involved with the communication subsystem to monitor the crosswind detector system to report the status of the system and speed restrictions.

5.9 UC5.2-008 RAIL ADHESION ESTIMATION USING PERCEPTION

5.9.1 Logical components involved

5.9.2 Activity summary (from WP5)

- 1) Sensor data of are collected and processed.
- 2) AI model performs the adhesion detection over prepared sensor data and further relevant features.
- 3) The current adhesion value shall be used to tune the current train braking curve
- 4) The current adhesion value shall be used by the ATO

5.9.3 Demonstrator assumptions

5.10 UC5.2-019 REACT TO OBSTACLE

5.10.1 Logical components involved

5.10.2 Activity summary (from WP5)

This Use Case details the actions to be taken in case of obstacle detection.

When an obstacle is detected, APM sends an obstacle EOA to ETCS via C16 and informs IPM-ISM (delay in operation). When the train is stopped, the feedback loop with the trackside permits to identify the problem and to restart when the problem is solved (false alarm for example). In case of obstacle EOA, if the train is stopped without trip, onboard ETCS will request a new MA to Train Control when the obstacle EOA is removed by APM. This removal can be done automatically if the obstacle has disappeared or via a confirmation of IPM-ISM through C19 interface if there is a doubt. If the obstacle is still present, the track must be closed until recovery. The case of an obstacle that has disappeared from Perception but is still present under the train must be considered. In case of trip, APM is safety related and can be used to acknowledge the transition to Post Trip mode. This authorisation should be given through C19 interface. Once in PT mode, onboard ETCS will request a new MA. The level crossing is a specific case. In France and Germany for example, the level crossing will be protected in time (20 to 30s) and thus, a driver is not supposed to brake while observing cars crossing a level crossing before the barriers are closed (it is different in station where the relevant level crossing barriers are closed before the train departure). In GoA3/4, APM must filter PER information (potential obstacle) according to the context (type of obstacle and level crossing area). Depending on country and location, a level crossing can be completed with a monitoring system that will warn in case a car is blocked on the track (track detection devices provide only clear information). PER can be used for the same purpose when there is no such trackside monitoring system.

5.10.3 Demonstrator assumptions

5.11 UC5.2-0027 SPEED RESTRICTION DUE TO WEATHER CONDITIONS

5.11.1 Systems involved

PER, APM, ADM

5.11.2 Activity summary (from WP5)

(Speed restriction due to weather conditions (x2Rail4-063))

5.11.3 Demonstrator assumptions

The restriction is active only in special driving modes like OS, and/or because of unprotected level crossing approach.

Weather condition in our UC is determined by PER (fog, less visibility)

5.12 UC5.2-030 WANDERING LIVESTOCK, ANIMALS OR OTHER OBJECTS ON OR CLOSE TO THE TRACKS

5.12.1 Logical components involved

PER, ADM, APM, ATP

5.12.2 Activity summary (from WP5)

This use case details the actions to be taken in case of objects are situated closely along or on the ego track**.

The presence of such objects can also be on tracks in vicinity of the ego track of the train itself. The PER system must be able to detect the present of one or more objects, and estimate their location, volume and if possible, a bounding box if there are several objects or a flock. Furthermore, PER may classify the objects into types.

In addition, the PER should be able to exclude the presence of mobile objects where there are natural or man-made structures that will prevent the livestock or animals from entering or approaching the ego track (fences, walls, canal, etc.). Such information should be available from the Infrastructure Management System.

PER needs to distinguish the objects into obstacles, which may pose a risk and be safety critical.

**Ego track – the track occupied by the train or already chosen and set for the train (the term is used to distinguish the track in a path of the train from adjacent track or other tracks in the vicinity).

5.12.3 Demonstrator assumptions

1. Train is in operational mode GoA3/4.
2. Train is operating in a mission.
3. Train is moving.
4. PER module is monitoring the area of interest.
5. Objects are in vicinity of the train.

5.13 UC5.2-0031 ACTIVATE HORN

5.13.1 Systems involved

REP (DM), APM, TCMS

5.13.2 Activity summary (from WP5)

This Use Case details the conditions for horn activation.

Horn shall be activated by APM at predefined locations or following a dynamic event.

5.13.3 Demonstrator assumptions

Horn activation will be based on location (DM information) or human on track detection / human/animal near track detection.

5.14 UC5.2-0036 LONG RANGE DETECTION AND RECOGNITION OF SIGNALS APPLICABLE TO TRAIN ROUTE

5.14.1 Systems involved

OAS, TAS, FSM

5.14.2 Activity summary (from WP5)

This use case describes the train driving over a CCS Class-B system with the additional lateral signalling information.

The additional lateral signalling information can be provided:

- by perception systems which can interpret the signals on the line side
- or it could be done also (or in addition) with data from a SIL4 interlocking which can be transmitted in a dynamic layer “signal aspects” in Digital Map.

Main Goal : GoA 3 & 4 train can safely run over Lineside signaling system

5.14.3 Demonstrator assumptions

- The train is driving over Lineside signaling system.
- Train is equipped with line side signalling detection.
- Track is equipped with line side signals.
- OAS (train protection) is in a mode in which it can drive with lateral signals (ETCS L1 LS or a national ATP).
- The train has an own reliable, accurate (and safe) localization.
- TAS includes Digital Map and Digital Map contains all necessary information about the signals.
- OAS (PER) is monitoring the ego track zone + buffer zones

5.15 UC5.2-0041 EVALUATING EGO TRACK

5.15.1 Systems involved

PER, REP, ASTP

5.15.2 Activity summary (from WP5)

Based on perception (Camera, filtering etc.) the system can define the ego track within the visibility range.

Note: This use case applies in different scenarios: Combination of weather (Fog, Rain, direct sunlight etc.), location (e.g. different tunnels, free Track) and operational procedures.

5.15.3 Demonstrator assumptions

No turnouts involved, only simple track will be tested

Information from PER and from DM/ASTP may be evaluated.

5.16 UC5.2-0059 TRAIN STOPS BY SIGNALING

5.16.1 Systems involved

ATP, ADM

5.16.2 Activity summary (from WP5)

(TAURO WP 4 - Task 1 - Deliverable 4.2 Appendix A)

5.16.3 Demonstrator assumptions

ATP will send MA up to signal pole and send the message to ADM. ADM will stop. After MA prolongation ADM restart train movement.

5.17 UC5.4-009 LOG-IN ON A REGISTERED STANDBY TRAIN

5.17.1 Systems involved

RC, APM, ADM

5.17.2 Activity summary (from WP5)

After completion of this scenario, RD is monitoring the train. Among others, he/she has the capability to request control of the train.

RD logs on a train initially registered and in standby. He / she is granted a monitoring access: display of train state; no control.

5.17.3 Demonstrator assumptions

from WP5: The train runs in state: RSC registration: registered Level of operations: standby User registration (RD): Observing.

5.18 UC5.4-010 TAKE CONTROL OF A MONITORED STANDBY TRAIN

5.18.1 Systems involved

RC, APM, ADM

5.18.2 Activity summary (from WP5)

After completion of this scenario, RD1 has control of this standby train. Among others he/she can wake-up the train – switch it to operative.

RD1 is monitoring a train. He/she requests its control. On success, he/she has gained control of the train.

5.18.3 Demonstrator assumptions

from WP5 The train runs in state: RSC registration: registered Level of operations: standby RD1 is monitoring the train, not yet controlling it. RODR2 may be controlling it already

5.19 UC5.4-015 DEMOTE A REMOTE DRIVER FROM CONTROLLING TO MONITORING

5.19.1 Systems involved

5.19.2 Activity summary (from WP5)

RD1 ends Monitoring the train. RD1 is Controlling his/her train. He/she wants to get back to Monitoring.

5.19.3 Demonstrator assumptions

5.20 UC5.4-016 STOP MONITORING A TRAIN BY A REMOTE DRIVER

5.20.1 Systems involved

5.20.2 Activity summary (from WP5)

RD1 ends observing the train. RD1 is Monitoring his/her train. He/she wants to stop this Monitoring.

5.20.3 Demonstrator assumptions

5.21 UC5.4-024 PERFORM ROUTINE DRIVING BY REMOTE DRIVER

5.21.1 Systems involved

5.21.2 Activity summary (from WP5)

The main goal of this use case is to ensure seamless train control by a Remote Driver.

This use case details remote train control operation by a person in the control centre. The Remote Driver should be able to drive the train remotely as if on the train itself. It is crucial that there is working communication between the train and the control centre and that the Remote Driver has working sensors based on which the Remote Driver drives and also access to warning sound devices.

5.21.3 Demonstrator assumptions

5.22 UC5.4-029 SHUNT IN CENTRALIZED AREA

5.22.1 Systems involved

5.22.2 Activity summary (from WP5)

The train can be driven (shunting) by RD from some RSC while the train is located inside a centralized area.

Driving the train in a centralized area (shunting). The train is driven remotely by a Remote Driver. Maximum speed 30 km/h.

5.22.3 Demonstrator assumptions

Vehicle is operated in a centralized area with some RSC. Remote operation is an independent system (from ATO)RD is monitoring the train, or has control over the vehicle. The vehicle is at standstill.

6 TESTING SCENARIO

To add: List of high-level test scenarios

Each testing scenario should validate at least one requirement related to selected Use Case.

UC Steps used in the Methodology/Steps are related to respective deliverables of R2DATO`s WP5, WP6, dealing with use-case definitions as well as definition of respective requirements. According to here presented high level Test scenarios, sequential diagrams and inter-module interfaces will be developed (as part of T46.3). These sequential diagrams supported by defined inter-module interfaces will fully describe the system behaviour and testing conditions.

Testing scenario table has the following sections, with the meaning as described below:

1. Preconditions

Preconditions are set of initial conditions that are necessary for the following testing scenario to be tested. These can consist of both physical components and functions required, as well as processes, statuses or situations that are needed to exist in the moment of performing (or immediately before) the test itself. Examples of preconditions might be needed TE functional, specific GoA in the moment of test performing or “status of “standby mode”.

2. Actors

Actors are all entities (systems, humans, items) that are interacting with or co-realising given functionality. It shall be assumed that actor is an external entity to our analysed system itself, and should be someone or something interacting with analysed/tested system during Use Case realisation.

3. Goals

The goal of the testing scenario shall be in line with developed Use Cases . In a case that only limited version of UC is tested (due to practical feasibility, site, demo limitations, gaps in specifications, etc.), only relevant goals to be achieved by test scenario shall be mentioned.

4. Expected Outcomes

Description of the expected behaviour of the autonomous train as a result of correctly performed Use Case. They could be listed as criteria of success (how to confirm test has passed) but could be also description of correct behaviour of system during the test or final status after positive test outcome.

5. Methodology

Description of the test realisation. How to initialize the test, what is the behaviour during the test, what should be checked and when the test is finished. If possible and suitable it should also define how to evaluate test result.

6. UC – Requirements covered

List of the requirements expected to be covered by the UC.

In case requirements from WP6 are covered by SRS specifications, WP6 requirements will be used for validation. If covered partially, or in case of deviations, SRS requirements will be used. These requirement evaluation will be used as added value from our demonstrator as a feedback to WP6.

It is important to note that the work presented in this section 6 has been done before the SRS1.1.0 is available while it has be decided and agreed by all WP46 stakeholders to use the SRS1.1.0 system specification as the only reference input system specifications for WP46 demonstrator.

As a result, the description of the testing scenario as presented below does not presume any changes required from the sequence diagrams and intermodular interfaces currently being defined as a result of the strict application of SRS1.1.0, which has been adopted as the sole system reference specification for WP46 UCs.

6.1 TS001 – UC5.1-003 PREPARE TRAIN UNIT FOR A MISSION - CONFIGURE GoA AUTOMATICALLY

<p>1 Preconditions</p> <p>Train is in Standby mode modes:</p> <p>Segment profile (for whole journey), Train data, Digital map and Mission Profile are stored and ready in Repository</p> <p>Journey profile is ready at ATO TS.</p> <p>Train number is known</p> <p>All OAS modules are functional.</p>
<p>2 Actors</p> <p>Tested enablers: TE1 - Automating functions</p> <p>Other actors: ETCS (PAL), REP - Repository</p>
<p>3 Goals</p> <p>To validate requirements related to UC “UC5.1-003 Prepare train unit for a mission – Configure GoA automatically”</p>
<p>4 Expected outcomes</p> <p>REP has data necessary for train run (MP, TD, DM, JP) and provides the data to relevant modules.</p> <p>Train is set to GoA4 state and ready for driverless journey.</p>
<p>5 Methodology Incl. Steps</p> <p>UC5.1-003 Step 1, 2, 3, 4, 5, 6, 7, 8, 9, 12.1, 12.1.1, 13, 13.1:</p>

These actions are not part of the demo (systems outside tested environment). Data (MP, TD, DM/segments) are prepared and stored in Repository. APM requests the Mission profile from REP. REP provides the Mission profile to APM. Mission GoA is GoA4. APM requests the Train data from REP. REP provides the Train data to APM.

UC5.1-003 Step 10: APM requests from REP to establish the communication with ATO TS. Other communication with TS is not part of this demo.

UC5.1-003 Step 11: APM extracts Train Running Number from MP and request Journey Profiles (JP) and the Digital Map (DM) from REP. REP requests JP from ATO TS

UC5.1-003 Step 12: REP provides JP and DM including SP to APM and JP to ADM

UC5.1-003 Step 14: APM sets the GoA level GoA4 according to the profiles it has received and the available on-board GoA level.

6 UC/Req covered

Req not part of the demonstrator WP46:

- T6.1.0371
- T6.1.0372
- T6.1.0373
- T6.1.0374
- T6.1.0375
- T6.1.0376
- T6.1.0377
- T6.1.0378
- T6.1.0379
- T6.1.0380
- T6.1.0381
- T6.1.0387
- T6.1.0388
- T6.1.0389
- T6.1.0390

Req validated partially:

Optional – up to partner decision: T6.1.0382: The ATO up to GoA4 onboard shall establish communication with ATO up to GoA4 trackside after awakening for obtaining Journey Profiles and Digital Map data. Not part of this demo (communication to TS not defined at the time) Only Journey profile on GoA2 level communication will be use during the demo

Covered by SRS: (SS-125 TD-1.1) Train data shall be reliable. Provide Train Protection parameters (REP) shall use these data and TCMS/DAC information to build safety related data.

See Step 10

Req validated:

Optional – up to partner decision: T6.1.0383: The ATO up to GoA4 onboard shall request from ATO up to GoA4 trackside a Journey Profile based on the Train Reference ID provided in the Mission Profile and the train location.

Covered by SRS:

See Step 11

Optional – up to partner decision: T6.1.0384: The ATO up to GoA4 onboard shall request from ATO up to GoA4 trackside segment Profiles referenced in the Journey Profile.

In case partner will communicate with (GoA2) ATO TS will be validated as WP6 requirements is covered by SRS.

See Step 11

Optional – up to partner decision: T6.1.0385: The ATO up to GoA4 Trackside shall provide Journey Profile upon request from ATO up to GoA4 Onboard based on the Train Reference ID and the train location.

Covered by SRS: (SS-125 10.1.7.9) Any “valid” JP sent by ATO-TS shall include at least all information to reach one TP.

(SS-125 10.1.7.13) A JP shall include only the TPs not yet passed or departed by the train (see §7.7.1.7).

(SS-125 10.1.7.15) The ATO-TS shall not send a JP for which there is no existing SP at the ATO-TS level.

See Step 12

Optional – up to partner decision: T6.1.0386: The ATO up to GoA4 Trackside shall provide Segment Profile upon request from ATO up to GoA4 Onboard based on the Segment ID.

Covered by SRS.

See Step 12

T6.1.0391: The ATO up to GoA4 onboard start the mission according to the highest level of grade of automation possible based on the data received from trackside and availability onboard.

Covered by SRS:

See Step 14

6.2 TS002 – UC5.1-005 DETERMINE AND SELECT TRAVELLING DIRECTION

1 Preconditions
2 Actors Tested enablers: TE1 - Automating functions Other actors: OAS, FMS, RU (railway undertaking)
3 Goals To validate requirements related to UC “UC5.1-005 Determine and select travelling direction” As the requirements from WP6 deviates from requirements from SRS 1.1.0b the SRS REQs will be used to validate.
4 Expected outcomes The change of cab is initiated by the On-board Automation System (OAS) using Mission Profile, Journey Profile and Segment Profile (Digital Map Information). The Serviceable train shall know its last orientation from last journey. Then it can select the correct cab based on the new Journey Profile and Segment Profile (Digital Map Information).
5 Methodology Incl. Steps UC5.1-003 Step 1, 2: These actions are not part of the demo UC5.1-003 Step 1.1: OAS executes the mission profile. The mission profile contains a task “change cab” or “set train into service”. The ATO up to GoA4 Onboard shall activate the virtual cab as determined in the mission profile. UC5.1-003 Step 1.2: OAS executes the mission profile. The mission profile contains a task “change cab” or “set train into service”. The ATO up to GoA4 Trackside shall determine the cab and the physical train unit ID of a train consist, based on the last position report of the train, and generate a specific mission for the respective ATO up to GoA4 Onboard system. UC5.1-003 Step 2: OAS determines the actual CAB by using Journey Profile, Segment Profile, Digital Map data, ETCS data, possible other data inputs such as physical sensors, data from previous journey. If not, OAS informs Fleet Automation System and TAS (Outcome 2).
6 UC/Req covered Req not part of the demonstrator WP46: T6.1.0711 T6.1.0712

Req validated:

T6.1.0432: The ATO up to GoA4 Onboard shall activate the virtual cab as determined in the mission profile

Deviating from SRS – WP6 Req will not be validated, instead the following SRS requirements are to be validated

-> (APM-1.1) APM shall activate the cab at the front end of the train unit.

(APM-1.3) This function, active for the master consist (defined by MP), shall compare the train orientation currently reported by ETCS (variable Q_DIR_LRBG) with the one derived from the Journey Profile (variable Q_SP_DIR) and relevant balise groups (variable NID_BG) from associated Segment Profiles at each start of mission. If the result of this comparison gives the same orientation, there is no change of train orientation and APM shall select the virtual cab corresponding to the last active cab reported by Train Protection (cab reference). If the result of this comparison gives a different orientation, there is a change of train orientation and APM shall select the opposite virtual cab waiting for the confirmation of TCMS (variable train configuration).

See Step 1.1

T6.1.0431: The ATO up to GoA4 Trackside shall determine the cab and the physical train unit ID of a train consist, based on the last position report of the train, and generate a specific mission for the respective ATO up to GoA4 Onboard system.

Deviating from SRS, SRS requirements to be validated:

-> MD-1.1 GoA3/4 exported constraint: MP and JPs shall always be consistent.

-> (MD-1.3) GoA3/4 exported constraint: In GoA3/4 operation, Mission Data (MD) logical component shall check MP consistency in respect to e.g. its structure before sending MP to REP. Refer to Appendix A (SRS) for the complete structure of MP packet and other packets related to MP.

See Step 1.2

T6.1.0433: The ATO up to GoA4 Onboard shall check if the intended movement direction as defined in the Journey Profile matches with train orientation and shall inform ATO up to GoA4 Trackside in case of mismatch.

Deviating from SRS – WP6 Req will not be validated, instead the following SRS requirements are to be validated

-> (APM-8.2) APM shall determine whether the consist is master or slave from the Mission Profile.

See Step 2

6.3 TS003 – UC5.1-006 ENTER AUTOMATICALLY ATP DATA

<p>1 Preconditions</p> <p>Cab is activated</p> <p>Train data are pre-stored in REP</p>
<p>2 Actors</p> <p>Tested enablers: TE1 - Automating functions</p> <p>Other actors: APM, ATP (PAL), REP</p>
<p>3 Goals</p> <p>To validate requirements related to UC “UC5.1-006 Enter automatically ATP data”</p>
<p>4 Expected outcomes</p> <p>The train data is supplied by Fleet Automation System (FAS). OAS should check whether the input data from FAS has conflict with determined train local data.</p>
<p>5 Methodology Incl. Steps</p> <p>UC5.1-006 Step 0, 1, 4, 8: These actions are not part of the demo</p> <p>UC5.1-006 Step 7: OAS executes activation confirmation. If the activation fails, OAS informs Fleet Automation System and inform TAS when necessary (Outcome 2).</p>
<p>6 UC/Req covered</p> <p>Req not part of the demonstrator WP46:</p> <p>T6.1.0441</p> <p>T6.1.0442</p> <p>T6.1.0443</p> <p>T6.1.0444</p> <p>T6.1.0445</p> <p>T6.1.0447</p> <p>Req validated:</p> <p>T6.1.0446: After the Train Data have been validated, the ATO up to GoA4 Onboard shall enter and confirm them into the ATP Onboard.</p> <p>Is covered by SRS</p> <p><i>See Step 7</i></p>

6.4 TS004 – UC5.1-010 REPORT END OF SHIFT OR ASSIGNMENT

1 Preconditions
2 Actors Tested enablers: TE1 - Automating functions Other actors: ADM, REP, APM
3 Goals To validate requirements related to UC “UC5.1-010 Report end of shift/assignment”
4 Expected outcomes The train arrives at the final destination, reports its end of shift, and sets the train in the mode (or state) specified by the mission profile.
5 Methodology Incl. Steps UC5.1-010 Step 3.1, 4.1, 5: These actions are not part of the demo UC5.1-010 Step 1: OAS detects and confirms whether the Serviceable train has reached the final stopping point. UC5.1-010 Step 2: OAS informs TAS that the Serviceable train is at End of Journey (if Serviceable train has reached the final stopping point). UC5.1-010 Step 3: OAS sends “end of shift/assignment” message to TAS. UC5.1-010 Step 4: OAS sets the train in the state which is demanded by mission profile.
6 UC/Req covered Req not part of the demonstrator WP46: T6.1.0554 T6.1.0556 T6.1.0557 Req validated: T6.1.0551: The ATO up to GoA4 Onboard shall detect whether the final stopping point marked in Journey Profile as End-of-Journey is reached. Will not be validated as only Partially covered by SRS and no explicit REQ displayed in SRS <i>See Step 1</i> T6.1.0552: The ATO up to GoA4 Onboard shall report that the final stopping point has been reached to the ATO up to GoA4 Trackside. Is covered by SRS:

See Step 2

T6.1.0553: The ATO up to GoA4 Onboard shall report that the "end of shift/assignment" is reached to the ATO up to GoA4 Tracksides.

Covered by SRS:

See Step 3

T6.1.0555: The ATO up to GoA4 Onboard shall request a train state as defined in the Mission Profile to the Rolling Stock Interfaces.

Covered by SRS: (APM-10.5) APM shall report current mission status (on-going task number, mission terminated) and task status when a task is rejected (task rejected) or not done within the planned time slot (task delay warning).

See Step 4

6.5 TS005 – UC5.1-012 LEAVE TRAIN IN READY MODE

1 Preconditions

Train must be in operating mode.

Train reached end of journey.

2 Actors

Tested enablers: TE1 - Automating functions

Other actors: REP, APM, ADM

3 Goals

To validate requirements related to UC "UC5.1-012 Leave train in ready mode"

4 Expected outcomes

Process to take train out of operating mode and into standby/ready mode. In standby/ready mode, the pantographs remain up and continue to provide power to the train.

5 Methodology Incl. Steps

UC5.1-012 Step 5: These actions are not part of the demo

UC5.1-012 Step 1: OAS: activate parking brake.

The ATO up to GoA4 Onboard shall command to apply parking brake to Rolling Stock Interfaces once the train reached the final destination position and when requested by the mission profile.

UC5.1-012 Step 2: OAS: set traction/brake command to 0.

The ATO up to GoA4 Onboard shall set traction/brake command to Rolling Stock Interfaces to zero once parking brake was applied.

UC5.1-012 Step 3: OAS: deactivate virtual cab.

The ATO up to GoA4 Onboard shall command 'service retention mode' to Rolling Stock Interfaces before deactivating the virtual cab when train shall be stabled.

The ATO up to GoA4 Onboard shall deactivate the virtual cab, when the train shall be stabled and parking brakes are applied and train mode was set according to mission profile.

UC5.1-012 Step 4: OAS: set train to 'standby' mode. (UIC612-1).

The Rolling Stock Interfaces shall maintain current operational status of equipment, when all cabs are deactivated and 'service retention mode' was requested.

6 UC/Req covered

Req not part of the demonstrator WP46:

T6.1.0601

T6.1.0607

Req validated:

T6.1.0602: The ATO up to GoA4 Onboard shall command to apply parking brake to Rolling Stock Interfaces once the train reached the final destination position and when requested by the mission profile.

Will not be validates as WP6 Requirement is only Partially covered by SRS, no explicit REQ in SRS

See Step 1

T6.1.0603: The ATO up to GoA4 Onboard shall set traction/brake command to Rolling Stock Interfaces to zero once parking brake was applied.

Covered by SRS.

See Step 2

T6.1.0604: The ATO up to GoA4 Onboard shall command 'service retention mode' to Rolling Stock Interfaces before deactivating the virtual cab when train shall be stabled.

Covered by SRS:

See Step 3

T6.1.0605: The ATO up to GoA4 Onboard shall deactivate the virtual cab, when the train shall be stabled and parking brakes are applied and train mode was set according to mission profile.

Covered by SRS.

See Step 3

T6.1.0606: The Rolling Stock Interfaces shall maintain current operational status of equipment, when all cabs are deactivated and 'service retention mode' was requested.

Will not be validates as WP6 Requirement is only Partially covered by SRS, no explicit REQ in SRS

See Step 4

6.6 TS006 – UC5.1-014 PERFORM MISSION

1 Preconditions

2 Actors

Tested enablers: TE1 - Automating functions

Other actors: REP, APM, ADM, LOC, ATP

3 Goals

To validate requirements related to UC “UC5.1-014 Perform Mission” - task provide journey to be tested

4 Expected outcomes

The mission is considered complete when all the segments have been completed. If necessary (due to disruptions, emergencies etc.), a mission can be modified (if conditions for modifying the current mission are met) or aborted before all segments have been completed.

5 Methodology Incl. Steps

UC5.1-014 Step 3, 4, 4.1, 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.2, 4.3, 4.4: These actions are not part of the demo

UC5.1-014 Step 1: OAS starts the mission.

UC5.1-014 Step 2: OAS sets the execution state for one mission segment* when timing point is reached (or starts stopping mission segments if there is no conflict with the scheduled movement segments).

UC5.1-014 Step 3: OAS or Relevant Actor** performs mission segment. (mission is journey)

**Relevant actor here refers to the actor that a task was assigned to. This could be depending on the nature of the task maintenance personnel, service personnel or even a driver (if the mission segment involves for instance GoA1/2 segments).

UC5.1-014 Step 5: OAS observes the mission execution state and registers that mission was completed.

UC5.1-014 Step 6: Mission is completed.

6 UC/Req covered

Req not part of the demonstrator WP46:

- T6.1.0634
- T6.1.0635
- T6.1.0636
- T6.1.0637
- T6.1.0638
- T6.1.0639
- T6.1.0640
- T6.1.0641
- T6.1.0642
- T6.1.0643
- T6.1.0644
- T6.1.0645
- T6.1.0646
- T6.1.0648

Req validated:

T6.1.0631: After the ATO up to GoA4 Onboard has received a Mission Profile from the ATO up to GoA4 trackside, it shall execute the related tasks and request related journey profiles for execution.

Covered by SRS.

See Step 1

T6.1.0632: The ATO up to GoA4 Onboard shall report the execution state of each task and each journey profile to the ATO up to GoA4 Trackside.

Covered by SRS.

See Step 2

T6.1.0633: The ATO up to GoA4 Onboard shall execute a task or journey profile, when it is assigned to it.

WP6 requirement will not be validated because it is only Partially covered by SRS.

Instead SRS requirements will be validated:

(APM-10.1) A change of mission shall only be required in particular circumstances (train degraded performance after a failure for example). If the train is at standstill, APM shall always authorize a modification of mission. If the train is moving, APM shall authorize the modification of mission only if the mission modification is not related to the current task, otherwise MP shall be rejected.

See Step 3

T6.1.0647: The ATO up to GoA4 Onboard shall supervise the execution tasks and journey profiles regarding the duration to be completed or regarding a time out.

Covered by SRS.

See Step 5

6.7 TS007 – UC5.1-019 STOP AT PLATFORM FOR PASSENGER SERVICE ANALYSIS

1 Preconditions

Train approaches platform.

Braking effort is set according to track conditions.

2 Actors

Tested enablers: TE1 - Automating functions

Other actors: ADM, APM, PIS

3 Goals

To validate requirements related to UC “UC5.1-019 Stop at platform for passenger service”

4 Expected outcomes

The train approaches the scheduled passenger exchange position, where it stops precisely. Passenger doors are prepared for opening.

5 Methodology Incl. Steps

UC5.1-019 Step 1, 2, 4.1, 4.2, 4.3, 4.4: These actions are not part of the demo

UC5.1-019 Step 3: OAS: Brake train according to set braking performance.

UC5.1-019 Step 4: OAS: Stop train precisely (if within door opening authorization window).

UC5.1-019 Step 5: OAS: Apply holding brake and authorize passenger door opening at standstill.

6 UC/Req covered

Req not part of the demonstrator WP46:

T6.1.0711

T6.1.0712

T6.1.0715

T6.1.0716

(optional up to partner decision) T6.1.0717

T6.1.0719

T6.1.0720

T6.1.0721
T6.1.0722
T6.1.0723
T6.1.0724
T6.1.0725
T6.1.0726
T6.1.0727
T6.1.0728
T6.1.0729
T6.1.0730

Req validated:

T6.1.0713: The ATO up to GoA4 Onboard shall brake the train according to the applicable braking performance as necessary to precisely stop according to time and stopping position of a station as defined in the Journey Profile.

Covered by SRS

See Step 3

T6.1.0714: The ATO up to GoA4 Onboard shall stop the train at the selected operational stopping point within tolerances.

Covered by SRS.

See Step 4

T6.1.0731: When train has stopped at the operational stopping point within the tolerances the ATO up to GoA4 Onboard shall apply the holding brake and release passenger doors at standstill.

Covered by SRS.

See Step 5

T6.1.0732: Traction and brake control

Covered by SRS.

See Step 5

6.8 TS008 – UC5.1-070.2 TEMPORARY SPEED RESTRICTION FOR LEVEL CROSSING

<p>1 Preconditions</p>
<p>2 Actors</p> <p>Tested enablers: TE1 - Automating functions, Other actors: TAS, OAS, ATO</p>
<p>3 Goals</p> <p>To validate requirements related to UC “UC5.1-070.2 Temporary Speed Restriction for Level crossing” according to SRS specification</p>
<p>4 Expected outcomes</p> <p>Temporary speed restriction for level crossing is applied.</p>
<p>5 Methodology Incl. Steps</p> <p>UC5.1-070.2 Step 1, 2, 2.1, 3: These actions are not part of the demo</p> <p>UC5.1-070.2 Step 2.2: TAS (Train Control) receives the TSR command and transmits the TSR to OAS (Train Protection).</p> <p>UC5.1-070.2 Step 2.3: OAS (Train Protection) monitors the speed of the train according to the new TSR received and the maximum wind speed able to withstand due to the particular characteristics of the train.</p> <p>UC5.1-070.2 Step 2.4: The ATP-OB shall recalculate the speed profile according to the information provided by ATP-OB.</p> <p>UC5.1-070.2 Step 3.1: OAS (REP) obtains the Journey Profile information from TAS.</p>
<p>6 UC/Req covered</p> <p>Req not part of the demonstrator WP46:</p> <p>T6.1.1561 T6.1.1562 T6.1.1563 T6.1.1564 T6.1.1568</p> <p>Req validated:</p> <p>T6.1.1565: ATP trackside shall transmit TSR orders to ATP Onboard.</p> <p>Covered by SRS: See Subset 26 / Chapter 3:</p> <p>3.7.2.4 It shall be possible for the trackside to send additional information when needed. The</p>

information referred to is

-
- Temporary speed restrictions
-
- LX speed restrictions
- ...

3.11.5 Temporary Speed Restrictions

3.11.5.1 The temporary speed restriction is defined in order to enable a separate category of track

infrastructure speed restriction, which can be used for working areas etc

3.11.5.2 All Temporary Speed Restrictions are independent of each other. This means that an individual Temporary Speed Restriction cannot affect, nor be affected by, any other individual Temporary Speed Restriction.

3.11.5.3 Whether a speed increase after the temporary speed restriction shall be delayed with train length, shall be determined by the temporary speed restriction information sent to the on-board equipment.

3.11.5.4 When two or more temporary speed restrictions overlap, the most restrictive speed of the overlapping temporary speed restrictions shall be used in the area of overlap.

3.11.5.5 Each Temporary Speed Restriction shall have an identity to make it possible to revoke the Temporary Speed Restriction using its identity. The speed restriction shall be revoked immediately when revocation is received from trackside, without delay for the train length

3.11.5.6 It shall be possible to identify whether a Temporary Speed Restriction is possible to revoke or not.

3.11.5.7 A new Temporary Speed Restriction shall not replace a previously received Temporary Speed Restriction with another identity.

3.11.5.8 Temporary Speed Restrictions shall only be revoked on request from the trackside.

3.11.5.9 If the on-board equipment receives a new Temporary Speed Restriction (TSR) with the

same identity as an already received TSR, the new Temporary Speed Restriction shall replace the previous one, except when the Temporary Speed Restriction is identified as

non revocable in which case this shall be considered as an additional TSR.

3.11.5.10 In case the train has changed its orientation any Temporary Speed Restriction shall be

deleted (operational requirement: will be executed due to the mode change).

3.11.5.12 It shall be possible for the RBC to order an ERTMS/ETCS on-board equipment in Level

2 to reject revocable TSRs from balises.

3.11.5.13 When ERTMS/ETCS on-board equipment has accepted an order to reject revocable TSRs from balises, this inhibition shall be stored and shall be effective immediately, but only for revocable TSRs received from balises thereafter.

See Step 2.2

T6.1.1566:

Covered by SRS: See Subset 26 / 3.13.7:

3.13.7.1 The Most Restrictive Speed Profile (MRSP) is a description of the most restrictive speed

restrictions the train must obey on a given piece of track.

3.13.7.2 The Most Restrictive Speed Profile shall be derived from elements corresponding to all

speed restrictions (see 3.13.2.2.13 & 3.13.2.3.2), some elements being compensated by the train length if requested by trackside (see 3.11.3.1.3 for SSP, 3.11.4.6 for ASP and 3.11.5.3 for TSR). To do so, the ERTMS/ETCS on-board shall continuously compute the MRSP current speed (V_{MRSP}), which is the lowest speed of the MRSP elements encountered between the min safe front end and the max safe front end of the train.

See Step 2.3

T6.1.1567: The ATO-OB shall recalculate the speed profile according to the information provided by ATP-OB.

Covered by SS-126

See Step 2.4

T6.1.1569: OAS (REP) obtains the Journey Profile information from TAS.

Covered by SS-125

See Step 3.1

6.9 TS009 – UC5.2-0008 RAIL ADHESION ESTIMATION USING PERCEPTION

<p>1 Preconditions</p> <p>PER system operational, to be tested only by FT PER</p>
<p>2 Actors</p> <p>PER</p>
<p>3 Goals</p> <p>To recognize (by PER) changed conditions for adhesion</p>
<p>4 Expected outcomes</p> <p>Different adhesion values due to changed adhesion on track</p>
<p>5 Methodology Incl. Steps</p> <p>1) Sensor data of are collected and processed.</p> <p>2) AI model performs the adhesion detection over prepared sensor data and further relevant features.</p> <p>3) The current adhesion value shall be used to tune the current train braking curve – adhesion value to be recorded to log file</p> <p>Will not be tested at this stage 4) The current adhesion value shall be used by the ATO</p>
<p>6 UC/Req covered</p>

6.10 TS010 – UC5.2-0019 REACT TO OBSTACLE

<p>1 Preconditions</p> <p>OAS operational</p> <p>To be tested only in configuration of AZD systems</p>
<p>2 Actors</p> <p>OAS (PER, APM, PAL, ADM, TCMS, LOC)</p>
<p>3 Goals</p> <p>To test the ability to recognize and evaluate obstacle and to react properly.</p>
<p>4 Expected outcomes</p> <p>Based on obstacle type to trigger horn and/or stop the train</p>
<p>5 Methodology Incl. Steps</p> <p>1) Detect obstacle (human, car) by PER and APM</p>

<p>2) Send the info to PAL (ETCS)</p> <p>3) PAL to send shorten MA</p> <p>4) Train to trigger the horn and try to stop</p> <p>5.1) in case obstacle disappear before train stop, MA is prolonged and train continues</p> <p>5.2) in case train stops, message from IPM-ISM is emulated and after this message, train continues</p>
<p>6 UC/Req covered</p> <p>A list of obstacles (including obstacle class and distance to each obstacle) shall be reported at a specified rate (Hz). The rate shall be configurable.</p> <p>Calculate distance to obstacle.</p> <p>Classify obstacles into the following categories: human, other object with a human, animal, object dangerous to a rail vehicle.</p>

6.11 TS011 – UC5.2-0027.1 SPEED RESTRICTION DUE TO VISIBILITY ISSUES WHILE DRIVING ON SIGHT - LOCAL

<p>1 Preconditions</p> <p>OAS functional</p> <p>To be tested only by AZD systems</p> <p>The restriction is active only in special driving modes like OS, and/or because of unprotected level crossing approach.</p> <p>Weather condition in our UC is determined by PER (fog, less visibility)</p>
<p>2 Actors</p> <p>On-board Automation System (PER, APM, ADM, TCMS, PAL (ETCS), LOC)</p>
<p>3 Goals</p> <p>OAS (PER, APM) detects bad weather conditions. OAS (APM) ensures that the train may always stop at the point of maximal visible distance.</p>
<p>4 Expected outcomes</p> <p>In case of OS ETCS mode or in case of approaching unprotected LX, PER measure its visibility and train reduce his speed to be able to stop the train in the distance of sensors visibility</p>
<p>5 Methodology Incl. Steps</p> <p>1) Train will get the request to ride according to sensor visibility (OS mode or unprotected LX approaching (packet 88))</p> <p>2) PER will send distance for sensors visibility</p> <p>3) APM/ADM will estimate max speed for the sensor visibility</p>

<p>4) APM will send the request for TSR to PAL</p> <p>5) PAL send TSR to the train systems</p> <p>6) ADM will restrict the train speed</p>
<p>6 UC/Req covered</p> <p>Detect and classify weather type from sensors This function detects and classifies the type of weather based on data from sensors. PER weather type: rain, heavy rain, storm, snow, fog etc. Note: Also for UC5.2-0008 - Rail Adhesion Estimation using Perception</p> <p>Monitor train front sensors This technical function monitors the train front sensors that can fail (not compatible with GoA4 operation) or have degraded performance. A self-test function is required to evaluate the distance of efficiency of these sensors. Note: this distance could depend on the environmental conditions (e.g. rain, fog, night, snow). Today, the driver runs in cab signalling with full speed in case of fog, but a radar could lead to another reaction like a slow down if its efficiency is reduced for example.</p>

6.12 TS012 – UC5.2-0030 WANDERING LIVESTOCK, ANIMALS OR OTHER OBJECTS ON OR CLOSE TO THE TRACKS

<p>1 Preconditions</p> <p>Train is in operational mode GoA3/4.</p> <p>Train is operating in a mission.</p> <p>Train is moving.</p> <p>PER module is monitoring the area of interest.</p> <p>Objects are in vicinity of the train.</p>
<p>2 Actors</p> <p>OAS (Onboard Automation System): Perception, ADM, APM, Automatic Train Protection (ATP)</p>
<p>3 Goals</p> <p>To validate the ability of PER to recognize properly livestock and conditions of it.</p>
<p>4 Expected outcomes</p> <p>Information of emulated livestock written in log.</p>
<p>5 Methodology Incl. Steps</p> <p>1) PER detects livestock</p> <p>2) PER evaluate conditions of livestock</p>

3) PER write livestock information to log
6 UC/Req covered

6.13 TS013 – UC5.2-0031 ACTIVATE HORN TRIGGERED BY ONBOARD PERCEPTION OR TRACKSIDE INFORMATION

<p>1 Preconditions</p> <p>Horn activation will be based on location (DM information) or human on track detection / human/animal near track detection.</p>
<p>2 Actors</p> <p>OAS (REP (DM), APM, TCMS, PER, LOC)</p>
<p>3 Goals</p> <p>To validate proper horn behaviour in case of place od obstacle of human or car category</p>
<p>4 Expected outcomes</p> <p>Horn is activated in case of specific place (based on DM info) or in case car or human is detected on track or close to track</p>
<p>5 Methodology Incl. Steps</p> <p style="padding-left: 40px;">Specific place is detected from the digital map</p> <p style="padding-left: 40px;">Human / car obstacle is detected</p> <p>2) Horn is activated for the period of 2 s.</p>
<p>6 UC/Req covered</p> <p>Detect animals</p> <p>This function monitors Physical Environment to detect animals that could endanger the train.</p> <p>Detect humans</p> <p>This function monitors Physical Environment to detect the possible presence of humans on the tracks.</p> <p>Not validated: Detect railway agents on or along the tracks</p> <p>This function senses the Physical Railway Environment to detect the possible presence of railway agents on or along the tracks.</p> <p>Detect road vehicle</p> <p>This function monitors Physical Environment to detect road vehicles that could endanger the train.</p> <p>Identify obstacle</p>

This function classifies the obstacles detected in the risk zone. Objects are identified and tracked. Movement of objects is identified and trajectories are calculated. Object types are defined in Table 7.1. This function evaluates which objects are an obstacle endangering the ego track zone.

Remark: The case of an obstacle that has disappeared from Perception but is still present under the train must be considered.

Monitor area of interest

This function monitors the area of interest in front of the train. The area of interest is hereby defined as the combination of track zones, near track zones, overhead line equipment zones and protection zones. The area of interest boundary is the system border. The function is informed of the location of infrastructure elements to avoid false alarms.

Note: today, a driver sees all tracks in sight range when leaving a station and can report an incident. The requirements associated to view angles and distances are different between an adjacent track and the current track associated to obstacle detection. Target is to avoid trackside equipment as much as possible, a full coverage by trackside CCTV camera would be expensive. Different requirements could imply different sensors for the running direction and the opposite direction, feedback from the test tracks is necessary.

Note: function is allocated to APM and not Train Protection for avoiding a change of SS-034.

6.14 TS014 – UC5.2-0036 LONG RANGE DETECTION AND RECOGNITION OF SIGNALS APPLICABLE TO TRAIN ROUTE

1 Preconditions

Train is in operational mode GoA3/4.

Train is operating in a mission.

Train is moving.

PER module is monitoring the area of interest.

Only PER system will be tested, weather signal aspects can be read

2 Actors

OAS (Onboard Automation System): Perception

3 Goals

To validate the ability of PER to recognize Signal aspects

4 Expected outcomes

Information status of signal aspects and the distance where the signal was recognized written in log.

5 Methodology Incl. Steps

<p>1) PER detects signal (position of signal may be known from DM)</p> <p>2) PER evaluate signal aspect</p> <p>3) PER write information to log</p>
<p>6 UC/Req covered</p>

6.15TS015 – UC5.2-0041 EVALUATING EGO TRACK

<p>1 Preconditions</p> <p>No turnouts involved, only simple track will be tested</p> <p>Information from PER and from DM/ASTP may be evaluated.</p>
<p>2 Actors</p> <p>OAS (PER, REP, ASTP)</p>
<p>3 Goals</p> <p>To evaluate ego track to enable to differentiate object and obstacle</p>
<p>4 Expected outcomes</p> <p>Ego track is marked in display. Object on ego track is recognized and marked as obstacle, object outside ego track is marked as object.</p>
<p>5 Methodology Incl. Steps</p> <p>1) PER recognize ego track, can use DM info for estimation of ego track for example in case snow is hiding the track</p> <p>2) PER / APM will recognize if object in on ego track -> is obstacle or is not on ego track</p>
<p>6 UC/Req covered</p> <p>Detect ego track</p> <p>This function detects the ego track and its detected length based on data from sensors, segment profile, digital map and localization.</p> <p>Monitor train front sensors</p> <p>This technical function monitors the train front sensors that can fail (not compatible with GoA4 operation) or have degraded performance. A self-test function is required to evaluate the distance of efficiency of these sensors.</p> <p>Note: this distance could depend on the environmental conditions (e.g. rain, fog, night, snow). Today, the driver runs in cab signalling with full speed in case of fog, but a radar could lead to another reaction like a slow down if its efficiency is reduced for example.</p>

6.16 TS015 – UC5.2-0059 TRAIN STOPS BY SIGNALLING

<p>1 Preconditions</p> <p>Only signal on simple track will be tested.</p> <p>Information from PER system will be displayed on PER DMI.</p>
<p>2 Actors</p> <p>PER</p>
<p>3 Goals</p> <p>Signal will be detected and evaluated by PER.</p>
<p>4 Expected outcomes</p> <p>Detected and evaluated signal is marked on video stream from camera on PER DMI.</p>
<p>5 Methodology Incl. Steps</p> <p>PER will detect and evaluate Signal.</p> <p>Per will mark signal on video stream from camera on PER DMI, and show information about signal.</p>
<p>6 UC/Req covered</p> <p>Driving according to journey based on lateral signalling.</p> <p>PER+SCV Shall provide lateral signalling information (movement authority and seep restriction) to the ATP based on visual observation.</p> <p>PER: Detect the signal /landmark.</p> <p>PER: Evaluate signal state (SCV) or identify landmark (LZ).</p>

6.17 TS016 – UC5.4-009 LOG-IN ON A REGISTERED STANDBY TRAIN

<p>1 Preconditions</p> <p>The train runs in state:</p> <p>Remote Supervisor Centre registration: registered</p> <p>Level of operations: standby</p> <p>User registration: observing</p>

<p>2 Actors</p> <p>Tested enablers: Remote driver</p> <p>Other actors: Train, Remote Supervisor Centre</p>
<p>3 Goals</p> <p>To validate requirements related to UC “UC5.4-009 Log-in on a registered standby train”</p>
<p>4 Expected outcomes</p> <p>Remote driver is monitoring the train. Remote driver can request control of the train.</p>
<p>5 Methodology Incl. Steps</p> <p>UC5.4-009 Step 4.0: These actions are not part of the demo</p> <p>UC5.1-003 Step 1: RD chooses a train in the fleet he/she is allowed to manage (competency, geography). He / she adds this train to the list of trains he/she is Monitoring.</p> <p>UC5.1-003 Step 2: Automatically, the Remote Supervisor Centre issues a RemoteMonitoringRequest to the train.</p> <p>UC5.1-003 Step 3: The train checks if the user is allowed to monitor the train.</p> <p>UC5.1-003 Step 4.1: The train sends an acknowledgement to the RSC. The train counts the user in its list of Monitoring users. The remote user monitors the train.</p>
<p>6 UC/Req covered</p> <p>Req not part of the demonstrator WP46:</p> <p>T6.7.0143 T6.7.0182</p> <p>Req validated:</p> <p>T6.7.0134 When the RD requests monitoring the train, the RC-TS shall manage the user profile of RDs.</p> <p>T6.7.0135 When the RD requests monitoring the train, the RD user profile shall include needed attributes to manage the access rights.</p> <p>T6.7.0132 When the RD requests monitoring the train, the RC-OB shall continue to transmit the observation information.</p> <p>T6.7.0133 When RD monitors the train, the RC-OB shall start to transmit monitoring information (e.g., OAS (TCMS) Information, Video, Sound, OAS (ETCS, APM and TCMS) Alarms).</p> <p>T6.7.0136 When the RD requests monitoring a train, the RC-TS shall display the observation information of trains observed by the RD.</p>

T6.7.0137 The RC-TS user interface shall allow RD to make a monitoring request to the train he is allowed to monitor.

T6.7.0138 Before RD requests to monitor a registered standby train, the RC-TS shall display the list of trains ready to be monitored by the RD taking into account her/his user profile.

T6.7.0321 Once monitoring has successfully been established by the RC-TS, RC-TS shall display monitoring information of the trains monitored by RD.

6.18TS017 – UC5.4-010 TAKE CONTROL OF A MONITORED STANDBY TRAIN

1 Preconditions

The train runs in state:

Remote Supervisor Centre registration: registered

Level of operations: standby

User registration: observing

2 Actors

Tested enablers: Remote driver

Other actors: Train

3 Goals

To validate requirements related to UC “UC5.4-010 Take control of a monitored standby train”

4 Expected outcomes

After completion of this scenario, remote driver has control of this train.

5 Methodology Incl. Steps

UC5.4-010 Step 4.0, 4.1: These actions are not part of the demo

UC5.4-010 Step 1: RD issues a RemoteControlRequest by pushing the button RSC-ClaimGrant.

The RSC checks the validity of RD’s control request, and potentially associated speed restrictions.

The RSC sends to the train a control request for RD1. It contains RD1’s certification profile.

UC5.4-010 Step 2.0: The train receives RD’s request for control. It checks its validity.

UC5.4-010 Step 3.0: The train checks whether some other remote driver is already controlling the train.

If not, the train grants control to RD: it sends a confirmation message. The train grants control to RD.

6 UC/Req covered

Req not part of the demonstrator WP46:

T6.7.0146

T6.7.0150

T6.7.0151

T6.7.0318

T6.7.0156

T6.7.0157

T6.7.0155

T6.7.0318

T6.7.0154

Req validated:

T6.1.0148: The RD control authorizations shall be validated by the RDS and ensured operationally.

T6.1.0149: The RDS shall only accept valid control requests.

T6.1.0153: The RDS shall ensure that at most one authorized RD is in control of the train.

T6.1.0152: The RDS shall notify the RD of his/her control status.

6.19 TS018 – UC5.4-015 DEMOTE A REMOTE DRIVER FROM CONTROLLING TO MONITORING

1 Preconditions

The train runs in state:

Remote Supervisor Centre registration: registered

Level of operations: operative

User registration: controlling the train

2 Actors

Tested enablers: Remote driver

Other actors: Train

3 Goals

To validate requirements related to UC “UC5.4-015 Demote a remote driver from Controlling to Monitoring”

<p>4 Expected outcomes</p> <p>After completion of this scenario, remote driver ends controlling of train.</p>
<p>5 Methodology Incl. Steps</p> <p>UC5.4-015 Step 3, 5: These actions are not part of the demo</p> <p>UC5.4-015 Step 1: RD: sends the train a RemoteControlDemoteRequest.</p> <p>UC5.4-015 Step 2: Train: receives the message issued in Step 1.</p> <p>Train checks if the user is allowed to start Monitoring the train:</p> <ol style="list-style-type: none"> 1. ETCS is in full supervision 2. PER and APM are ready or up working 3. ATO is ready or working <p>UC5.4-015 Step 4: In addition to TCMS already running (by definition of operative), the train starts ATO and all components of autonomous driving if not yet started (PER and APM).</p> <p>UC5.4-015 Step 6: The train demotes RD to Monitoring.</p>
<p>6 UC/Req covered</p> <p>Req not part of the demonstrator WP46:</p> <p>T6.7.0018</p> <p>T6.7.0319</p> <p>Req validated:</p> <p>T6.1.0060: "When a GoA4 handover request is received, the OAS shall set its readiness to transition to GoA4 when the following conditions are met:</p> <ul style="list-style-type: none"> - conditions to operate in GoA4. - operational and engagement conditions as defined in sub-125 if the train is moving. - the train speed is under the speed limit resulting from sensors efficiency distance and clearance of the track." <p>The last condition will not be covered and validated.</p> <p>T6.1.0061: When a GoA4 handover request is received, the OAS shall send to the RDS the readiness of OAS to transition into GoA4.</p> <p>T6.1.0062: When a GoA4 handover request is in progress and OAS is ready to transition to GoA4, RDS shall inform OAS that it is ready to release the Remote cab.</p> <p>T6.1.0063: If ready to release the remote cab has been received, OAS shall start to operate the Train in GoA4.</p>

T6.1.0176: When the RD triggers the "Mastership Negotiation Component" for a handover to GoA4, the RDS shall request handover from the OAS.

T6.1.0177: When GoA4 handover is in progress, and RC-OB detects the train is operating in GoA4, RC-OB shall send handover confirmation to the RC-TS.

T6.1.0178: When handover to GoA4 is confirmed, RDS shall transition RD from controlling to monitoring.

T6.1.0179: When OAS is not ready to transition to GoA4, RDS shall inform RD that handover to GoA4 is rejected.

T6.1.0180: When handover to GoA4 is rejected, RDS shall keep RD in control and shall display the reason of the rejection to RD.

6.20TS019 – UC5.4-016 STOP MONITORING A TRAIN BY A REMOTE DRIVER

1 Preconditions

The train runs in state:

Remote Supervisor Centre registration: registered

Level of operations: operative

User registration: monitoring the train

2 Actors

Tested enablers: Remote driver

Other actors: Train, Remote Supervisor Centre

3 Goals

To validate requirements related to UC "UC5.4-016 Stop monitoring a train by a remote driver"

4 Expected outcomes

Remote driver ends observing the train.

5 Methodology Incl. Steps

UC5.4-016 Step 3, 4: These actions are not part of the demo

UC5.4-016 Step 1: RD1: sends the train a RemoteControlDemoteRequest

UC5.4-016 Step 2: Train: receives the message issued in Step 1

The train checks if RD1 is allowed to quit Monitoring the train.

UC5.4-016 Step 5: The train demotes RD to Observing

6 UC/Req covered

Req not part of the demonstrator WP46:

T6.7.0246

T6.7.0306

Req validated:

T6.7.0245: When the RD requests a transition from monitoring to observing (via the Mastership Negotiation Component), the RDS shall demote the monitoring RD to observing.

6.21 TS020 – UC5.4-024 PERFORM ROUTINE DRIVING BY REMOTE DRIVER

1 Preconditions

The train is operated in a centralized area; ETCS is available and functional.

The Train is under control of the remote driver. The communication between the train and the control centre is operational.

When this use-case starts, the train is stopped Train is stopped.

2 Actors

Tested enablers: Remote driver

Other actors: ATO, Perception system

3 Goals

To validate requirements related to UC5.4-024 “Perform routine driving by remote driver”

4 Expected outcomes

The main goal of this use case is to ensure seamless train control by a Remote Driver.

5 Methodology Incl. Steps

UC5.4-024 Step 1, 4.3, 4.4, 4.6, 4.7, 4.8, 4.9, 6: These actions are not part of the demo

UC5.4-024 Step 2: The train starts. The Remote Driver attends the train motion.

UC5.4-024 Step 3.1: The Remote Driver decreases the train's speed: controls the train's brakes lever.

UC5.4-024 Step 3.2: The Remote Driver uses the emergency brake button to stop the train in a potential danger situation.

UC5.4-024 Step 3.3: The Remote Driver uses warning sound devices: sounds the horn.

UC5.4-024 Step 4.1: At Standstill, select / revert the driving direction: showing video and sensors of an extremity cabin or the other.

UC5.4-024 Step 4.2: The Remote Driver corrects the train's speed (controls the train's traction and brakes).

UC5.4-024 Step 4.1: At Standstill, select / revert the driving direction: showing video and sensors of an extremity cabin or the other.

UC5.4-024 Step 4.5: The Remote Driver manages external lights.

UC5.4-024 Step 4.10: The Remote Driver engages the train holding brake.

UC5.4-024 Step 5: The Remote Driver stops the train at a safe place.

6 UC/Req covered

Req not part of the demonstrator WP46:

T6.7.0285

T6.7.0408

T6.7.0282

T6.7.0401

T6.7.0406

T6.7.0278

T6.7.0283

T6.7.0113

Req validated:

T6.7.0003: The RDS shall provide the controlling RD the possibility to select the driving direction of the train.

T6.7.0163: The RDS shall provide the RD the possibility to check the status of all operationally relevant subsystems.

T6.7.0266: The RDS shall have access to diagnostic information about the functionality status of the train and OAS components.

T6.7.0267: The RDS shall provide the RD access to diagnostic information about the functionality status of the train and OAS components.

T6.7.0269: When the RD is monitoring the train, the RDS should provide the RD the possibility to trigger emergency braking of the train.

T6.7.0276: The RDS shall provide the controlling RD the possibility to control the speed of the train.

T6.7.0280: The RDS shall provide the controlling RD the possibility to monitor and control the external lights of the train.

T6.7.0287: The RDS shall provide the controlling RD the possibility to control the holding brake of the train.

6.22 TS021 – UC5.4-029 SHUNT IN CENTRALIZED AREA

<p>1 Preconditions</p> <p>The train runs in state:</p> <p>Remote Supervisor Centre registration: registered</p> <p>Level of operations: standstill</p> <p>User registration: controlling the train</p>
<p>2 Actors</p> <p>Tested enablers: Remote Driver</p> <p>Other actors: Train</p>
<p>3 Goals</p> <p>To validate requirements related to UC “UC5.4-029 Shunt in centralized area”</p>
<p>4 Expected outcomes</p> <p>The train can be driven (shunting) by RD from some RSC while the train is located inside a centralized area.</p>
<p>5 Methodology Incl. Steps</p> <p>UC5.4-029 Step 0, 1, 4, 6.1, 6.2, 8, 9: These actions are not part of the demo</p> <p>UC5.1-029 Step 2: RD selects shunting mode</p> <p>UC5.1-029 Step 3: RD assures the position where the vehicle is and reads the signal aspects.</p> <p>UC5.1-029 Step 5: RD waits for signal aspect allowing driving</p> <p>UC5.1-029 Step 6: RD moves the vehicle to the planned position obeying the regulations for this track and type of train.</p> <p>UC5.1-029 Step 7: Train arrives at its supposed destination.</p>
<p>6 UC/Req covered</p> <p>Req not part of the demonstrator WP46:</p> <p>T6.7.0037</p> <p>T6.7.0038</p> <p>T6.7.0094</p> <p>Req validated:</p> <p>T6.7.0003: The RDS shall provide the controlling RD the possibility to select the driving direction of the train.</p>

T6.7.0005: The RDS shall provide the controlling RD the possibility to control the emergency brake of the train.

T6.7.0014: The RDS shall provide the controlling RD the current speed of the train.

T6.7.0032: The RDS should display the maximum shunting speed to the RD.

T6.7.0276: The RDS shall provide the controlling RD the possibility to control the speed of the train.

7 TESTING ENVIRONMENT

7.1 REGIONAL LINE CHARACTERISATION

- "Kopidlno line" is a non-electrified single-track regional line located in North-Eastern Bohemia. The line was built in 1883 and is about 23 km long. For most of its existence, the line was owned and operated by the state, until 2010, when the regular service has been discontinued and the line abandoned. Later, in 2014, the line was offered for sale and in 2016 it was sold to a private company AZD Praha. The line is now being converted to line for testing the new railway technologies, especially focusing on automatic train operations.

7.1.1 Test line location

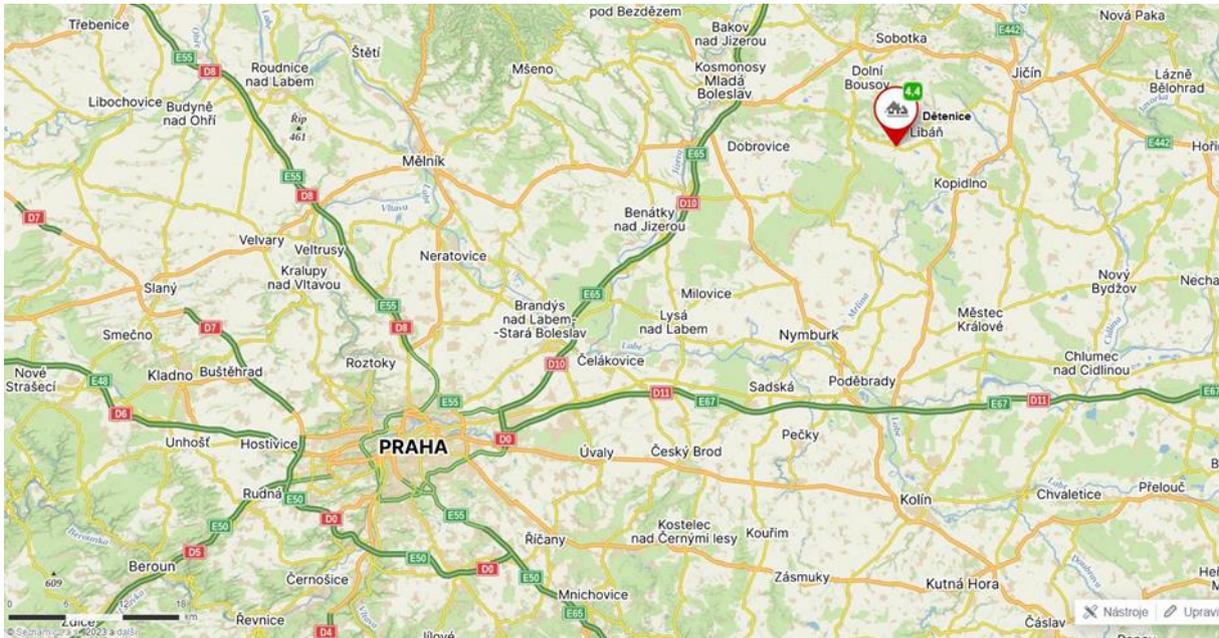


Figure 6: Test line location

Location of the test line

- 65 km NE from Praha (air distance)
- Road distance: approx. 80 km
- Travel time by car: approx. 75 minutes

7.1.2 Line details

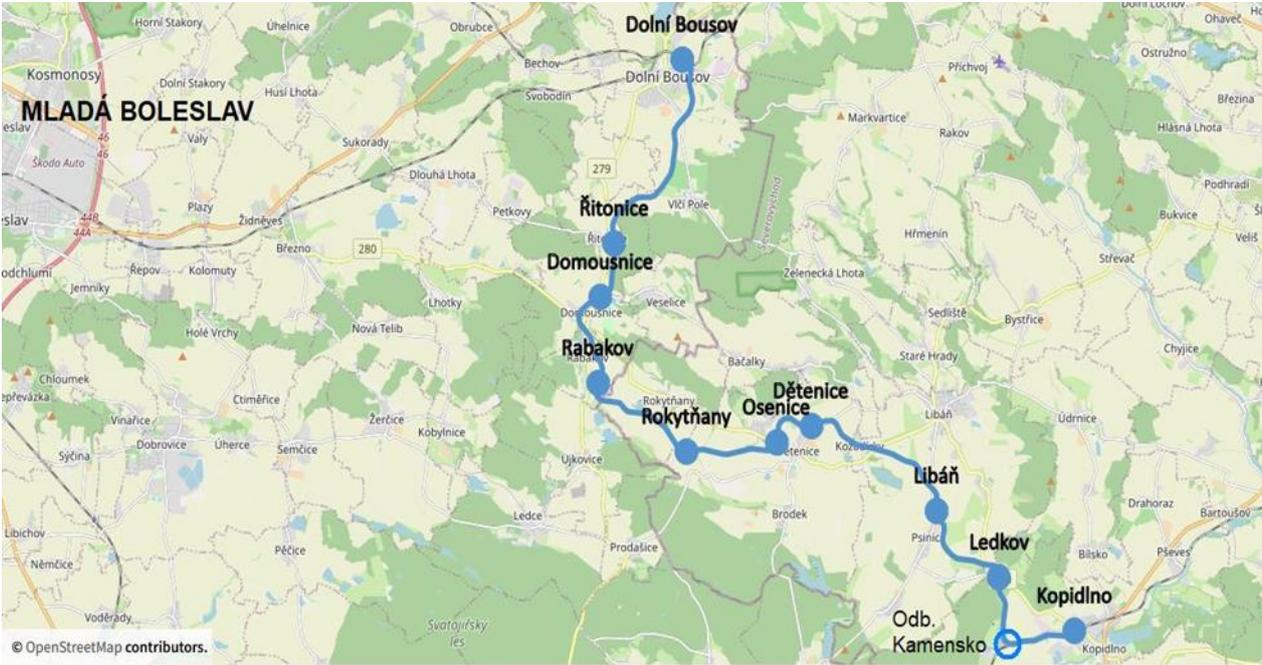


Figure 7: Test line – stops and stations



- Length: 23 km
- Standard gauge 1435 mm
- Non electrified
- Max. speed: 60 km/h
- Max. gradient: 12 ‰
- Commercial operation: 1882 - 2010
- Owned by AŽD since: 2016
- Currently: no regular services, sporadic touristic services on summer weekends
- Being converted to testing line for modern technologies (ETCS, ATO, 5G mobile network, autonomous trains, modern infrastructure devices - level crossings, LED light signals...)

Figure 8: Test line schema

7.1.3 Stations and Stops

name	type	km	altitude	note
Kopidlno	station (SŽ CZ)	25,501	219	
odbočka Kamensko	junction (SŽ CZ / AŽD)	0,021	216	= km 24,050
Ledkov	halt	1,646	231	
Libáň	halt	3,987	219	
Dětenice	station	7,710	235	
Osenice	halt	9,110	239	
Rokytnany	halt	11,297	225	former jct.
Rabakov	halt	14,100	254	
Domousnice	halt	16,377	267	
Řitovice	halt	17,600	263	
Dolní Bousov	station (SŽ CZ)	22,528	238	

7.1.4 Position – altitude diagram

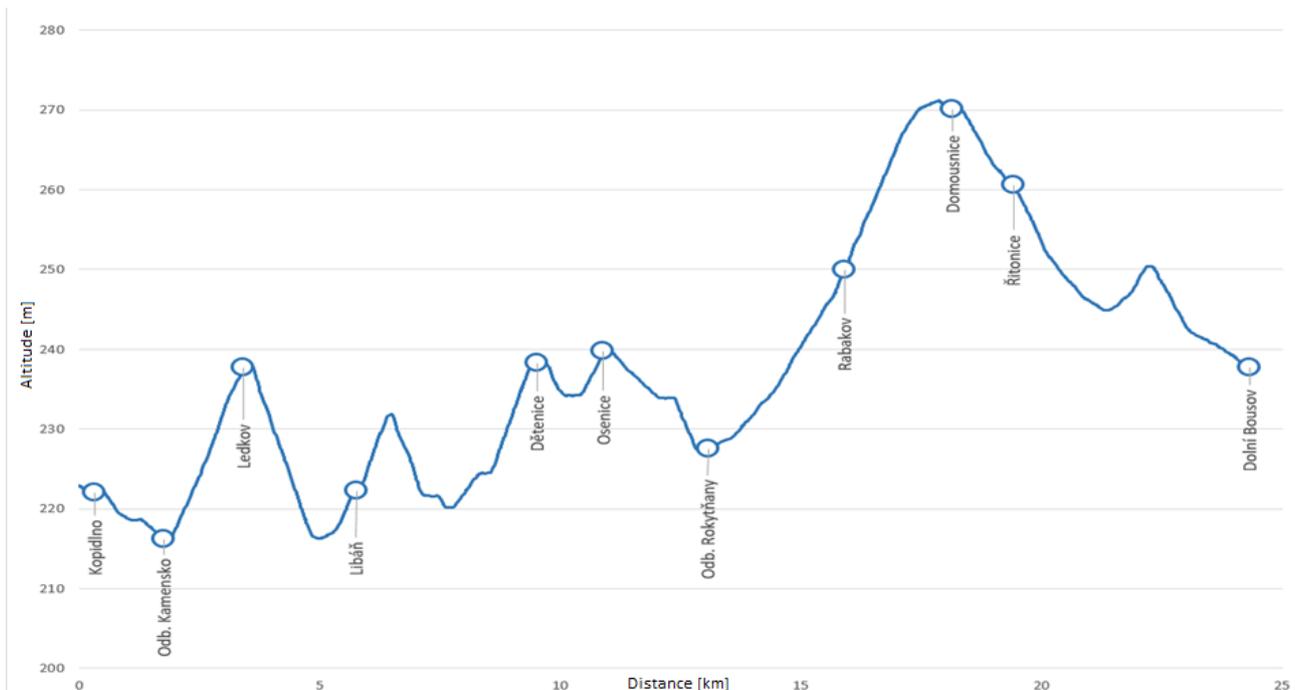


Figure 9: Test line – altitude diagram

7.1.5 Part of the line planed to be used for pilot tests

For the train operation scenarios , a particular section of the line between station Dětenice and Junction Kamensko is planned to be used. However, for the integrational and operational testing of each involved systems, the whole line will be used, with the exclusion of frontend stations Kopidlno and Dolní Bousov in order to avoid any traffic interference, since they are under a regular passenger and freight service.

For one direction of demonstrational run, a Journey profile containing the following Segment profiles has been used:

NID_Country	NID_SP	Length	Description
504	0 557 108 109	124,49 m	Dětenice station track no.1 – section 2
504	0 557 108 009	69,80 m	Dětenice station track no.1 – section 1
504	2 557 108 109	62,93 m	Station – track transition
504	1 111 102 005	2207,69 m	Open track (containing unprotected LX)
504	1 111 102 003	5414,92 m	Open track (containing Libáň and Ledkov stations)

For the other direction of demonstration run, a Journey profile containing the following Segment profiles has been used:

NID_Country	NID_SP	Length	Description
504	1 111 102 002	5414,92 m	Open track (containing unprotected LX)
504	1 111 102 004	2207,69 m	Open track (containing Ledkov and Libáň stations)
504	2 557 108 008	62,93 m	Track – station transition
504	0 557 108 008	69,80 m	Dětenice station track no.1 – section 1
504	0 557 108 108	124,49 m	Dětenice station track no.1 – section 2

Note: The circumstances of the line do not allow the use of bi-directional Segment Profiles, therefore each direction of travel requires its specific SPs.

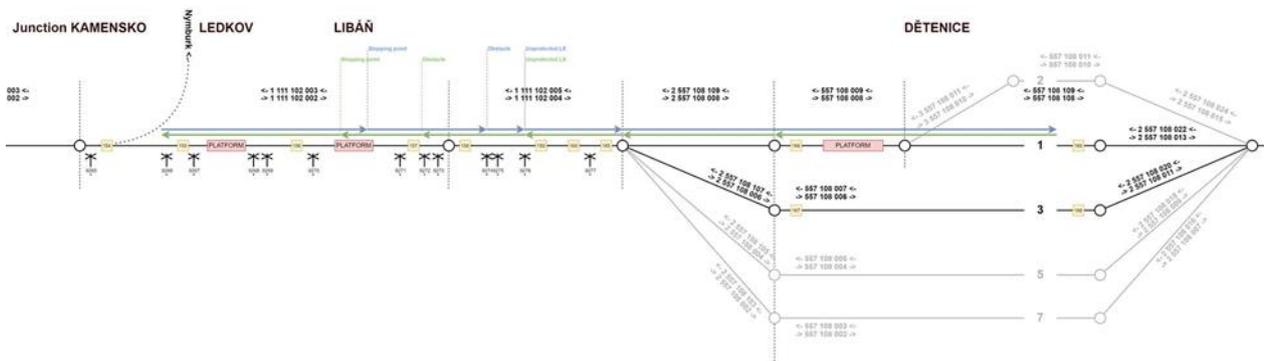


Figure 10: Kamensko – Dětenice track schema



Figure 11: Dětenice railway station: Vizualization

7.2 INSTALLED CCS TECHNOLOGIES

Installed conventional CCS systems

Railway Interlocking	AŽD, type ESA 51 for segment Dolní Bousov – Dětenice – Kopidlno
Train detection	Axel counters covering the whole line, type Frauscher FaDC
Level Crossings	Different types from AZD production (9x PZZ-J, 6x PZZ-GTS for securing level crossing in the track, 5x PZZ-ACE for level crossing in stations (Dětenice, Dolní Bousov), light warning system for pedestrians in Dětenice type AŽD VZPK
Automatic block system	AZD AHP-03D (Dolní Bousov – Dětenice) - partially using GSM-P, AH-ESA in segment Dětenice – Kopidlno
Centralised track control	DOZ-1 controlled from Kopidlno
ETCS	ETCS-L2 (the whole track)
Diagnostic system	AŽD LDS-3
Traffic management system	AŽD GTN (local dispatching system) with automatic route setting

Telecommunications, PIS

- GSM-R coverage – the whole track
- Voice announcement for passengers at Dětenice railway station
- Camera system at Dětenice railway station
- Passenger information system at Dětenice railway station
- Intelligent stop (Domousnice)

Systems for the needs of autonomous railway (planned)

- ATO over ETCS
- Clearance control of level crossings (Laser scanner, ADEROS camera system)
- 5G radio network
- Autonomous inspection cart

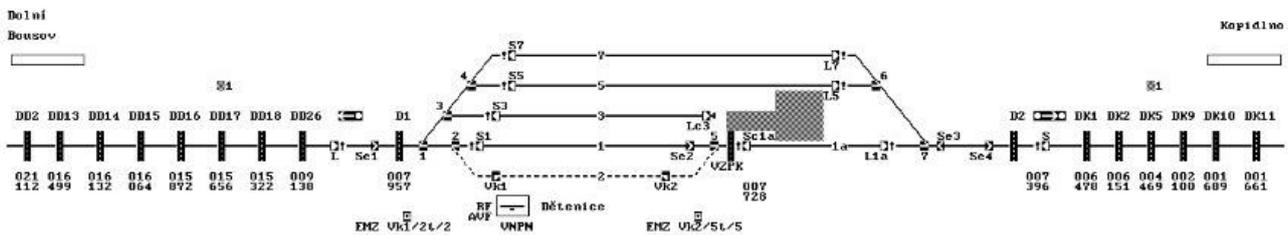


Figure 12: Dětenice railway station: Situation diagram

7.3 TESTING VEHICLE

For testing purposes, new experimental testing vehicle (EDITA) has been prepared. This vehicle underwent a complete renovation of the original class 810 vehicle (in particular, 810.111). The perception sensors are fully integrated to the front of the vehicle, four 19" cabinets for special equipment are on-board and the railcar is fully modernized and equipped with the new technologies.

- Independent traction, diesel engine 242kW
- Up-to-date train control system (type TCMS AVV) with electric braking
- ETCS on-board with ATO GoA2 (TSI compliant)
- Fully integrated Perception system to the vehicle body
- Modular system for several roof antenna installations

- Modular space inside the train accessible for developers for new technologies installations, with available 230V AC, 24V DC and already built-in ethernet networking



Figure 13: Experimental testing vehicle EDITA

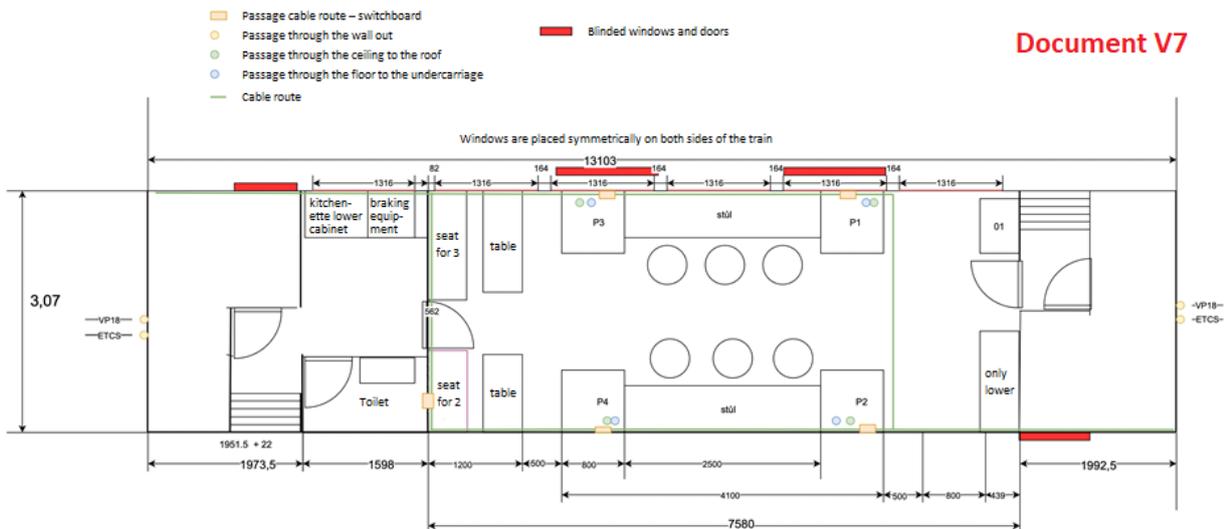


Figure 14: Organisation of testing vehicle EDITA`s internal space

7.3.1 Detailed parameters

- Diesel railcar
- Originally built in 1976 as a passenger motor car (M 152.0111)
- Total reconstruction in 2022-23
- Diesel engine TEDOM TD 242 RH TA 25
- Nominal power 242 kW, but torque reduced not to overstep gearbox input torque 900 Nm
- Hydromechanic transmission - gearbox Praga 2M90
- Max. speed 80 km/h
- Wheel arrangement A'1'
- Length over buffers 13 970 mm
- Nominal wheel diameter 840 mm
- Empty weight 22 t
- Automatic (indirect) brake DAKO, electrically controlled
- Brake weight P 20 t.
- Mechanical parking brake, brake weight 5 + 5 t.
- Braking distance from max. speed: 350 m (on 0 ‰) (determined from brake percentage diagram)
- ETCS by CAF (Level 2)
- National (Class B) KBS 06 (Vigilance check)
- National ATO - AVV type with GPS localisation, fully prepared for ERTMS/ATO

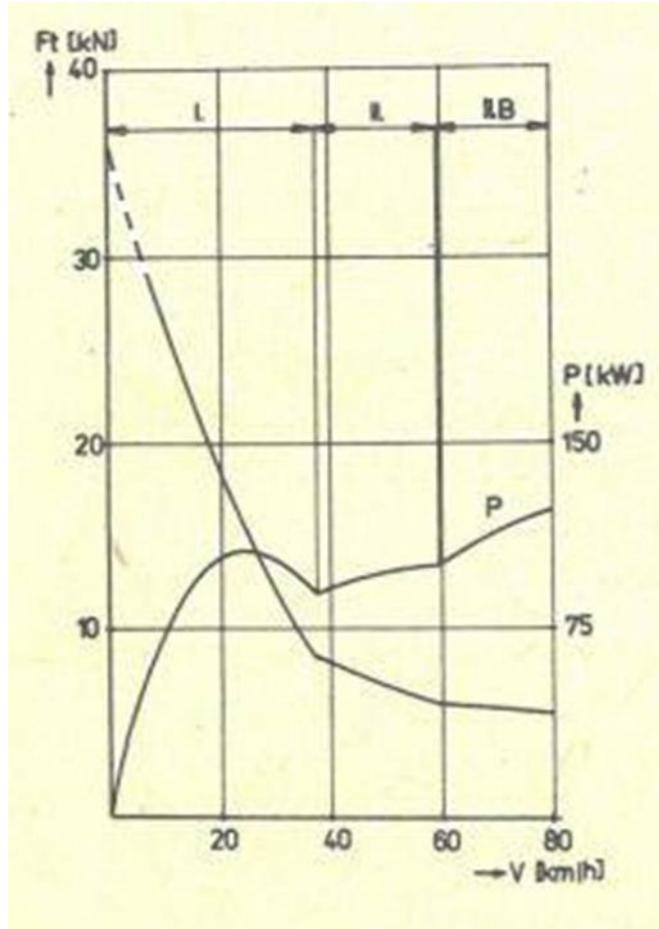


Figure 15: Tractive force diagram

7.3.2 External cabinet for hosting of Perception system

Perception system of AZD will be fully integrated to the vehicle body. To be able to test perception systems of other companies, external cabinet has been developed.

Partners may set up internal plate with their sensors and put it to the cabinet placed in front of the vehicle.



Figure 16: Console for external sensors under the development



Figure 17: Test of console mounting on another vehicle of the same type (810)

8 INTEGRATION & DEMONSTRATION PLAN

8.1 TEST SETUP

8.2 TECHNICAL COMPONENTS: BASIC IMPLEMENTATION CONSIDERATION AND NEEDS

8.2.1 ADM (AZD)

8.2.1.1 Implementaion of the technical component

AŽD's ADM is a self-standing block, which communicates with other components of TCMS and its own peripherals. The block is mounted at suitable place near TCMS (to have convenient cabling).

8.2.1.2 Requirements for testing vehicle

AŽD's ADM is connected to power supplying (typically, 24 V DC, 1 A). It communicates with TCMS using ERTMS Subset 139 (GoA2) and C55 extension for GoA3/4. It requires direct access to speed sensors (adapted to sensors used on given vehicle), but it does not need exclusive (not shared) sensors, it can share sensors with TCMS, WSP etc. All axles of the vehicle should be equipped with speed sensors connected to ADM.

Additionally, AŽD's ADM uses a specific driver's touchscreen display allowing to be controlled by virtual buttons.

AŽD's ADM can directly communicate with ATO-TS using GSM radio network.

ADM is capable of electric control of traction power and brakes (by means of TCMS) .

8.2.1.3 Other specific needs

For AŽD's testing car, no specific needs are required - this car is already equipped with AŽD ADM.

8.2.1.4 Deviations from current generic specifications

Automatic shunting, integration with remote control and registered standby are not yet implemented

.

8.2.2 ADM (ALSTOM)

8.2.2.1 Implementation of the technical component

ATSA’s ADM module is nothing else than the “Automating Driving functions”-related ATO up to GoA4 module being specified within EURAIL FA2 R2DATO WP6 & WP10.

The ATSA’s ADM module shall implement the sequence diagrams and the inter-modules interfaces that shall be defined and agreed between all WP46 partners to support the Use Cases selected for WP46 as resulting from the strict and only application of the available SRS 1.1.0

As any other ATO GoA4-related module, the ATSA’s ADM module is an applicative software that shall be implemented on an “Automating Driving functions”-dedicated computing unit that, as shown in Figure 18 below, is part of the ATO GoA4 solution that ATSA intends to deliver for the sake of WP46.

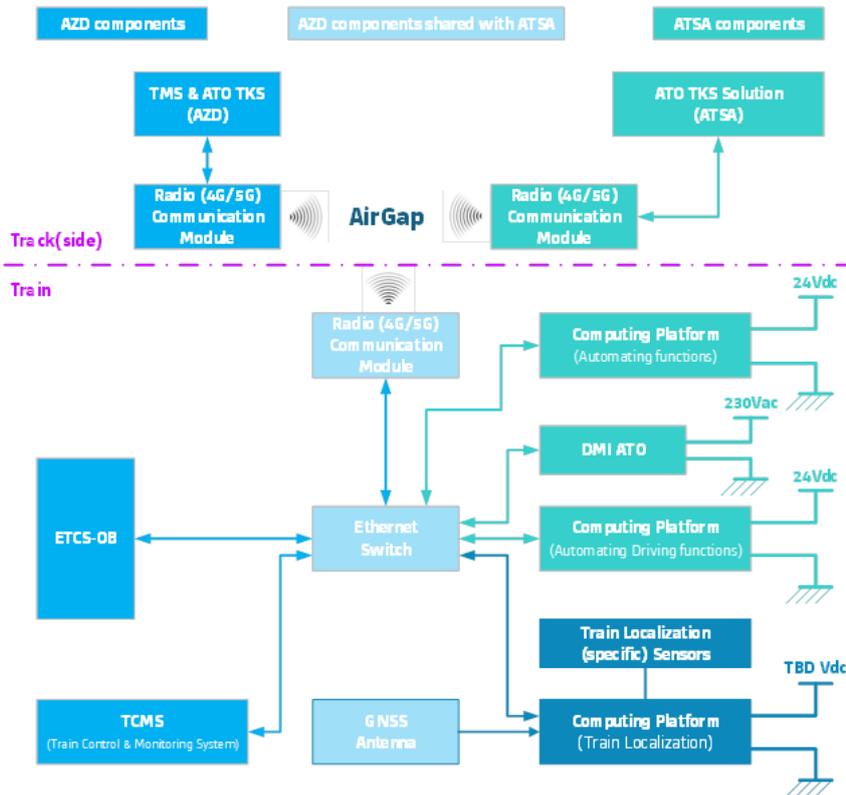


Figure 18: ADM module as part of the ATO GoA4 solution delivered by ATSA

8.2.2.2 Requirements for testing vehicle

As illustrated in Figure 18 above, the ATSA’s ADM module shall be implemented within a “Automating Driving functions”-dedicated computing unit whose main (but not exhaustive) features are listed below :

- Dimension : 482.6 x 88 x 221.3 mm (19" x 3.46" x 8.71") with mounting kits
- Power supply : 24Vdc / Power consumption : 20 watts (max)
- Fanless computer for railway vehicle applications, fully compliant with EN 50155
- Satisfies temp. standard: EN 50155 TX (-40 ~ 70 °C) and IEC 61373 body mount class B
- Compliant with EN 50121-3-2/ EN 50121-4 EMC test standard
- Ruggedized connectors (M12) used for communication and power

More details / features could be given later to support the installation design studies deemed to be in charge of AZD as knowing perfectly the reality of the train and specially the risk of disturbance with equipments / antenna that should / could already be installed.

The only requirement for implementing the “Automating Driving functions”-dedicated computing unit is to take care for this computing unit to be carefully installed in a dedicated cabinet while considering the installation constraints that results from the main features listed above and that should / could be completed later.

8.2.2.3 Other specific needs

Prior to any testing phase and therefore, in the last quarter of 2025 or early in 2026, it will be necessary to plan :

- One or 2 days to test and commission the ADM module, i.e. specially but non exhaustively the ability of the ADM module :
 - To exchange data with the other ATO GoA4-related modules (addressing plan, same implementation of the interfaces defined and agreed)
 - To interface with the TCMS (SS-139 interface) so as to activate / monitor the train peripherals, i.e. traction, break, doors, ...
- Two train characterization sessions with the objective to define and set the correct parameters for the ADM module so that the ADM module is able to drive the train cleanly.

Those 2 sessions will each last 2 days and will be separated by 10 working days.

The ADM module as any ATO GoA4-related modules developed and delivered by ATSA for the sake shall be subject to a laboratory test campaign prior to any formal tests on site.

Any test (scenario) that is to be carried out during the WP46 test campaign on, site planned for the first half of 2026 will have to be clearly and precisely described in a WP46 detailed test plan that is yet to be written.

8.2.2.4 Deviations from current generic specifications

The ADM module as any ATO GoA4-related modules delivered by ATSA for the sake of the EU RAIL FA2 WP46 shall be designed and developed according to the sequence diagrams and inter-modules

interfaces agreed by all partners as resulting from the strict and only application of the SRS 1.1.0 delivered by EU RAIL FA2 WP6 which is the most up-to-date system specification currently available.

The only deviations allowed (if any) shall only result from lack (if any) of system specification to cover the Use Cases selected for WP46. They shall be fully agreed by all WP46 before and for being implemented.

This is indeed the only way to secure the demonstration of the interchangeability between ATO GoA4-related modules as delivered by different suppliers.

8.2.3 APM (AZD)

8.2.3.1 Implementaion of the technical component

AŽD's APM is a multi-threaded application based on multi-criteria decision making. The computing unit for APM is located in a cabinet inside the train, which is connected to the internal communication network over Ethernet.

8.2.3.2 Requirements for testing vehicle

APM communicates with other modules using communication interfaces defined in the SRS ATO up to GoA3/4 v1.1.0 - annex A. Required communications:

- APM - PER (C8)
- APM - TCMS (C55)
- APM - REP (C28)
- APM - PAL (C16)
- APM – LOC (C62)

8.2.3.3 Deviations from current generic specifications

For Use-Cases related to remote control, we add information about the activation of the cabin to the M_CAB_STATUS variable in the TCMS_APM_MSG_DESK packet in the C55 communication. Specifically, the values:

CAB_A_OPENED_BY_RC, CAB_B_OPENED_BY_RC

We will add information about the reason for the train stopping to the C55 communication between TCMS and APM. For example, in case a passenger triggers an alarm handle in UC in section 5.5.

8.2.3.4 Other specific needs

To ensure interoperability within the demonstrator, we propose the following procedure:

- Approval of necessary modifications to the interfaces between modules (C8, C16, C28, C55, C62)
- Define sequence diagrams to describe the exact behaviour of APM
- Identify laboratory testing options. Testing single interfaces vs. testing a complete system with the need to implement a train simulator
- Laboratory testing
- Testing in a real environment on a train

8.2.4 APM (ALSTOM)

8.2.4.1 Implementation of the technical component

ATSA's APM module is nothing else than one of the "Automating functions"-related ATO up to GoA4 module being specified within EURAIL FA2 R2DATO WP6 & WP10.

The ATSA's APM module shall implement the sequence diagrams and the inter-modules interfaces that shall be defined and agreed between all WP46 partners to support the Use Cases selected for WP46 as resulting from the strict and only application of the available SRS 1.1.0

As any other ATO GoA4-related module, the ATSA's APM module is an applicative software that shall be implemented on an "Automating functions"-dedicated computing unit that, as shown in Figure 18 above, is part of the ATO GoA4 solution that ATSA intends to deliver for the sake of WP46.

8.2.4.2 Requirements for testing vehicle

As illustrated in Figure 18 above, the ATSA's APM module shall be implemented within a "Automating functions"-dedicated computing unit.

This "Automating functions"-dedicated computing unit will be the same as the "Automating Driving functions"-dedicated computing unit.

Ergo, its main (but not exhaustive) features will be the ones listed in section 8.2.2.2.

More details / features could be given later to support the installation design studies deemed to be in charge of AZD as knowing perfectly the reality of the train and specially the risk of disturbance with equipments / antenna that should / could already be installed.

The only requirement for implementing the "Automating functions"-dedicated computing unit is to take care for this computing unit to be carefully installed in a dedicated cabinet while considering the installation constraints that result from the main features listed above and that should / could be completed later.

8.2.4.3 Other specific needs

Prior to any testing phase and therefore, in the last quarter of 2025 or early in 2026, it will be necessary to plan :

- One or 2 days to test and commission the APM module, i.e. specially but non exhaustively the ability of the APM module :
 - To exchange data with the other ATO GoA4-related modules (addressing plan, same implementation of the interfaces defined and agreed)
 - To interface with the TCMS (C55 interface [if any]) so as to activate / monitor the train peripherals, i.e. horn, doors, ...

The APM module as any ATO GoA4-related modules developed and delivered by ATSA for the sake shall be subject to a laboratory test campaign prior to any formal tests on site.

Any test (scenario) that is to be carried out during the WP46 test campaign on, site planned for the first half of 2026 will have to be clearly and precisely described in a WP46 detailed test plan that is yet to be written.

8.2.4.4 Deviations from current generic specifications

The APM module as any ATO GoA4-related modules delivered by ATSA for the sake of the EU RAIL FA2 WP46 shall be designed and developed according to the sequence diagrams and inter-modules interfaces agreed by all partners as resulting from the strict and only application of the SRS 1.1.0 delivered by EU RAIL FA2 WP6 which is the most up-to-date system specification currently available.

The only deviations allowed (if any) shall only result from lack (if any) of system specification to cover the Use Cases selected for WP46.

They shall be fully agreed by all WP46 before and for being implemented.

This is indeed the only way to secure the demonstration of the interchangeability between ATO GoA4-related modules as delivered by different suppliers.

8.2.5 DIGITAL REGISTER/REPOSITORY OB (AZD)

8.2.5.1 Implementaion of the technical component

AZD implementation of repository is based on the SRS ATO up to GoA3/4 v1.1.0.

Repository process and further provide information exchanged through communication interfaces, stores and provides information from ATO components (on-board and trackside), mediate and monitor mission execution, provide and pre-process the digital map according to the information about the travelled route of the train and its location, provide other additional information from the digital map, and monitor and control the state of itself and the components connected to the repository.

Functions, which are performed by the AŽD repository system:

- Stores the digital map and provides information from the digital map.
 - Creation of micro mapping points based on the received JP.
 - Processing and transmitting track conditions from the digital track map.
 - Processing and transmitting signal locations and descriptions for SCV.
- Fully functional interception of communication over the SS 126 communication interface (mainly includes SP and JP reception and processing).
- Processing MP.
- Autonomous data input to the train.
- Provide information about travelled route to the LOC (micro mapping nodes with segment ID, segment country code and depth in the segment).

Communication:

- PAL – REP (C5)
- APM – REP (C28)
- LOC – REP (communication interface defined by AZD)
- Intercept ATO-OB – ATO-TS (SS 126)

Communications are based on the SRS ATO up to GoA3/4 v1.1.0, (interface communications are specifically described in annex A). It is necessary to correctly intercept communication on the SS 126 interface and communicate with other systems located on the train (APM, PAL, LOC).

8.2.5.2 Deviations from current generic specifications

For further development, there is a need to have support on the track side to provide digital maps, train operational data and to perform missions.

8.2.5.3 Other specific needs

To ensure interoperability within the demonstrator, we propose the following procedure:

- Approval of necessary modifications to the interfaces between modules (C5, C28, SS 126)
- Define sequence diagrams to describe the exact behaviour of REP
- Identify laboratory testing options. Testing single interfaces vs. testing a complete system with the need to implement a train simulator
- Laboratory testing
- Testing in a real environment on a train
- Provide data on the line Kopidlno - Dolní Bousov for the preparation of a digital map

8.2.6 REPOSITORY-OB Module (ALSTOM)

8.2.6.1 Implementaion of the technical component

ATSA's REPOSITORY-OB module is nothing else than one of the "Automating functions"-related ATO up to GoA4 module being specified within EURAIL FA2 R2DATO WP6, WP9 and WP27.

The REP-OB module intends to implement the set of ATO up to GoA4 related functions that will be necessary to ensure the collection of all the Mission or Journey or Segment Profiles-related data that are required to be available on board to ensure the future operation of semi- or fully-autonomous trains covered by the system specifications currently being defined within the EU RAIL programme.

The ATSA's REP-OB module shall implement the sequence diagrams and the inter-modules interfaces that shall be defined and agreed between all WP46 partners to support the Use Cases selected for WP46 as resulting from the strict and only application of the available SRS 1.1.0.

As any other ATO GoA4-related module, the ATSA's REP-OB module is an applicative software that shall be implemented on an "Automating functions"-dedicated computing unit that, as shown in Figure 18 above, is part of the ATO GoA4 solution that ATSA intends to deliver for the sake of WP46.

Finally, the REP-OB module developed and delivered by ATSA shall take benefit of the discretion let to the suppliers of the REP-OB to define the way that the Mission / Journey & Segments profiles data related to the WP46 scenarios to be validated on site connect with the ATO-TKS module finally put at disposal will be available on board.

For this objective, a Trackside subsystem based on Digital Register &Traffic and Train Management System-like solution should be developed and interfaced (by radio) to only the ATSA REP-OB module.

8.2.6.2 Requirements for testing vehicle

As illustrated in Figure 18 above, the ATSA's REP-OB module shall be implemented within a "Automating functions"-dedicated computing unit.

This "Automating functions"-dedicated computing unit will be the same as the "Automating Driving functions"-dedicated computing unit.

Ergo, its main (but not exhaustive) features will be the ones listed in section 8.2.2.2.

More details / features could be given later to support the installation design studies deemed to be in charge of AZD as knowing perfectly the reality of the train and specially the risk of disturbance with units / antenna that should / could already installed.

The only requirement for implementing the "Automating functions"-dedicated computing unit is to take care for this computing unit to be carefully installed in a dedicated cabinet while considering the installation constraints that results from the main features listed above and that should / could be completed later.

8.2.6.3 Other specific needs

Prior to any testing phase and therefore, in the last quarter of 2025 or early in 2026, it will be necessary to plan :

- One or 2 days to test and commission the REP-OB module, i.e. specially but non exhaustively the ability of the REP-OB module :
 - To exchange data with the other ATO GoA4-related modules (addressing plan, same implementation of the interfaces defined and agreed)
 - To interface by radio with the Trackside subsystem designed to provide all the Mission, Journey and Segment profiles data related to a test scenario to be executed

The REP-OB module as any ATO GoA4-related modules developed and delivered by ATSA for the sake shall be subject to a laboratory test campaign prior to any formal tests on site.

Any test (scenario) that is to be carried out during the WP46 test campaign on, site planned for the first half of 2026 will have to be clearly and precisely described in a WP46 detailed test plan that is yet to be written.

This test plan shall detail for each scenario the Mission or Journey to be executed and the list of Segments that the train will use for moving along the track so as to ensure the proper and complete execution of the test scenario.

8.2.6.4 Deviations from current generic specifications

The REP-OB module as any ATO GoA4-related modules delivered by ATSA for the sake of the EU RAIL FA2 WP46 shall be designed and developed according to the sequence diagrams and inter-modules interfaces agreed by all partners as resulting from the strict and only application of the SRS 1.1.0 delivered by EU RAIL FA2 WP6 which is the most up-to-date system specification currently available.

The only deviations allowed (if any) shall only result from lack (if any) of system specification to cover the Use Cases selected for WP46.

They shall be fully agreed by all WP46 before and for being implemented.

This is indeed the only way to secure the demonstration of the interchangeability between ATO GoA4-related modules as delivered by different suppliers.

The use of mono-directional Segment Profiles and therefore the necessity to have specific Segment profile for each direction of travel is not really consistent with the data model currently being defined within EURAIL FA2 WP27. This point will need to be discussed before adoption such a strategy for describing track layout.

8.2.7 PAL (generic description)

The Protection Adaptation Layer component is in the eyes of AZD considered a system, whose main objective is to create a temporary extension of standardized up-to-GoA2 ATO compatible ETCS, to implement new train protection-related functionalities and interfaces to enable development and testing of GoA3 to GoA4 operation. It represents a virtual field for discovery, research, development and testing, to be able to determine all the prerequisites for future GoA3-4-compatible interoperable train protection system. The system is placed between standard ETCS and other key components of an autonomous train. It works both with existing interfaces that are preserved towards GoA2-standardized systems, while at the same time it implements completely new interfaces towards GoA3-4 specific components. In the case of existing interfaces, it can modify existing data as it passes through to or from ETCS, while through new interfaces it acquires and provides key information leading to how to modify the affected existing data to achieve driverless operation.

In simple terms, the system should adapt new automated safety-related functions and behaviours that, in GoA2 or lower grades of automation, would be performed by the driver – e.g. stopping for an obstacle in front of the train. However, the system itself does not make any decisions and is not a direct actor reacting with physical train components such as brakes or traction. It does not have any of its own independent data sources - the system only responds to commands from systems such as APM, and based on these commands adjusts the data flowing towards final actors such as ADM/ATO. According to the previously mentioned example of stopping in front of an obstacle, PAL reacts to information about this obstacle from APM, after which it shortens the speed profile and movement authority of ETCS to the position of this obstacle, while the final actor of this procedure is ADM/ATO, which leads the train to stop in front of this obstacle.

8.2.8 PAL (AŽD)

8.2.8.1 Implementaion of the technical component

AZD's specific research & testing HW implementation is based on ARM64 architecture, with SW implemented using generic programming language with cross-platform compatibility, along with a REP module and simulation applications that can be used to emulate surrounding systems, serving as a backup solution or enabling test scenarios that deviate from regular railway operation scenarios. The aim of this approach is, among other things, to limit the system's dependence on a specific vehicle and to enable connectivity with various systems from other manufacturers. Also, a multi-platform control and diagnostic user interface will be implemented for REP, PAL, and simulation systems.

System functions are divided into several categories:

1) Enable reaction to a track obstacle by shortening MA, reaction to an unprotected level crossing by changing the ETCS speed profile.

- Affected interfaces: C16, Subset-130

2) Enable driverless train data entry using a dedicated interface to REP

- Affected interface: C5

3) Respond to the recognition of traffic signs by incorporating the relevant ETCS packets into the data communication (SCV support)

- Affected interface: C17

8.2.8.2 Deviations from current generic specifications

Regarding manufacturer-specific implementation, there are no fundamental specifics of AZD's solution, but it is the specifics resulting from the provider of the given ETCS-OB system, that must be considered. In this demonstration, used ETCS-Onboard on the test vehicle provides implementation of the Subset-130 interface, that is sufficient for the autonomous train movement, but some other functionalities may have to be implemented as some form of a workaround. For example, the ETCS-OB sends static and dynamic profiles to ADM/ATO, but it is not capable of providing train data values. Therefore, a specific solution for (automated) train data entry to both ETCS and ATO is going to have to be used as part of PAL implementation.

8.2.9 PAL (ALSTOM)

8.2.9.1 Implementaion of the technical component

ATSA's PAL module is nothing else than one of the "Automating functions"-related ATO up to GoA4 module being specified within EURAIL FA2 R2DATO WP6 & WP9.

The PAL module intend to (temporally) implement the set of ETCS-OB related functions that will be required to ensure the future operation of semi- or fully-autonomous trains covered by the system specifications currently being defined within the EU RAIL programme.

The ATSA's PAL module shall implement the sequence diagrams and the inter-modules interfaces that shall be defined and agreed between all WP46 partners to support the Use Cases selected for WP46 as resulting from the strict and only application of the available SRS 1.1.0

As any other ATO GoA4-related module, the ATSA's PAL module is an applicative software that shall be implemented on an "Automating functions"-dedicated computing unit that, as shown in Figure 18 above, is part of the ATO GoA4 solution that ATSA intends to deliver for the sake of WP46.

8.2.9.2 Requirements for testing vehicle

As illustrated in Figure 18 above, the ATSA's PAL module shall be implemented within a "Automating functions"-dedicated computing unit.

This "Automating functions"-dedicated computing unit will be the same as the "Automating Driving functions"-dedicated computing unit.

Ergo, its main (but not exhaustive) features will the ones listed in section 8.2.2.2.

More details / features could be given later to support the installation design studies deemed to be in charge of AZD as knowing perfectly the reality of the train and specially the risk of disturbance with units / antenna that should / could already installed.

The only requirement for implementing the "Automating functions"-dedicated computing unit is to take care for this computing unit to be carefully installed in a dedicated cabinet while considering the installation constraints that results from the main features listed above and that should / could be completed later.

8.2.9.3 Other specific needs

Prior to any testing phase and therefore, in the last quarter of 2025 or early in 2026, it will be necessary to plan :

- One or 2 days to test and commission the PAL module, i.e. specially but non exhaustively the ability of the PAL module :
 - To exchange data with the other ATO GoA4-related modules (addressing plan, same implementation of the interfaces defined and agreed)
 - To interface with the ETCS-OB (SS-130) so as to collect the driving instructions/movement authority to be considered by the ADM module

The PAL module as any ATO GoA4-related modules developed and delivered by ATSA for the sake shall be subject to a laboratory test campaign prior to any formal tests on site.

Any test (scenario) that is to be carried out during the WP46 test campaign on, site planned for the first half of 2026 will have to be clearly and precisely described in a WP46 detailed test plan that is yet to be written.

8.2.9.4 Deviations from current generic specifications

The PAL module as any ATO GoA4-related modules delivered by ATSA for the sake of the EU RAIL FA2 WP46 shall be designed and developed according to the sequence diagrams and inter-modules interfaces agreed by all partners as resulting from the strict and only application of the SRS 1.1.0 delivered by EU RAIL FA2 WP6 which is the most up-to-date system specification currently available.

The only deviations allowed (if any) shall only result from lack (if any) of system specification to cover the Use Cases selected for WP46.

They shall be fully agreed by all WP46 before and for being implemented.

This is indeed the only way to secure the demonstration of the interchangeability between ATO GoA4-related modules as delivered by different suppliers.

8.2.10 PERCEPTION (AZD)

8.2.10.1 Implementaion of the technical component

The implementation of the AŽD Perception system is based on the specifications and requirements developed in Task 6.3 of R2DATO project.

The AŽD Perception system consists of three basic parts.

- On-board sensors

Each train head is equipped with a set of sensors that monitor the area in front of the train. The sensors are mounted in special weatherproof pockets. There is a pair of cameras with different focal lengths, two LiDARs with IMU and an infrared camera on each head of train.

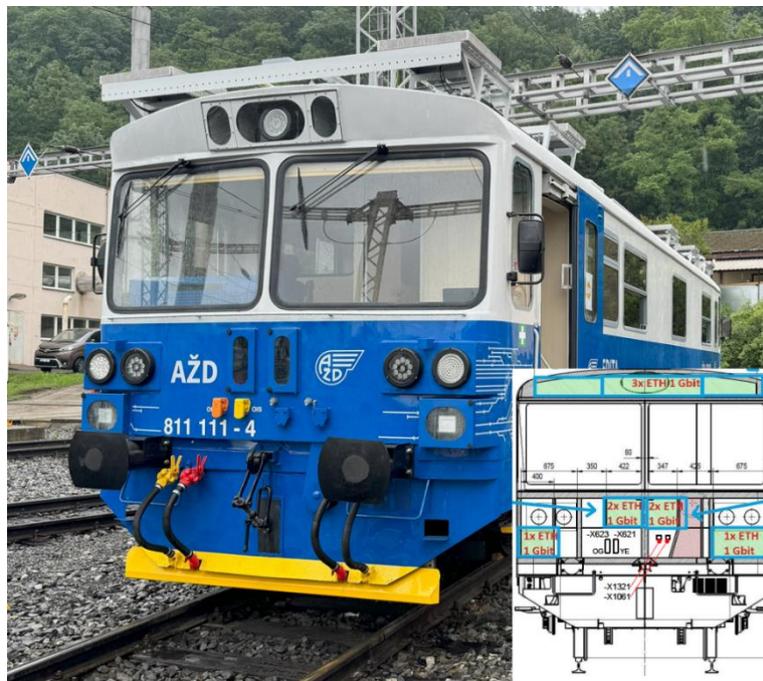


Figure 19: Integration of Perception system into vehicle

- Trackside sensors

An intelligent camera that is installed on the track and is able to inform an approaching train of a possible dangerous situation. This camera is used to monitor the unprotected level crossing.

- Computing unit

A computing machine, which processes all the sensor data, is placed in the switchboard inside the train. This machine is connected to the internal technology network, where communicates with other modules.

8.2.10.2 Deviations from current generic specifications

The AŽD perception system will differ from the system described in chapter 4.4 in that it will not include the features for “Detection of infrastructure defects and anomalies”. The perception system must be connected to the internal network over Ethernet where communication will take place:

- PER - APM (C8)

This communication is based on the SRS ATO up to GoA3/4 v1.1.0

- PER - LOC (NAV_INFO C62)

This communication is based on the same document. For proper functionality and higher accuracy of the system, it is necessary to ensure that data from LOC will be sent at 50 Hz.

8.2.10.3 Other specific needs

We require laboratory testing of the communication between PER-APM and LOC to verify system interoperability. For these tests we can use real sensor data captured from previous runs.

8.2.11 PERCEPTION (WABTEC)

The implementation of the WABTEC Perception system is based on the specifications and requirements developed in Task 6.3 of R2DATO project.

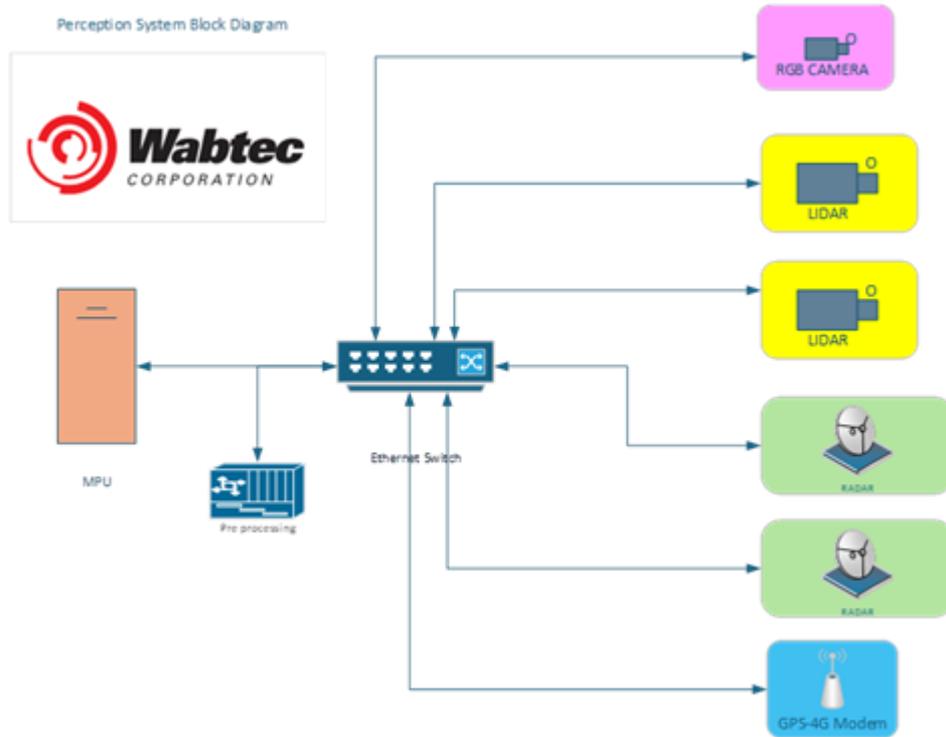
8.2.11.1 Introduction

The WABTEC On-Board Railway Perception System aims to provide real-time detection and monitoring capabilities directly onboard the train. The system must be able to gather data from environmental sensors and detect potential obstacles, railway signals, track conditions, and other critical events along the railway route and its surroundings. The collected data should be processed in real-time and used to optimize train operations, enhance safety, and prevent emergency situations.

8.2.11.2 Functional Requirements

- **EGO Track Identification and Real-Time Objects Detection and Classification:** The system must be capable of detecting and classifying objects or obstacles along the track (e.g., people, vehicles, stationary trains, animals, etc.) in real-time.
- **Railway Signal Monitoring (Optional):** The system must be able to detect and interpret railway signals along the route (e.g., light signals, stop signals) and provide this information to the driver.
- **Track Monitoring for Weather Conditions:** The system shall detect rain\snow conditions affecting railway tracks.

8.2.11.3 Block diagram architecture



8.2.11.4 Main Components

- **MPU:** Main Process Unit: data processing,
- **Pre Processing Data:** data fusion
- **Ethernet Switch:** data routing
- **High-Resolution Camera (Optical Sensors):** RGB camera to detect objects along the track, even in low-light or reduced visibility conditions (e.g., at night or in fog).
- **LIDAR (Light Detection and Ranging):** LIDAR sensors for distance measurement and creating a 3D map of the railway route and surrounding objects.
- **RADAR Wave Millimetre:** Radar systems to detect obstacles and objects in adverse weather conditions, such as rain, fog, or snow.
- **GPS unit:** To determine the precise geographical position of the train along the railway line.

8.2.11.5 Use Cases

- Wabtec Perception system HW/SW setup for the below use cases.
- UC5.2-0008 Rail Adhesion Estimation using Perception
- UC5.2-0030 Wandering livestock, animals or other objects on or close to the Tracks
- UC5.2-0036 Long range detection and recognition of signals applicable to train route (Optional)
- UC5.2-0041 Evaluating ego track and Obstacle detection

8.2.11.6 Deviations from current generic specifications

The Wabtec perception system (during demo test) will not communicate with any internal Train logic system (TCMS\OAS\ATP): Standalone Perception system

8.2.11.7 Other specific needs

A dedicated train inspection needs before to proceed with the PER system integration on Train, installation requirements should be defined, cable routing study and space measurement are mandatory before to start any activities on Train.

8.2.12 LOCALISATION (AZD)

8.2.12.1 Implementaion of the technical component

The key technology used in AZD's ASTP solution is GNSS supported with GNSS augmentation (EGNOS). The ASTP output itself (absolute position output) is generated using a fusion algorithm where GNSS measurements are combined with kinematic sensors. The role of the kinematic sensors is to ensure the overall safety requirements for the ASTP output but also to enable an absolute position in GNSS challenging environments.

AZD's ASTP solution also uses ETCS balises, the track map and route information (or switch status information at least).

The ASTP demonstrator consists of two 19" subracks (2U and 3U height) and other components (sensors, sensor interface unit, antennas). These two subracks are installed in a common rack. Details follow:

- The 2U subrack is an industrial computer designed according to CENELEC EN 50 155. This is a central part of the demonstrator processing all receiver and sensor data and producing the required outputs (position, speed, attitude). The ASTP output is made available to other consumers via an Ethernet interface.
- The 3U subrack consists of 2x GNSS receivers, a power supply unit, RF power splitters and DC blocks, and a supporting unit for an external optical marker detector.
- The sensor interface unit is installed in a separate rack and connected with the industrial computer with Ethernet. The role of this unit is to power the sensors (wheel encoder, Doppler radar) but more importantly to act as a common interface towards other vehicle systems.
- The wheel encoder is mounted on a non-driving axle (the axle arrangement of the EDITA test vehicle is 1'A'), the Doppler radar then under the vehicle frame. The optical marker detector is also mounted on the vehicle frame close to the longitudinal axis of the vehicle.
- The ASTP demonstrator (all its components) is powered by 24 V DC.

8.2.12.2 Deviations of AZD's localisation solution

AZD's ASTP solution reflects most of the requirements and current assumptions agreed upon in WP21 and WP22 of R2DATO. However, there are certain AZD's extensions and deviations from the common ASTP specifications. In addition, the implementation of the ASTP solution as a demonstrator also includes compromises (simplifications) that allow its testing in a situation where not all counterparts are fully developed or even specified. All such compromises and simplifications are described in this section.

The following bullet points summarise and explain the main deviations of the AZD localisation solution with respect to the baseline documents [4]:

- Track map extension: AZD's map contains an additional map layer "a priori reception information".
- Utilisation of vehicle reference point: All information generated by the ASTP (position, speed, ...) is related to the vehicle reference point (not to the front of the train).

- Attitude restricted to the track map: Due to the strong map dependency of AZD's solution, all ASTP output information (position, speed, but also attitude) is provided on the track axis (i.e. all outputs are track centreline constrained).

For the purpose of the ASTP demonstrator (to allow testing of ASTP and other components relying on ASTP output), certain simplifications have been proposed. These are explained below:

- GNSS augmentation: GNSS augmentation interface will be emulated and data generated on board using a simple model.
- Map data: AZD's ASTP demonstrator relies on "a priori reception data", which is an individual layer in the map data (on top of the track axis description). This layer will be part of map data too.
- Route data or Switch status information: Data will be prepared for specific test cases and uploaded on board before the tests.
- The interface between BTM and the ASTP demonstrator will not be implemented. In case there is a need to test discrete spot position improvement in the ASTP algorithm, optical markers and an optical detector can take over this role.
- The interface between CMD and the ASTP demonstrator will not be implemented.

8.2.12.3 Specific needs for integration of ASTP/LOC demonstrator

This section proposes the steps (tests) necessary to integrate an ASTP demonstrator (from any provider) into the integrated demonstrator of an autonomous train. The relevant actors used in the description below are: ASTP demonstrator provider (ADP), EDITA vehicle owner (AZD)

Internal interfaces:

- GNSS receivers: two Septentrio receivers (Mosaic-T) are already installed on the EDITA vehicle. The utilised data format is SBF (Septentrio Binary Format) and is defined in this document [5].
 - ADP: The configuration of Septentrio receivers (either common one or individual, different for each receiver) is prepared.
 - AZD: The configuration is uploaded to the receivers. The receiver output data streams are recorded into a file during the movement of the EDITA vehicle. Note that this record is done simultaneously with the sensor data record.
 - ADP: lab test: The output data stream generated by the receivers is fed into the ASTP demonstrator core to check that the data are correctly parsed and understood.
 - ADP: on-site test: One or both receivers are connected with the ASTP demo core. The physical interface can be either UART/RS232, USB or Ethernet (in line with the provided configuration). The demonstrator core then checks that the receiver data generated in real-time are correctly parsed and understood.
- Kinematic sensor data: The EDITA test vehicle has installed the wheel pulse generator BAUMER BPIV2-D1F1.QRU.V1.B1.B1.0.4/ELEKTRONIKA and the Doppler radar Deuta

DRS05/3, data of both devices are available via the common interface card. The physical interface is an Ethernet interface. The format of sensor data is described in this document [6].

- AZD: The sensor output data streams are recorded in a file during the movement of the EDITA vehicle. Note that this record is done simultaneously with the receiver data record.
- ADP: lab test: The output data stream generated by sensors (wheel impulse generator, Doppler radar) is fed into the ASTP demonstrator core to check that the data are correctly parsed and understood.
- ADP: on-site test: The demonstrator core is connected to sensors via an Ethernet interface. The sensor data, real-time generated, are fed into the demonstrator core to check if correctly parsed and understood.

External interface: input:

- Map data: The track map, containing the complete 3D description (in the node edge model) of all track sections, is provided as a file. The format description is available in this document [7].
 - ADP: lab test: The map data file is read by the demonstrator core to check that the map data are correctly parsed and understood.
- Route info: The route info is provided in the form of a list of segment profiles (SPs) on which the train is moving. The format describing this information is available in this document [8].
 - AZD: The route info (list of SPs), which is valid for that EDITA vehicle move, for which receiver and sensor data were recorded, is provided.
 - ADP: lab test: The route information is provided to the demonstrator core to check that the information is correctly understood. Also the fact that the parsed route info results into the unique route in the map is checked.
- GNSS Augmentation data: The way how this data is provided are not decided yet. One of the option is that the data are emulated directly inside the demonstrator core (thus, in that case, they are not provided via an external interface).

External interface: output:

- The output position and kinematic information (position, speed, attitude, etc.) estimated by the demonstrator are provided in the format described in this document [9].
 - ADP: lab test: The output information (position, speed, attitude, ...) is generated (estimated) using demonstrator while fed with recorded receiver and sensor test data. The output information is provided in the agreed format.
 - AZD: The output information is read to check that the data can be correctly parsed and represent the corresponding train move (used during the test data preparation).
 - ADP: on-site test: The ASTP demonstrator is connected with receiver(s) and sensors, ASTP demonstrator output is connected via the Ethernet interface to all on-board

consumers inside Autonomous train demonstrator (PER, ATO-AV, APM). During the EDITA train movement, the real-time position, speed, attitude, etc. are generated (estimated) by the demonstrator and this information is provided to all consumers.

- AZD: on-site test: The provided output information at all consumer inputs (PER, ATO-AV, APM) is read and analysed if represents correct train movement.

8.2.13 LOCALISATION (INDRA)

Description of INDRAS's localisation solution

- The INDRA ASTP solution makes use of different inputs from external sources and onboard systems. The demonstrator will fuse the information obtained from different GNSS positioning sources GPS, GALILEO and EGNOS. From onboard sources odometry system, accelerometer and track side beacons.

What are the requirements of this implementation towards demo vehicle or infrastructure

- Only in the wagon after the locomotive is required install:

A rack composes with all the different devices that composed the Indra architecture for TIMS and ASTP performance (CMW, MIT central process unit, JRU)

WSN coordinator.

Positioning system (INDRAS's ASTP or other external sources)

1 display (INDRAS's HMI)

- Specific needs for integration of this particular device to the demo (actions or activities to be done prior the demonstration)
- The INDRAS's TIM and ASTP modules have been designed to work in synergically to improve its performance. Take this into account, the demonstrator is an opportunity to test the efficiency of both systems. Also, some MIT functionalities use data from ASTP to determinate the length of the track that is occupied by the train when its lost integrity.

In addition, how both systems have been designed to be deployed in the same infrastructure, the installation complexity and time are reduced. The only great difference between install or not together is that is mandatory deploy a TIM module in each wagon that composed the train.

Any deviation or limitation from the generic description (chapter 5)

- The ASTP demonstrator relies on external inputs that should be provided by interoperable interfaces this information is managed by the Position manager decision. The specifications of these interfaces (in WP22) are still volatile and therefore their implementations are not yet at an advanced stage.

These interfaces are explained below:

GNSS augmentation: The ASTP positioning algorithm processes GPS Galileo and Glonass. GNSS receptors are integrated in INDRA's ASTP solution. ML Measurements Correction Module receives the input from all the available sources through the standard interfaces of each one. The module

selects the optimal GNSS source based on the provided metadata, included in the information transmitted from the GNSS source.

On-Board accelerator system: Accelerometer system is integrated in INDRA's ASTP solution. In particular, INDRA intends to use an Inertial Measurement Unit (IMU) device. It provides information relating the acceleration of the train in three axis and the orientation of these acceleration components, providing 6D information.

Digital Map data: Map data are available for the entire line, including all station tracks. The data are static (valid for all test scenarios), so they can be uploaded on board.

Train Position Agent Decisor: Interface providing 1D corrected positioning measurements from the ML Measurements Correction Module.

8.2.14 REMOTE CONTROL (AZD)

8.2.14.1 Implementaion of the technical component

The implementation of the AZD remote control conforms to the specifications and requirements developed in Task 6.7 of R2DATO project. The AZD remote control implementation will consist of two parts.

The first part is Remote Control - Trackside (RC-TS), where two types of control panels will be developed. The first will be a control panel placed at the operator's workstation for remote control, designed according to the classical console on the train. The second will be a mobile device for the pedestrian driver, designed for shunting.

The second part is Remote Control - On-board (RC-OB), which provides connectivity between RC-TS and the on-board modules (e.g. ADM, APM...).

It is important to ensure connectivity between the remote-control panel and the vehicle. It is important to emphasize the quality and transition speed of the connection, because of the high-resolution video stream transfer with low latency. The second requirement is low latency for the transmission of data between the train and the remote-control panel. It is also necessary to ensure the security of transmission, authorization and permissions. Additionally, the vehicle must be equipped with the necessary sensors.

8.2.14.2 Deviations from current generic specifications

The Remote control will need to communicate with ADM, APM, sensors and LOC. The interfaces are not yet fully specified.

8.3 IMPLEMENTATION AND DEMONSTRATION PLAN

This chapter outlines the comprehensive plan of Task 46.3 and Task 46.4 for implementing and demonstrating the project's key components. The plan is divided into several phases, each with specific milestones and related activities designed to ensure systematic progress and successful outcomes. The milestones and activities are structured to provide a clear roadmap from initial

specifications to final deliverables, ensuring thorough testing and validation at each stage. Below is a detailed breakdown of each phase.

8.3.1 Milestones and related activities

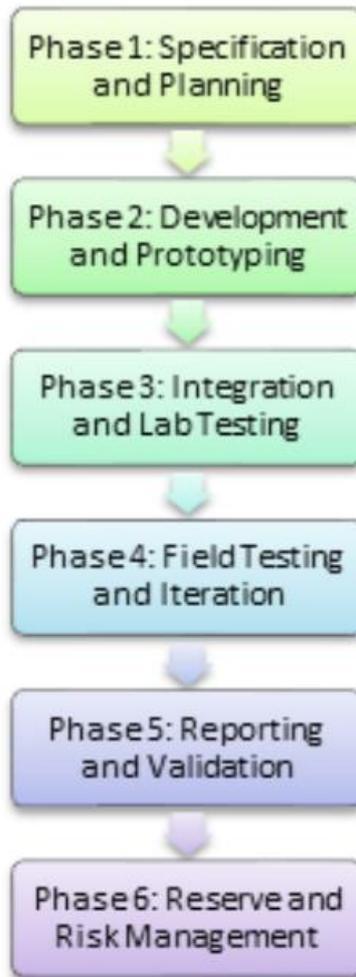


Figure 20: Overview of the WP46 project phases

8.3.1.1 Phase 1: Specification and Planning

1. Specs Finalisation

Duration: Week 1–15

This initial phase focuses on finalising the technical specifications that will guide the development of prototypes and testing scenarios.

It sets the foundation for subsequent development activities.

8.3.1.2 Phase 2: Development and Prototyping

2. Prototype Developments

Duration: Week 11–42

In this overlapping phase, technical components and solutions are developed based on the finalised specs.

The long duration suggests extensive work on software, hardware, or system integration elements.

8.3.1.3 Phase 3: Integration and Lab Testing

3. Lab Tests

Duration: Week 40–48

Components developed in the previous phase are tested in a controlled lab environment.

This phase helps identify early issues before real-world testing.

4. Prototype Installations

Duration: Week 49–53

During 12/2025 all prototypes (WP9,10,11,12,22) must be delivered to be installed on the train

This involves integrating and installing prototypes into actual test platforms (e.g. train, test track).

It marks the transition from lab to field readiness.

8.3.1.4 Phase 4: Field Testing and Iteration

5. Test Executions

Duration: Week 54–58

The core field-testing phase includes three **rounds** of execution with interleaved periods for potential modifications.

Round 1 (Week 54)

Modifications 1 (Week 55)

Round 2 (Week 56)

Modifications 2 (Week 57)

Round 3 (Week 58)

This approach allows iterative improvements and maturity checks of the system under test.

8.3.1.5 Phase 5: Reporting and Validation

6. Deliverable Finalisation

Duration: Week 59–62

Results and outcomes from the testing phase are compiled into a deliverable.

Includes documentation, analysis, and conclusions.

7. Deliverable – Internal Review

Duration: Week 63–66

The compiled deliverable undergoes internal quality checks and validation by project partners.

8. Deliverable – Project Review

Duration: Week 67–72

Final review process at the project level, possibly involving external stakeholders or reviewers.

8.3.1.6 Phase 6: Reserve and Risk Management

9. Reserve

Duration: Week 73–75

A planned buffer phase for risk mitigation, delayed tasks, or final wrap-up activities.

9 CONCLUSIONS

The D46.1 deliverable marks a significant milestone in the R2DATO project's pathway toward demonstrating and validating autonomous train operation technologies within a regional railway environment. The work detailed herein represents the successful completion of the first phase of Work Package 46, specifically addressing the activities under Tasks 46.1 and 46.2 — the definition of testing scenarios and the preparation of the regional line demonstration plan.

Through close collaboration among the WP46 partners — AŽD, ALSTOM, FAIVELEY, INDRA— a comprehensive framework has been developed, focusing on identifying the technical enablers, selecting relevant and feasible use cases, and defining test environments and scenarios. The approach taken adhered strictly to the “SRS ATO up to GoA3/4 v1.1.0” specification, ensuring consistency, standardization, and forward compatibility of the demonstrator with future European specifications.

One of the core strengths of this planning phase was the pragmatic handling of challenges, such as incomplete or evolving specifications and practical limitations in the regional test infrastructure. Interim solutions and agreed assumptions allowed the project to maintain momentum while staying aligned with the overarching objectives of R2DATO and the Europe's Rail Joint Undertaking.

The outcome of this deliverable includes:

- A structured plan for testing a wide range of use cases that reflect realistic and critical operational scenarios for ATO up to GoA3/4.
- A validated methodology for defining and executing test cases with clarity on success criteria, actors involved and expected outcomes.
- A thoroughly characterized regional test line environment, including test vehicle configuration and supporting infrastructure.
- An integration and demonstration plan that synchronizes technological components developed across multiple partners.

The deliverable establishes a solid foundation for the next phase of WP46 — implementation, testing, and validation. It enables the upcoming activities in Tasks 46.3 and 46.4, which will focus on execution, evaluation, and refinement of the demonstrations. In conclusion, D46.1 not only consolidates the preparatory efforts made by the consortium but also reflects a high level of technical coordination and readiness for conducting meaningful, specification-driven demonstrations. The insights and test results generated in the forthcoming phases will provide valuable feedback for future autonomous rail systems and contribute to the maturation of key technologies underpinning digital and automated rail operations in Europe.

Building on the results achieved in this phase, the Use Cases and corresponding test scenarios defined in D46.1 will form the basis for the development of detailed sequence diagrams, which will specify the behaviour of each module and the communication flows between them. These diagrams will support alignment among partners on the expected system interactions and will guide the adaptation of the interfaces required for integration in the demonstrator.

The next phase will also include the definition of the segment profiles of the test line, followed by the refinement of the hardware and software configurations of all involved components. Prototype implementations will be adapted according to the characteristics of the vehicle and the testing environment, and the test schedule will be further detailed down to the level of individual activities planned for each testing day.

REFERENCES

During the development of this deliverable there were numerous documents that served as a basis for establishing common base for identification of tested use cases, common base for prototypes development, definition of test cases and scenarios for testing. These documents, for clarity reasons are not mentioned individually next to each positions where these references are valid, but rather are enumerated here and as references and source documents are valid for whole document D46.1.

- [1] FP2-T5_1-D-NSR-124-05 - Deliverable D5.1 Documentation of use cases for automating functions
- [2] FP2-T5_2-D-FTS-040-05 - Deliverable D5.2 Documentation of use cases for Perception system
- [3] FP2-T5_3-D-STO-027-03 - Deliverable D5.3 ATO GoA3/4 Specifications review documentation
- [4] FP2-T5_4-D-MER-011-04 - Deliverable D5.4 Documentation of use cases for Remote Driving
- [5] FP2-T6_1-D-SMO-035-03 - Deliverable D6.1 Report on sets of non-functional and functional requirements (SRS) for automating functions
- [6] FP2-T6_3-D-FTS-045-03 - Deliverable D6.3 Architecture and System Specification for Perception System
- [7] FP2-T6_5-D-STO-057-03- Deliverable D6.5 ATO GoA3-4 Specifications and modelling (SRS 1.1.0b)
- [8] FP2-T6_7-D-NSR-027-03 - D6.7 Report on set of non-functional and functional requirements (SRS) for remote driving
- [9] FP2-T22_1-B-SMO-001-01: WP22 D22.1 – ASTP Report on Common Overall Design and Architecture. 28/11/2024.
- [10] mosaic-T Reference Guide, 2024-12-02 / Applicable to version 4.14.10.1 of the Firmware. Septentrio NV.
<https://www.septentrio.com/resources/mosaic-T/mosaic-T+Firmware+v4.14.10.1+Reference+Guide.pdf>
- [11] R2D-WP46-I-AZD-001-04: RF and Speed/Distance Sensor Onboard Interface for ASTP Demonstrators. 22/04/2025.
Filename: R2D-WP46-I-AZD-001-05 - RF and Sensor Onboard Interface for ASTP demonstrators.docx
- [12] Track Map Data Format Specification for ASTP Demonstrator (in preparation)
- [13] Route Info Interface Specification for ASTP Demonstrator (in preparation)
- [14] Output Format Specification for ASTP Demonstrator (in preparation)