

# Rail to Digital automated up to autonomous train operation

## D5.5 – Documentation of Freight specific user requirements for automation process

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## EXECUTIVE SUMMARY

Automatic train operation (ATO) has been employed for many years, primarily within local public transport and mass transit. However, the knowledge and experiences gained from these applications is only partly transferable to freight transportation and is better suited for multiple-unit passenger transport. The coupling between locomotives and coaches impacts the braking and propulsion behavior of a freight train in a non-uniform way. Accordingly, with the application of ATO to freight trains new challenges arrive that until today were not extensively tackled by.

To close this gap, this deliverable provides a definition of freight specific user requirements for the different tasks of automatic train driving up to Grade of Automation 4 (GoA4), a safe perception system and remote driving. The freight specific user requirements are presented as a structured list compiled by the Freight Railway Undertakings working together in this Task 5.5. The developed list provides an important basis for further collaboration on the development of ATO, especially within FP2 R2DATO. The requirements shall be used to verify and validate the design and demonstrator outcome for freight against all defined requirements herein. In addition to this deliverable, the requirements will be provided as a separate list (see Annex A) for better usability. But since such a file is not document proof, this main document remains the only reference for further discussions.

The scope of the presented user requirements is freight specific. Accordingly, general ATO requirements are out of scope. Similarly, the user requirements focus on mainline operation with ATO GoA2-4 as the main target operation. This implies that remote operation is meant for supervision of GoA4 operation and remote control of the train in degraded mode or in the case of an emergency. Remote operation is not intended as target operational mode.

In addition to the freight specific user requirements, a stakeholder analysis and the description of operational modes are presented. The definition of a (preliminary) hazard log as well as of testing and validation cases are presented within the Annex of this document. They are out of scope of this document but are useful for further discussions. Accordingly, they are integrated informatively as best-case examples.

In the further course of FP2 R2DATO, the freight specific user requirements will be applied enabling their further refinement in future projects. Moreover, the definition of a common set of use cases, test and validation cases and hazard logs will be necessary towards the development of a commercially usable product.

## ABBREVIATIONS AND ACRONYMS

Abbreviation	Explanation
AC	Alternating Current
AFB	Automatische Fahr- und Bremssteuerung (Automatic driving and braking control)
AL	Incident Leader
AoE	ATO over ETCS System
AsBo	Assessment Body
ATO	Automatic Train Operation
ATO-OB	ATO onboard
ATO-TS	ATO Trackside
ATP	Automatic Train Protection
bdd	Block definition diagram
CAB	Conformity Assessment Body
CAS	Cargo ATO System
CBTC	Communication-Based Train Control
CCD	Control and Command Display
CCS	Locomotive Command Control and Signaling
CEFR	Common European Framework of Reference
CENELEC	Comité Européen de Normalisation Electrotechnique
CSD	Circuit switched data
CSM	Common Safety Methods
CSM-RA	Common Safety Method for Risk Assessment
CSM-REA	Common Safety Method for Risk Evaluation and Assessment
DB	Deutsche Bahn
DBC	Deutsche Bahn Cargo
DeBo	Designated Body
DMI	Driver Machine Interface
DTA	Driver Task Analysis
DTO	Driverless Train Operation
DVL	Traffic Operator
EC	European Commission
ECM	Entity in Charge of Maintenance
EG	ATO engaged
EM	Emergency Management
EoA	End of Authority
ERA	European Union Agency for Railways
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
EVC	European Vital Computer
FBS	Fixed block systems
FFFIS	Form, Fit, Function, Interface Specification
FHA	Functional Hazard Analysis
FIS	Functional Interface Specification
FOC	Freight Operating Companies
FS	Full Supervision
GoA	Grade of Automation
GPS	Global Positioning System
GPRS	General Packet Radio Service

Abbreviation	Explanation
GSM-R	Global System for Mobile Communication – Railways
HCD	Human Centred Design
HMI	Human Machine Interface
ibd	Internal Block Diagram
ICD	Interface Control Document
ID	Identification
IM	Infrastructure Manager
IP	Internet Protocol
IPR	Intellectual Property Rights
ISA	Independent Safety Assessor
ISMS	Information Security Management System
IXL	Interlocking, control system that deals the routing of trains
JP	Journey Profile
JPP	Journey Profile Packet
JRU	Juridical Recording Unit
LTD	Local Train Driver
MA	Movement Authority
MCB	Main Circuit Breaker (also known as main switch)
MTTR	Mean time to repair
MTBF	Mean time between failures
MVB	Multiple Locomotive Bus
NA	National Railways Netherlands
NoBo	Notified Body
NSA	National Safety Authority
NTC	National Train Control (mode of ETCS)
OB	Onboard
OBU	Onboard Unit
OCCR	Operational Control Centrum Rail
OCD	Operational Concept Document
OCORA	Open CCS Onboard Reference Architecture
OCTYS	Open Control of Trains, Interchangeable & Integrated System
ODS	Obstacle Detection System
ODU	Obstacle Detection unit
OEM	Original Equipment Manufacturer
OPE	Operation and traffic management
OS	On Sight
OSD	Operating Sequence Diagram
OSI	Open System Interconnection
PHA	Preliminary Hazard Analysis
PLMN	Public Land Mobile Network
PTC	Positive Train Control
QRT	Quick Response Team
R2DATO	Rail to Digital automated up to autonomous train operation
RAMS	Reliability, Availability, Maintainability and Safety
RBC	Radio Block Centre
RCS	Rail Control System
RE	Ready mode
RF	Radio Frequency
RFC1	Rail Freight Corridor 1
RINF	Register of Infrastructure

Abbreviation	Explanation
RSC	Remote Supervision and Control
RSCC	Remote Supervision and Control Centre
RSC OB	RSC Onboard
S2R	Shift2Rail
SE	Systems Engineering
SH	Shunting mode ETCS
SIL	Safety Integrity Level
SMB	Stop Marker Board (Marked stop position)
SME	Subject Matter Expert
SoM	Start of Mission
SP	Segment Profile
SPAD	Signal passed at danger
SR	Staff Responsible
SRAC	Safety Related Application Conditions
SRT	Safety in Railway Tunnels
SS	Subset
SuC	System under Consideration
SyHA	System Hazard Analysis
TAF	Track Ahead Free
TCMS	Train Control Management System
TCS	Traffic Control System
TDD	Technical and Diagnostics Display
Tf	Driver (German abbreviation)
TMS	Traffic Management System
TP	Time Point
TraCo	Transport Control
TRD	Train Radio Display
TRDL	Signal Operator
TS	Trackside
TSI	Technical Specifications for Interoperability
UC	Use Case
UTO	Unattended train operation
UNISIG	Union Industry of Signalling
VCO	Voltage Change-over
VDT	Visual Display Terminal

## GLOSSARY

Business Term	Definition
Adhesion (Railway; Traction)	The term adhesion railway or adhesion traction describes the most common type of railway, where power is applied by driving some or all of the wheels of the locomotive. Thus, it relies on the friction between a steel wheel and a steel rail.
ATO Area	The area where, for Grades of Automation (GoA) 2 to 4, Automatic Train Operation is possible, informed by real-time dynamic update of operational data via a telecommunications link between the ATO on-board and ATO trackside subsystems.
ATO Available	ATO Available is the ATO state when the ATO-OB is ready for operation and is waiting for the Engagement Conditions to be fulfilled.
ATO Configuration	ATO Configuration is the ATO state when the ATO-OB executes self-tests procedures and receives the required ETCS Train Data.
ATO Disengaged	The status of the ATO on-board sub-system when it is not controlling train functions.
ATO Disengaging	ATO state when the ATO-OB losses the ATO Operational conditions while being engaged. The ATO-OB controls the braking command in order to bring the train to standstill waiting for the driver to disengage the ATO.
ATO DMI	The Driver Machine Interface (DMI) is used in the European Train Control System European Train Control System (ETCS) as an interface between the driver in the cab and the train. Complies with ERA_ERTMS_015560_modified for ATO
ATO Engaged	ATO state in which the ATO Onboard is responsible for driving the train, controlling brake and traction according to the computed ATO Operational Speed Profile.
ATO Failure	ATO state when the ATO Onboard has failed to power up, has failed its self-tests, has an in-service failure, or when it has detected a failure that does not allow it to perform its functions. This is applicable to the Failure state (FA).
ATO (Train, Area) Hold	The functionality that allows trains to be hold at a defined location for regulation purposes. This functionality can be applied to either one train only or a defined area with multiple trains or the whole service which may run through multiple traffic management-controlled areas.
ATO Inhibition Zone	The prevention of the ATO functionality over a defined area of the railway in the direction of travel. It may be in either or both directions of a bi-directional section of track.

Business Term	Definition
ATO Isolation Mode	ATO state when the ATO Isolation Switch is set to isolation position. In this state, some functions of ATO are inhibited.
ATO Not Available	ATO state when the ATO-OB is not ready for operation and it is waiting for the Operational Conditions to be fulfilled.
ATO Not Selected	ATO Not Selected is the ATO state when the ATO Selector is in NS position.
ATO OB System	Providing control to the train to GoA4 level
ATO Onboard	The sub-system and set of automated non-safety-related driver functions, depending on the grade of automation.
ATO Operational Speed Profile	The ATO operational speed profile will be calculated taking into account that during the powerless section ATO cannot command power.
	The most energy efficient speed profile calculated by the ATO on-board sub-system that fulfils the Journey Profile and respects the ETCS safe braking envelope.
ATO over ETCS System (AoE)	The set of interrelated or interacting components that provides ATO and ATP functionalities. The ATO over ETCS Operational Requirements cover ATO systems that shall be able to operate in GoA1, GoA2, GoA3 and GoA4
ATO Trackside	A set of functions that interfaces with the necessary trackside systems which contain the operational data and infrastructure data that is required by the ATO on-board.
ATO Trackside Handover	It is the process of passing the responsibility for an ATO train between two ATO trackside subsystems.
ATO TS System	Providing communication between TMS/TCS and train.
Automatic driving and braking control (ABF)	Technical system that is used in locomotives to support the driver in his work. The system takes on the driver task of accelerating or braking the locomotive and the train to a speed pre-selected by the driver and maintaining the speed.
Automatic Train Control System (ATC)	System which effects an emergency brake application if the driver does not react to certain signal aspects or speed restrictions.
Automatic Train Operation (ATO)	A method of operation in which different train operation tasks are automated, according to the Grade of Automation (GoA) level present, up

Business Term	Definition
	to GoA4 level, where the train is automatically controlled without the presence of staff on board.
Automatic Train Protection (ATP)	A system that enforces obedience to signals and speed restrictions by speed supervision, including automatic stop at signals.
Brake Blending	The service brake requires a brake blending as an interaction of those brakes which are designed for the use during service braking. In that case more than one brake system may act upon the same wheelset
Communication-Based Train Control	Railway signaling system that makes use of telecommunications between the train and track equipment for traffic management and infrastructure control. By means of CBTC systems, the position of a train is known more accurately than with traditional signaling systems. This results in a more efficient and safe way to manage railway traffic.
Configurable System	Capability of the AoE to co-exist with other systems in the same transport network without any interference.
Degraded Mode	Degraded modes are modes of operation designed to deal with faults. They have been taken into account when designing the Control-Command and Signaling Subsystems.
Degraded Operation	Any elementary component, group of components, sub-assembly or complete assembly of equipment incorporated or intended to be incorporated into the AoE.
Dispatch Order	The process whereby signalers or controllers can change the order or timing of trains to maximize overall train service performance in real time.
Disruptive Event	Any event or circumstance which prevents or disrupts the operation of trains.
Dynamic Brake	<p>The brake system that realizes the braking force using the motion of the locomotive but not involving friction.</p> <p>Note 1: There exist several types of dynamic brakes, e.g. electrodynamic brake (further divided to rheostatic and regenerative brake), hydrodynamic brake (retarder), aerodynamic brake or eddy current brake. If there are more types of dynamic brakes available on the entire train, the brake force distribution between them is done by TCMS.</p> <p>Note 2: From the principle, the braking force can be realized only if the speed of the locomotive is greater than a specific value.</p>

Business Term	Definition
ERTMS Users Group	The European Economic Interest Group established in 1995 by the national railways of France, Germany and Italy. The group currently consists of the infrastructure managers: ADIF (Spain), Banedanmark (Denmark), Banverket (Sweden), DB (Germany), Infrabel (Belgium),
ETCS	ETCS is a train control standard. ETCS can perform Automatic Train Protection (ATP) supervision on movement. This means, it can stop the train if the speed exceeds a maximum speed based on a corresponding calculated braking curve or a specified ceiling speed. This process can be performed with the ETCS equipment on the train and equipment on the track.
ETCS Level 1 FS	ETCS Level 1 Full Supervision (FS) enables full supervision, in which the position of the signals is also transmitted to the locomotive
ETCS Level 2	ETCS Level 2 is a radio based system which displays signaling and movement authorities in the cab. The train is continuously sending data to the Radio Block Centre (RBC) to report its exact position and direction. Eurobalises are used as passive positioning beacons.
ETCS Service Brake (curves)	The braking curve is the shape formed on a speed/distance chart by a train as it slows down from normal speed to a stop. A typical curve looks like this: The curve begins when the driver applies the brake
ETCS Track Side	Module and interface to be provided by ProRail. These modules shall be provided by ProRail. The function of the modules is to communicate between the RBC and ETCS OBU via ETCS SS 026 standard.
Full Service Brake	Service Brake set at maximum allowed effort.
Generic Application	Application which contains all mandatory and all or a subset of optional functions, with predefined configurability and customizable for different specific applications.
Global Navigation Satellite System	A worldwide position, time and velocity radio determination system comprising space, ground and user segments. (EN 61209:1999-08)
Grade of Automation (GoA)	Automation level of train operation, in which a train can be operated, resulting from sharing responsibility for given basic functions of train operation between operations staff and system.
Grade of Automation 0 (GoA0) On-sight train operation	In this grade of automation, the driver has full responsibility, and no system is required to supervise his activities. However, points and single tracks can be partially supervised by the system.

Business Term	Definition
Grade of Automation 1 (GoA1) Non-automated train operation	In this grade of automation, the driver is in the front cabin of the train observing the guideway and stops the train in the case of a hazardous situation. Acceleration and braking are commanded by the driver in compliance with wayside signals or cab-signal. The system supervises the activities of the driver. This supervision may be done at specific locations, be semi-continuous or continuous, notably in respect of the signals and the speed. Safe departure of the train from the station, including door closing, is the responsibility of the operations staff. NOTE: In addition, in this GoA the system may provide advisory information to the driver (DAS)
Grade of Automation 2 (GoA2) Semi-automated train operation	In this grade of automation, the driver is in the front cabin of the train observing the guideway and stops the train in the case of a hazardous situation. Acceleration and braking is automated and the speed is supervised continuously by the system. Safe departure of the train from the station is the responsibility of the operations staff (door opening and closing may be done automatically). NOTE: Please refer to GoA2 operational principles document for more details.
Grade of Automation 3 (GoA3) Driverless train operation	In this grade of automation, additional measures are needed compared to GOA2 because there is no driver in the front cabin of the train to observe the guideway and stop the train in case of a hazardous situation. In this grade of automation, a member of the operations staff is necessary on-board. Safe departure of the train from the station, including door closing, can be the responsibility of the operations staff or may be done automatically. NOTE: Please refer to GoA 3/4 operational principles document for more details.
Grade of Automation 4 (GoA4) Unattended train operation	In this grade of automation, additional measures are needed compared to GOA3 because there is no on-board operations staff. Safe departure of the train from the station, including door closing, has to be done automatically. More specifically, the system supports detection and management of hazardous conditions and emergency situations such as the evacuation of passengers. Some hazardous conditions or emergency situations, such as derailment or the detection of smoke or fire, may require staff interventions. NOTE: Please refer to GoA 3/4 operational principles document for more details.
Hazard	Potential source of harm

Business Term	Definition
Human Machine Interface (HMI)	Part of a system an operator interacts with. The interface is the aggregate of means by which the users interact with a machine, device, and system (the system). The interface provides means for input, allowing the users to control the system and output, allowing the system to inform the users.
Infrastructure Equipment	Fixed installations of the railway system (e.g. tracks, power supply, signaling, communication).
Infrastructure Manager	Organization responsible for establishing and maintaining railway infrastructure. This may also include the management of infrastructure control and safety systems. Defined by EU Directive 2012/34 as 'any body or firm responsible for the operation, maintenance, and renewal of railway infrastructure on a network, as well as responsible for participating in its development as determined by the Member State within the framework of its general policy on development and financing of infrastructure.'
Interchangeability	The capability of system components identified in this document to be procured from any number of suppliers and replaced without any substantial change in functionality or performance.
Interlocking	An arrangement of switches and signals interconnected in a way that each movement follows the other in a proper and safe sequence.
Interoperability	Ability of a transport network to operate trains and infrastructures to provide, accept and use services so exchanged without any substantial change in functionality or performance.
Journey Profile	The Journey Profile contains the set of dynamic infrastructure data and operational data required by the ATO-OB in order to drive the train. The operational data contains the list of Timing Points to be traversed by the train along its journey. This list is defined in real time on the basis of the scheduled timetable and on-line traffic regulation. The Journey Profile may be updated during the journey.
Journey	Scheduled movement of a locomotive along a single route.
Juridical Recorder	In the ETCS/ERTMS area, there is a specification in Subset-027 for juridical recording in the sense of accident data storage. This is provided by the manufacturers in the form of a Juridical Recording Unit (JRU), which stores the events of the ETCS main computer (European Vital Computer / EVC) as well as the signals of the Class B systems.

Business Term	Definition
Locomotive Control System	A comprehensive locomotive control system (ATO GoA2/GoA4 Freight Functions) that enables operators to safely control the locomotive via a remote control system
Locomotive Diagnostic	General term covering all locomotive diagnostic data
Locomotive Interface	Locomotive Interface Gateway (LIG) is a network communications and interface device that provides locomotive control-system data to third-party applications
Modular Design	A design approach that subdivides a system into smaller parts called modules or skids, that can be independently created and then used in different systems. A modular system can be characterized by functional partitioning into discrete scalable, reusable modules; rigorous use of well-defined modular interfaces; and making use of industry standards for interfaces.
Multiple traction	Multi traction is an important subject for transport companies. In the daily business, the transport capacity must be flexibly adapted to the passenger volume. For this, more trains of the same company are coupled together which are normally operating as single units in slack times.
Neutral Section	An arrangement of insulators in the Overhead Line Equipment designed to ensure that two sections are kept electrically separate even during the passage of a pantograph.
Obstacle Detection System	A sub-system able to supervise the area in front of or around the train in order to detect and identify objects on or close to the track that might adversely affect safe train operation.
OCORA Functional Vehicle Adapter	Open CCS On-board Reference Architecture
Operations	Operation covers all functions which deal with the safety and regular exploitation of the transportation service.
Passing point	A Timing Point defined in the Segment Profile, where the train is planned to pass within a given time window defined in the Journey Profile.
Perception system	See Obstacle detection system. While the scope of a perception systems might be larger than that of an obstacle detection system, here, both expressions are used as synonyms.
Powerless section	A section where no electrical traction power is available.

Business Term	Definition
Public Radio Network	Data transmission service that is established and operated by a telecommunication administration, or a recognized private operating agency, and uses a public data network. A public data transmission service may include Circuit Switched Data packet-switched, and leased line data transmission
Radio Module for ATO	The radio module for ATO uses the IP interface according to Subset-126 Appendix A to connect the ATO unit.
Railway Undertaking (RU)	Defined by EU Directive 2012/34 as 'Any public or private undertaking licensed according to this Directive, the principal business of which is to provide services for the transport of goods and/or passengers by rail with a requirement that the undertaking must ensure traction; this also includes undertakings which provide traction only.'
Rolling Stock	General term covering all locomotives with or without motors.
RSC	Remote Supervision Control is an external working space desk for remote control and supervision of the locomotive
RSC Control	RSC control the train via ATO OB or RSC Onboard
RSC Driving	Driving the Train over the remote control (RSC)
RSC mode	Train is in RSC mode by using HMI
RSC onboard system interface	Supervision (Diagnostic) & Control)
RSC Operator	The RSC Operator has the task to supervise and to control in case of incidents and/or degraded mode operation. Responsible for testing RSC functionalities
RSC Supervision	System functions of RSC system include data acquisition and processing, remote control, alarm processing, historical data, graphical human-machine interface (HMI), emergency control switch.
RSC Track Side	RSC System part on the Landside in e.g. DB Cargo facility
Safe Braking Model	An analytical representation of a train's performance while decelerating to a complete stop, allowing for a combination of worst-case influencing factors and failure scenarios.

Business Term	Definition
Segments Profile	Set of static infrastructure data required by the ATO on-board to compute the Operational Speed Profile.
Shall not	The use of “shall not” is restricted to formal requirements statements. It indicates obligation not to do something or to make sure that something does not happen, or not having permission / not being permitted to do something.
Shall	The use of “shall” is restricted to formal requirements statements. It indicates obligation – that something must happen/ be done or that someone must do something.’ Some full example sentences could follow:
Signaller / Signal operator	Manage safe train path execution, handling of incidents
Status	State condition of a component or system.
Stopping Point	A Timing Point defined in the Segment Profile where the train is planned to stop within a given time window defined in the Journey Profile, usually to carry out a specific activity such as allowing passengers to join and leave the train.
Supervision	Activity, performed either manually or automatically, intended to observe the state of an item.
Timetable	Planned chronological occupation of rail infrastructure for train movements.
Traction/Braking Lever	Lever(s) used by the driver to drive the train. It may be composed by one or more levers (e.g. traction lever, EDB lever, pneumatic brake lever...) but from the ATO-OB functional point of view it has only three different positions: 1. Traction: when it is requesting the rolling stock to traction; 1. Neutral: when it is requesting the rolling stock neither to traction nor braking; 1. Braking: when it is requesting the rolling stock to brake.
Traffic Management System (TMS)	A non-safety-critical system which advises the control command and signaling system, based on the current traffic situation and other internal or external information, in order to improve the level of service.
Traffic Operation and Management	The procedures and related equipment enabling a coherent operation of the different structural subsystems, both during normal and degraded operation, including in particular train driving, traffic planning and management.

Business Term	Definition
Traffic Operator	Train dispatcher
Train Control Management System	Train subsystem managing the interfaces with traction/braking controls and other train devices e.g. train doors.
Train Operation	The control command of routes, loading and unloading (of passengers and freight), driving of trains and shunting.
Train at Standstill	A train is considered to be at standstill when its speed has decreased to 3 km/h or less.
Train Driver	A person capable and authorized to drive trains, including locomotives, shunting locomotives, work trains, maintenance railway locomotives or trains for the carriage of passengers or goods by rail in an autonomous, responsible, and safe manner.
UNISIG	Union Industry of Signaling – an associated member of UNIFE, created to develop the ERTMS/ETCS technical specifications.
Unit	A set of one or more locomotives which cannot be decoupled during train operation.

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## 1 INTRODUCTION

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The present document constitutes the Deliverable D5.5 “Documentation of Freight specific user requirements for automation process” in the framework of the Flagship Project FP2- R2DATO as described in the EU-RAIL MAWP (Multi-Annual Work Programme). The document describes results for the Task 5.5 “Definition of freight specific user requirement”. WP5 is part of the FP2 cluster (1) “Automation Processes” containing the four technical enablers (TE): TE1 Automating Functions, TE4 ATO Technologies, TE6 Perception and TE7 Remote Driving.

The objective of this document is to provide specific user requirements for rail freight. The user requirements described in this document cover Grades of Automation GoA2 to GoA4, targeting of full automation of the freight sector. This document defines the user requirements definition for a fail-safe automatized freight train operation system as understood. Rail freight specific user requirements touch a broad range of automation process tasks, reaching from freight specific architecture, communication, perception systems to remote supervision and control as outlined in the main chapters.

The definition of consolidated freight specific user requirements – as provided within this document – is used to design the automation system and accordingly, represents the basis for the further development of the innovations in the Flagship Project FP2- R2DATO, especially in the work packages WP6 “Automation Processes Specifications”, WP7 “GoA3/4 Data Factory specifications and Implementation” and WP8 “Safety Analysis & Risk Assessment”. Via these work packages, this deliverable D5.5 is indirectly linked to the work packages developing prototypes: WP9 “Prototype development of automating functions”, WP10 “Prototype development of Automated Driving (ATO Technologies)”, WP11 “Prototype development of perception system” and WP12 “Prototype development of remote control”.

The following results rely on a broad body of already specified functions, use cases and user requirements from previous research activities in the European context (e.g., from S2R) as well as the expert knowledge from the involved operators. The work in FP2 Task 5.5 differs from other work, such as the other tasks of FP2 WP5, by focusing on user requirements that are so specific so that they can be used in specification sheets to ensure safe and reliable operation – in contrast to use cases that are a level of detail less specific. In addition, this work puts its focus especially on freight rail mainline operation. Accordingly, requirements apart from mainline operation, such as for shunting, are not within the focus of this work and need to be developed in a second step.

The main goal of the presented work as well as its added value compared to previous work is given in chapter 2 along with the methodology to obtain a consolidated list of freight specific user requirements. These requirements are clustered according to their automation subprocess (e.g. remote control and supervision, perception system) and presented accordingly in the result chapter 3. A conclusion, including the need for future work, is given in chapter 5.

## 2 OBJECTIVE AND METHODOLOGY

### 2.1 OBJECTIVE/AIM

The main goals of this work are:

- Defining specific freight user requirements for all automation process subproject tasks (e.g., automatic functions, up to ATO GoA4 specification, safe perception system and remote driving)
- The output of this work is a structured list of freight specific requirements for mainline operation defined by the users. The results section shows the user requirements in subchapters that correspond to the automation process subproject tasks. In addition, the user requirements are provided as a separate annex in an excel list.
- The developed user requirements list shall be used to verify and validate the design and demonstrator outcome for freight against all defined requirements herein.

#### 2.1.1 Task description

Task 5.5 started in month one and the outputs of this task are included in this document. The following table gives the direct match of the task definition from the proposal with the output and a link to the section where more details can be found. Greyed-out passages refer to WP5 description that concern description of use cases and operational scenarios that are not relevant for this document (see also chapter 3.3.3). However, they are presented in the following for the sake of completeness and better understanding of the tasks' embedding within WP5.

	Definition from proposal	Output of T5.5
WP5	<p>(...) The purpose of the WP is to capture the current rail operator behaviour, high level user requirements and use those to design the automation system. It involves a deep understanding of how an operator would use the Automation Processes and describe the various use cases and user requirements to ensure safe and effective operation. Based on the use case and user requirements definition, the expected outcome of the automation system shall be described. The output of this activity shall be a list of use cases and the expected behaviour of the Technical Enablers with the necessary constraints identified as well as the requirements for the system defined by the users.</p> <p>The various inputs will be collected to be used for an organic evolution of ATO up to GoA3-4. Starting from the ATO specifications released within S2R (by X2Rail4, ARCC (IP 5) and by TAURO) further tuning, refining, developing, validating and extended analysis will be conducted on the following topics:</p>	<p>2.2</p> <p>State of the art</p> <p>2.2.2 ATO System technology status quo</p> <p>2.3 Definition of user requirements within FP2</p> <p>3.1 Scope</p> <p>6.1.1 Annex A: Freight Specific user requirement</p>

	Definition from proposal	Output of T5.5
	<ul style="list-style-type: none"> <li>• New available technologies (from this and other Fas for taking benefits and ensuring a successful integration);</li> <li>• Additional use cases and user requirements encompassing a variety of railway sectors/context (passenger, freight, regional, urban/line, station, depot, yard, stabling, ...etc.) and type of train (fixed trainsets, loco with variable number of coaches or freight wagons, speeds/traction/brake characteristics);</li> <li>• Specifications gap analysis for freight trains must be performed. (...)</li> </ul>	
T5.5	<p>Apart from the generic set of requirements, there is a need to define specific freight user requirements for all automation process subproject tasks e.g., automatic functions, up to ATO GoA-4 specification, safe perception system and remote driving. This refers to e.g., freight specific driving strategy, train characteristic, longitude forces, dynamic behaviour, etc.</p>	<p>2.2</p> <p>State of the art</p> <p>3.2 Freight Specific Architecture</p> <p>3.3</p> <p>Freight Specific General Functional Requirements</p> <p>3.4 Freight Specific User Requirements for ATO GoA2-GoA4</p> <p>3.5 Remote Supervision and Control (freight specific)</p> <p>3.6 Perception System / Obstacle Detection</p> <p>3.7 Telecommunication</p> <p>3.8 Vehicle Integration</p> <p>6.1.1 Annex A: Freight Specific user requirement</p>
T5.5	<p>Furthermore, this task will verify and validate methodology and plan for the design and demonstrator outcome for freight against the user requirements.</p>	<p>The developed user requirements list shall be used to verify and validate the design and demonstrator outcome for freight against all defined requirements herein. Also design requirements for test system must be applied.</p> <p>3.9 Test System Specification</p> <p>6.1.3 Annex C: Testing and validation</p>

	Definition from proposal	Output of T5.5
D5.5	This deliverable will contain a set of documents defining user freight specific user requirements for all automation process subproject tasks e.g., automatic functions, ATO GoA 3/4 specification, safe perception system and remote driving.	<p>2.2</p> <p>State of the art</p> <p>3.2 Freight Specific Architecture</p> <p>3.3 Freight Specific General Functional Requirements</p> <p>3.4 Freight Specific User Requirements for ATO GoA2-GoA4</p> <p>3.5 Remote Supervision and Control (freight specific)</p> <p>3.6 Perception System / Obstacle Detection</p> <p>3.7 Telecommunication</p> <p>3.8 Vehicle Integration</p> <p>6.1.1 Annex A: Freight Specific user requirement</p> <p>Annex B: Requirements to Safety, Security and Quality (Plan &amp; Concept) &amp; Preliminary Hazard Log</p> <p>Annex C: Testing and validation</p>

**Table 1: Deliverable sections matching task description**

## 2.2 STATE OF THE ART

### 2.2.1 ATO (for freight): State of the Art

Closed systems have employed ATO GoA2 - 4 for many years, primarily within mass transit and local public transport contexts such as subways and airport passenger transport (e.g., Nuremberg metro, Paris metro line 14, Copenhagen metro, etc.). The recent adaptations of ATO GoA2 - 4 standards for open rail systems largely draw upon the expertise gained from these experiences in mass transit. Nevertheless, this previous knowledge only partially applies to freight transportation and is better suited for multiple-unit passenger transport.

When comparing the application of electric multiple units to loco-hauled trains, the latter exhibits increased complexity, which consequently raises the demands on future ATO systems. On one hand, new parameters and variables come into play, and on the other hand, not all previous parameters can be treated as constants. Even within passenger transportation using locomotive-hauled trains, the complexity of the parameters and variables required for automated control escalates due to coupling systems and the presence of at least two brake types (electrodynamic and electropneumatic brakes). This intensifies the demands placed on the ATO system, necessitating advanced algorithms, calculations, and tasks.

The couplings between locomotives and coaches create a mass-spring system that impacts force calculation and force requirements, which can be effectively integrated into the control loop of an automated braking and propulsion system. In loco-hauled passenger services, there's the added complexity of independent locomotive air brakes and train air brakes, not found in mass transit. Consequently, the precise control of force by the automated braking and traction system (ATO) becomes more intricate since it now involves managing the intricate force equation, dynamically controlling electric and independent locomotive brakes, and overseeing train air brakes. Mishandling of the electrodynamic brake by the ATO system could, in the worst case, result in derailment, as the rear cars' braking is delayed due to pressure drops in the brake line. Therefore, locomotive-hauled trains must also consider the effects of longitudinal forces to ensure safe operation.

In freight transport employing loco-hauled trains, mass and length parameters can no longer be treated as constants, further elevating the complexity level. The following list provides an overview of the relevant parameters and specific requirements for rail freight:

1. The system must accommodate trains with varying weights.
2. The system must control trains of different lengths.
3. The presence of various brake types (electrodynamic, locomotive pneumatic independent, and train pneumatic brake) complicates brake control.
4. The coupling system between locomotive and freight wagon introduces a mass-spring system, affecting the force calculation of the automatic braking and driving system (GoA2).
5. Longitudinal forces cannot be disregarded in locomotive-hauled freight trains; they must be considered and managed by the automatic braking and driving system (GoA2).

All these factors impact the braking and propulsion behavior of a freight train in a non-uniform and inconsistent manner, posing diverse challenges for an automated braking and driving system (GoA2).

## 2.2.2 ATO System technology status quo

For the purpose of rail freight transport there is still no mature and proven ATO system in use. The automation of locomotive-hauled freight trains is of the highest complexity and there is also a lack of empirical data compared to passenger transport. The technologies and projects that are already available on the market but have not yet established themselves as market standards are briefly presented below:

Name	Rio Tinto AutoHaul®
Highlight	First fully automated ATO over ETCS L2 GoA4 long distance heavy-haul railway.
Description	2.5km long trains travel autonomously on Rio Tinto's rail network, without a driver on board. The system was commissioned in mid 2018.  The system was designed before the CENELEC standards Subset-126 was developed. The rolling stock (locomotives and train consists) is relatively homogeneous in contrast to the European railway system.

Name	Vectron ECO Cruise®
Highlight	The driver assistance system Vectron ECO Cruise is fully integrated into the Vectron locomotive platform as an innovative energy-saving system.
Description	The drivers are relieved by the connection of the system to the AFB and can concentrate on monitoring the train movement. The basic system works with offline data autonomously and without data connection to the infrastructure side. Available online data improve the achieved energy saving. Due to its locomotive-focused conception and the strict separation of safety functions, Vectron ECO Cruise can easily be migrated.

Name	Trip Optimizer (TO) - General Electric
Highlight	A state-of-the-art onboard train control system comparable to an aircraft's autopilot.
Description	TO is a smart cruise-control system for diesel trains that considers terrain, train composition, speed restrictions and operating conditions to calculate an optimum speed profile. It then automatically controls locomotive throttle and dynamic brakes to reduce fuel burn and provide efficient train handling.

Name	LEADER® AutoPilot™ by Knorr Bremse: New York Air Brake LLC (NYAB)
Highlight	On a 77 km test track, LEADER® AutoPilot™ autonomously drove a heavy goods train consisting of three locomotives and 30 loaded freight wagons with a total load of 4,725 t under the supervision of railway engineers.
Description	In the process, the system succeeded in starting and stopping the train formation in a purely computer-controlled manner uphill, downhill and on level ground. The test took place in a PTC (Positive Train Control) environment.

Name	Automatic driving and braking control (legacy automatic driving and braking control of the locomotive)
Highlight	The system takes on the driver task of accelerating and braking the locomotive and the train to a speed (target speed) pre-selected by the driver and maintaining the speed. Such systems are referred to as Automatic Train Operation without connection to the Traffic Management System (TMS).
Description	The automatic driving and braking control (AFB) is a technical system that is used in locomotives to support the driver in his work. For driverless railway systems, AFB is a basic functionality.

Name	S2R - GoA2 ATO Demonstrator Freight (DB Cargo), Switzerland
Highlight	First freight train test drives in automated operation (ATO GoA2) between October and December 2020 under real operating conditions
Description	The trial operation in Switzerland was set up and financed as part of the "Horizon 2020" program (Shift2Rail). Under the management of DB Cargo AG, the project was implemented together with industrial partners Bombardier, AZD, Siemens, Alstom, and Hitachi.

Name	DZSF - Functional requirements for sensors and logic of an ATO unit (ATO-SENSE)
Highlight	The aim of the project (until 05/2023) was to generate a definition basis from which the requirements for a technical ATO can be derived.
Description	Project by Deutsches Zentrum für Schienenverkehrsforschung (DZSF; engl.: German Centre for Rail Traffic Research) Among other things, the aim is to investigate which senses play a role in a driving process, how quickly decisions are derived from this and implemented, and to what extent misjudgments are to be expected.

Name	Fully automatic shunting locomotive (VAL)
Highlight	The locomotive is highly automated with an almost fully automatic control, which is closely connected to the infrastructure via innovative interfaces
Description	The approach of the VAL project in the federal program Z-SGV (Zukunft Schienengüterverkehr) (FKZ: 53T20008DC) lasting from December 2020 to December 2024 includes equipping existing shunting locomotives with a corresponding environment sensor system, which can take over all the monitoring tasks of today's locomotive shunter.

Name	Alstom / Rotterdam Rail Feeding - ETCS on the Betuweroute
Highlight	Practical knowledge for automation operations (GoA2) on a freight route.
Description	At the end of 2018, Alstom carried out an ATO function test with a class 203 locomotive of the Rotterdam Rail Feeding (RRF) on the Betuweroute.

Name	Thales / Vodafone - 5G driverless driving in the Ore Mountains
Highlight	First cooperation to control a train using the 5G mobile communications standard
Description	On a test track in the Annaberg-Buchholz area in the Ore Mountains (Germany), a test train completed an exit from and an entry to a station without manual controls on the locomotive.

Name	ProRail Pilots in NL
Highlight	ProRail was carrying out various trials with automatically controlled trains together with partners. Lineas, the largest private rail freight operator in Europe, was supporting ProRail and Alstom to test ATO in shunting activities.
Description	A diesel-hydraulic shunting locomotive of Lineas was equipped with Alstom's automatic control technology as well as intelligent obstacle detection and recognition. Tests were started in 2021 under the supervision of authorised train staff and have finished in 2023. <a href="https://lineas.net/en/news-overview/ato">https://lineas.net/en/news-overview/ato</a>

Name	Obstacle detection systems in light rail vehicles of HTM Avenio trams
Highlight	First tram fleet equipped with the innovative system.
Description	70 trams for the city of the Hague were retrofitted with the new collision warning system "siemens tram assistant" to avoid accidents. <a href="https://assets.new.siemens.com/">https://assets.new.siemens.com/</a>

Name	Obstacle detection systems in light rail vehicles of RATP & Alstom
Highlight	The system I-CBTC can carry out remote operating functions, monitoring safety in operations and controlling traction and braking systems to run the metros automatically, with different levels of automation, according to the configuration chosen by RATP.
Description	Alstom has been selected by public transport operator Régie Autonome des Transports Parisiens (RATP) to provide its automatic train operation system I-CBTC to several lines of the Paris metro, in France. <a href="https://www.alstom.com/press-releases-news/2021/5/alstom-supply-its-board-automatic-train-operation-system-lines-10-7bis">https://www.alstom.com/press-releases-news/2021/5/alstom-supply-its-board-automatic-train-operation-system-lines-10-7bis</a>

Name	JSC NIIAS Lastochka passenger train
Highlight	The train system can detect obstacles at a distance of 500 meters, but also at a distance of 700 meters it can detect obstacles like pedestrians, in winter conditions.
Description	In the Moscow region, state-owned company RŽD is currently testing two different passenger trains, and a third for GoA4 is under design. The first two are suitable for the driverless GoA3. <a href="https://www.railtech.com/digitalisation/2021/04/07/im-convinced-ato-obstacle-detection-works-better-than-a-human-driver/">https://www.railtech.com/digitalisation/2021/04/07/im-convinced-ato-obstacle-detection-works-better-than-a-human-driver/</a>

Name	S2R CONNECTA project
Highlight	CONNECTA aims at contributing to the S2R's next generation of TCMS architectures and components with wireless capabilities as well as to the next generation of electronic braking systems.
Description	CONNECTA will conduct research into new technological concepts, standard specifications and architectures for train control and monitoring, with specific applications in train-to-ground communications and high safety electronic control of brakes. (S2R Website)

Name	S2R IP 5 ARCC Demonstrator
Highlight	Delivering first ATO freight prototype demonstrator feedback by applying specification from S2R
Description	Demonstrator has been executed on SBB infrastructure and demonstrating of ATO-OB systems from Hitachi, Alstom, Siemens and AZD.

### 2.2.3 Freight Automation subsystems – overview and TRL

The components of a potential ATO solution for rail freight consists of the following modules:

1. European Train Control System (ETCS)  
Train protection system.
2. ATO onboard System (ATO-OB)  
Locomotive component, e.g., for automated driving and braking.
3. ATO trackside (ATO-TS)  
Interface between the ATO-OB and the IM
4. Perception system  
Specified perception functions
5. Remote Supervision & Control (RSC)  
remote control for all ATO level and control e.g. in case of "degraded mode" for GoA 4.
6. Driving Style Engine (DSE): Functionality to control and supervise freight specific driving style requirements.
7. Functional Vehicle Adapter FVA: Specific adapter as translator from generic ATO OB to Vehicle specific Locomotive system.

The different components are explained in the following, highlighting their degree of maturity, the range of functions and the need for adaptation for an ATO system.

#### European Train Control System - ETCS:

ETCS is an already used component. For ATO, additional interfaces will be necessary. For example, the ETCS onboard system might be adapted to route the safety-critical braking curve signals to the ATO onboard system.

##### *Maturity Level:*

A basic specification of an ATO onboard system including an interface to the ETCS onboard system is already available as result of European research (Shift2Rail, IP2 X2Rail4 and IP5 ARCC). The system has achieved at least TRL 6.

##### *ATO target functionality:*

In ATO target operation, the ETCS shall transmit

- the safety-critical braking curve parameters to the ATO onboard system as limit values.
- ETCS status information to the ATO onboard system. This can lead to the ATO onboard system to be switched on or off.

In addition, the ATO onboard system shall transmit system-relevant data to the ETCS onboard system for monitoring its status.

#### Automatic Train Operation Onboard System:

The ATO onboard needs to have interfaces between the locomotive and ETCS.

##### *Maturity level*

A basic specification of an ATO onboard system including an interface to the ETCS onboard system is already available as result of European research (Shift2Rail, IP2 X2Rail4 and IP5 ARCC). It will be implemented in Luxembourg (CFL) on the network which is equipped with ETCS L1FS.

*ATO target functionality:*

The system shall allow for automated driving and braking, here specifically for freight traffic. To this aim, the freight-rail specific functions need to be considered. First, the train needs to be dynamically controlled with constantly changing parameters regarding length, dimensions, and cargo behavior (full/empty wagons, liquid/solid cargo, and interdependencies). Second, critical operating conditions need to be avoided. To this aim, correct brake control that complies with specific rules, the physical train model and the operating environment is essential for all brake variants (dynamic – independent and train brake –, direct, indirect). Since freight-specific longitudinal forces may also lead to critical operating conditions, the correct control of accelerating behavior is as important as a correct braking behavior.

**Automatic Train Operation Trackside - ATO TS:**

The trackside ATO system and the interfaces required for sending the track-dependent optimized travel signals (journey profiles) to the ATO onboard system are provided by the infrastructure manager.

ATO -TS will have an interface to the Traffic Management System to exchange relevant information on e.g., time planning for journey profile and infrastructure data for segment profile.

**Perception system:**

An AI system is to be used for safe route monitoring, obstacle recognition and perception, including the interfaces to the locomotive.

*Maturity level*

A basic specification is available as result of several projects (listed below) and expanded further.

- S2R IP5 SMART (completed)
- S2R IP5 ARCC (completed)
- DSD Sensors4Rail (ongoing)
- S2R IP5 SMART2 (completed)
- DB AG Advanced Train Lab (ongoing)
- DZSF ATO-SENSE (ongoing)
- S2R IP2 X2Rail 4 (about to be completed)
- S2R IPX TAURO (ongoing)

The system has achieved at least TRL 4.

*ATO target functionality*

The system shall have a perception functionality that is taking over the observation task currently performed by the driver, also including the observation of the environment. The perception system of a freight train will have the same requirements as for passenger trains.

**Remote Supervision & Control**

Driving operation will ideally be relying on ATO. However, while this will apply on nominal operation, there must be a fallback-option in degraded mode. Remote Driving, or Remote Supervision and Control (RSC) is meant as such a fallback option where a remote driver can remotely control the

train to manage the situation. In this position, a person remains the highest decision-making authority of the railway system. Operational modes are defined within chapter 3.1.2.

The RSC will be a new work environment with a new role for the RSC manager. Accordingly, the driver's job description needs to be adapted as well as the organizational structure within the railway undertaking.

*Maturity level:*

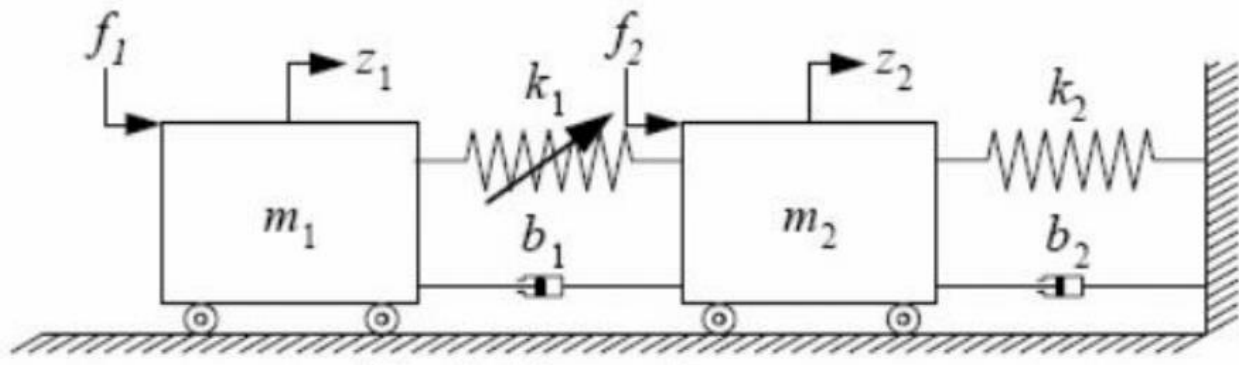
A basic specification of a remote driving system is currently developed within the scope of European research (Shift2Rail, IP2 X2Rail4 and IPX TAURO). The system has achieved at least TRL 4. In addition, Thales / Vodafone 5G driverless driving in the Ore Mountains as well as SNCF Train Autonome in France have tested remote driving.

*ATO target functionality:*

Remote driving shall resolve malfunctions for GoA2 - 4 with an unoccupied locomotive. As such, it is an essential function of the ATO system.

**Driving Style Engine (DSE)**

A freight train set composition incl. the coupler and wagons must be understood as dynamic control of a spring-mass-damper system. The figure below shows the mass-spring-damper system as it needs to be considered by a supplier. Spring  $k_2$  and damper  $b_2$  are attached to the wall and mass  $m_2$ . Mass  $m_2$  is also attached to mass  $m_1$  through spring  $k_1$  and damper  $b_1$ . Mass  $m_2$  is affected by the disturbance force  $f_2$ . The system is controlled via force  $f_1$  acting on mass  $m_1$ .



**Figure 1: Freight train set dynamic control of a spring-mass-damper system**

Though important influence factors for the running resistance, e.g. the track gradients profile, the length, composition, and weight of the train, other important influence factors are unknown, such as the real running resistance of each wagon. These constraints need to be taken into account for ATO freight product deployment.

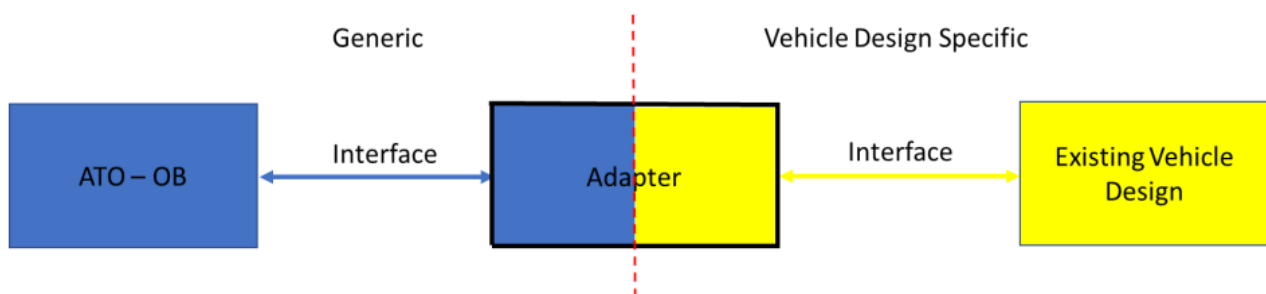
*Maturity level:*

Today application of such a system has been applied in USA and Australia (Rio Tinto) by e.g., LEADER® AutoPilot™ by Knorr Bremse: New York Air Brake LLC (NYAB) see chapter 2.2.2. However, there is currently no system existing for European freight environment.

### Functional Vehicle Adapter (FVA)

The Functional Vehicle Adapter is a legacy vehicle design solution. Current ATO GoA2 vehicle interface would be easy to integrate into a new vehicle design. For existing vehicle designs, the gap is typically much larger. To achieve the objective of defining a fully generic interface between the ATO Onboard and the vehicle there will always be a requirement for an “adapter” solution. This is the most economical way to realize the Plug & Play integration of an ATO GoA2 system – see figure below.

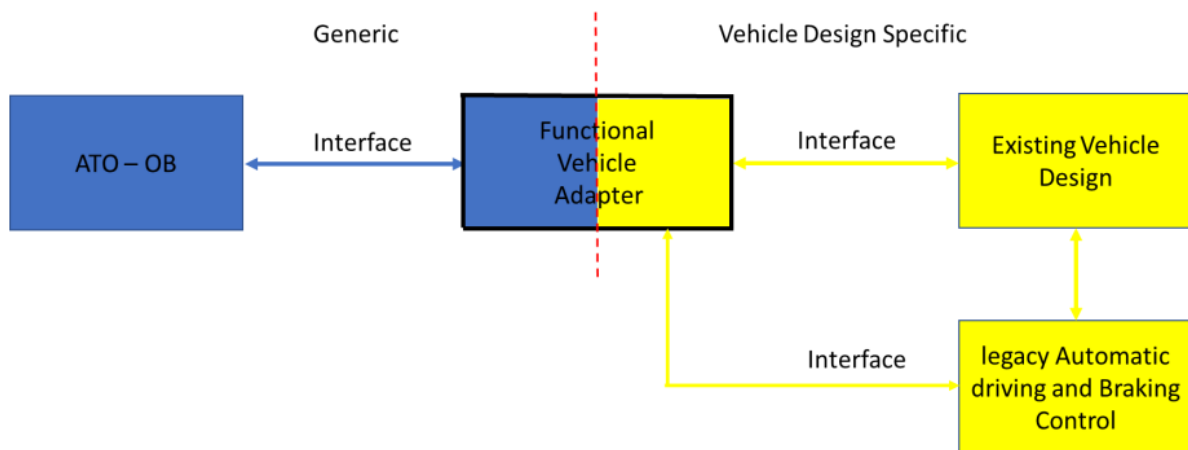
An economical solution for existing vehicle designs is highly needed today for freight RU's. At DB AG RU a retrofit solution for ETCS & ATO is estimated to be required for 80 % of the fleet.



**Figure 2: Adapter between generic ATO and Existing Vehicle Design**

The proposed Functional Vehicle Interface as a common standard can be understood as a solution for ATO retrofit for all generations of vehicles including the continued use of legacy automatic driving and braking control systems such as AFB.

One important goal of this solution is to provide on the one hand a common solution for adaptation functions to Existing Vehicle Design and on the other hand to use the advantage of highly matured legacy automatic driving and braking control systems – see Figure 3. For legacy vehicles, this can be a better solution in many cases than to try “to reinvent the wheel” by fine-tuning the low-level control loops of the ATO onboard.



**Figure 3: Use of FVA with Existing Vehicle Design and Legacy Automatic Driving and Braking Control**

The FVA proposal can be a solution to overcome the challenge of the Plug & Play interface for existing vehicle design while continuing to use the highly matured existing legacy automatic driving and braking control systems. A strategic discussion to be held on sector level to support the quick ATO rollout and migration of RU fleet in particularly freight is required to define and roll-out such a solution.

Overall, the modules presented here provide the functional basis for the operational implementation of ATO on a real line and operational environment.

#### **2.2.4 Applicable railway norms**

For the development of railway applications, the following norms shall be applied:

- EN 50126: Railway Applications - the specification and demonstration of Reliability, Availability, Maintainability and Safety.
- EN 50127: Railway Applications - Guide to the specification of a guided transport system
- EN 50128: Railway Applications - Software for railway control and protection systems.
- EN 50129: Railway Applications - Safety related electronic systems for signalling

## 2.3 DEFINITION OF USER REQUIREMENTS WITHIN FP2

### 2.3.1 The role of user requirements in FP2 WP5

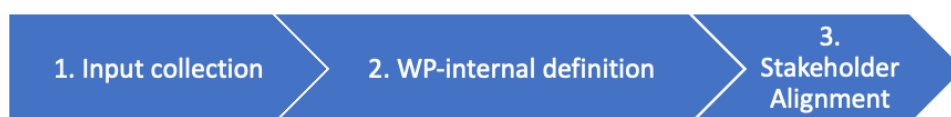
The definition of freight specific user requirements within Task 5.5 differs from the other tasks in WP5 in scope and level of detail. While the scope of Task 5.5 focuses especially on freight specific aspects, both freight and passenger rail operations are within the scope of WP5. With regard to the level of detail, Task 5.5 defines user requirements, the other tasks within WP5 have a more general view of use cases. Accordingly, Task 5.5 takes on a special role within WP5.

Task 5.5 is included in the discussions on use cases managed on WP5 level [4]. Accordingly, the T5.5 user requirements are in line with the use cases defined in the other tasks of WP5. However, a harmonization in a sense of aggregating the user requirements of T5.5 with the use cases of the other WP5 tasks is neither meaningful nor efficient. Accordingly, the here defined user requirements need to be seen as a separate work stream. Still, the work on WP5 level to create a use case index of all use cases already defined in previous work (e.g., S2R) can be seen as an important preparatory work for the coordination of creating a freight specific user requirements index within T5.5 (see also next subchapter).

### 2.3.2 Best Practice: Defining user requirements in FP2 WP5.5

In Task 5.5 user requirements are collected as input from the team members who have a different background and specific ideas and goals. For the collection, three aspects are important. First, the work done before needs to be incorporated, especially in the context of (past) European funded projects. Not only does this prevent double work, but it is also crucial for the harmonization of the different aspects already looked at before. Second, it is important to capture and align with the different perspectives of all participants. This is achieved by a parallel collection and review process of the requirements. Finally, a timely alignment with other receiving work packages is necessary to ensure alignment beyond the Work Package.

The three process steps are summarized in Figure 1.



**Figure 4: FP2 T5.5 Process steps**

#### 1. Input Collection

As an input, use cases and user requirements from previous research activities in the European context (e.g., from S2R) as well as the expert knowledge from within the involved operators were gathered. Within WP5, a use case index is created which was used as a first starting point to identify user requirements and to delimitate them from use cases.

#### 2. WP-internal definition

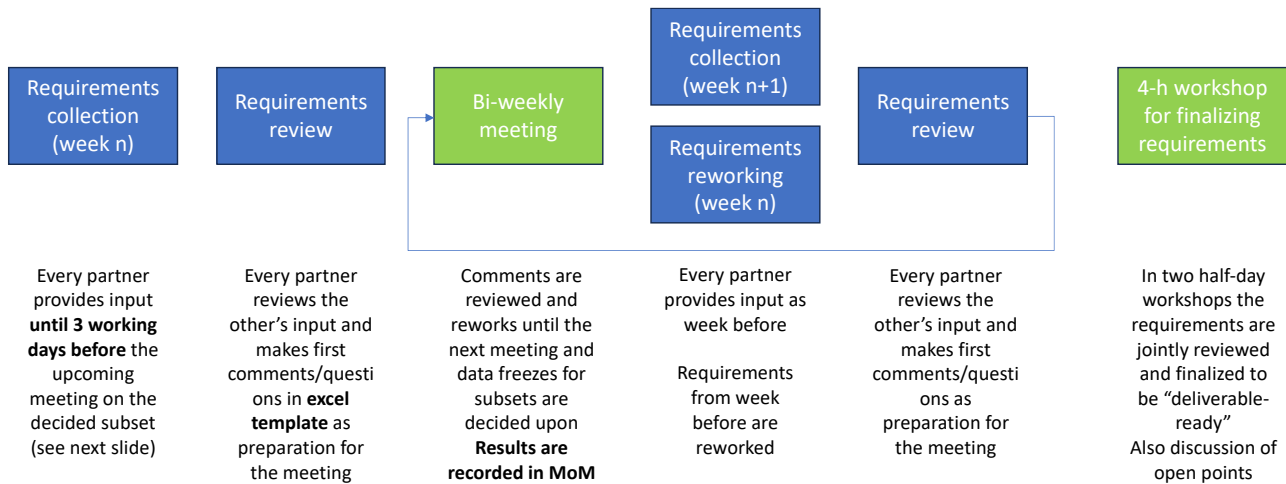
The user requirements described in this document cover grades of automation GoA2 to 4, targeting of full automation of the freight sector. The process of user requirements definition is described in Figure 5 and summarized in the following paragraph.

#### 3. Stakeholder Alignment

Within this context, the alignment with FP2 WP6 (“Automation Processes Specifications”) and, WP12 (“Prototype development of remote control”) is especially important, as described in chapter 2.3.3.

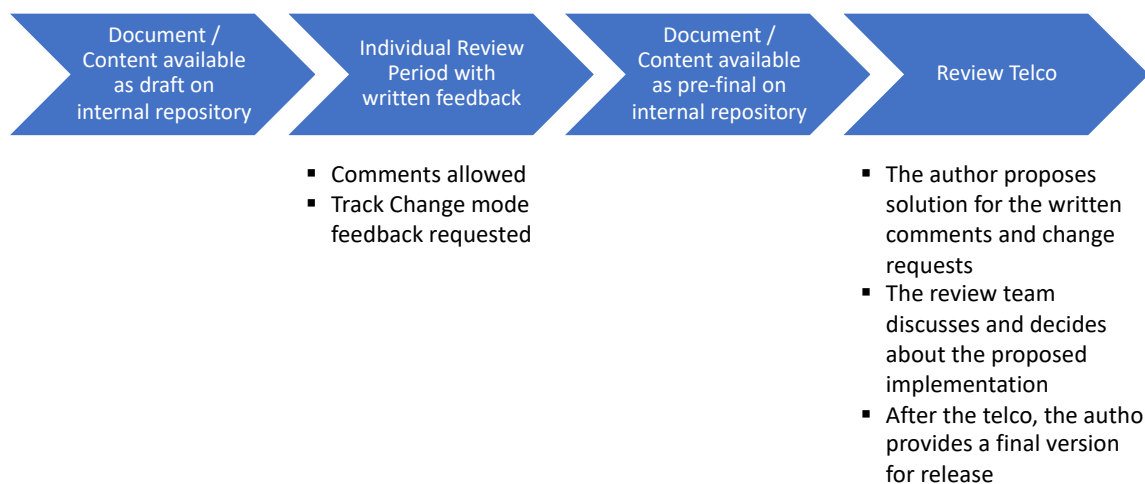
The process for WP-internal definition of the freight specific user requirements is summarized in Figure 5. While the work package leader is responsible for consolidating the given input into a document, the other work package members contribute and constantly ensure that their respective organizations are in line with the team's key decisions. Requirements are provided by the members at least 3 working days before the (bi-weekly) meetings. This timeline gives the other partners enough time to review the given input until the (bi-weekly) meetings in which the requirements are discussed and agreed upon. These steps are repeated before every meeting.

Finally, half-day workshops ensure a holistic view and alignment of the whole team. Potential ambiguities and inconsistencies are identified, and the set of requirements is made “deliverable-ready”.



**Figure 5: User requirement definition within FP2 T5.5**

The process for finalizing the Deliverable is based on best practice for creating *OCORA High Level Methodology* and is shown in Figure 6.



**Figure 6: Best practice document review [2]**

Documents submitted for final review must be provided to the review team at least 2 weeks prior to the final review Workshop. Review comments are due at least 1 week prior to the workshop for final review. This allows sufficient time for the author to incorporate all comments and forward a revised

version to the review team. Review team members must be in possession of the revised document no later than 2 days prior to the final review workshop.

A final review cycle is very costly, especially in terms of the time required. At least 2 weeks are required. Therefore, the workstream leader must ensure that the documents submitted for final review are in good order, and the workstream members must ensure that their organization's ideas are consistent with the documents submitted. [2]

### **2.3.3 Alignment within FP2**

The definition of freight specific user requirements is relevant and crucial to all freight related research within FP5. The result of this work is a direct input to the specification modelling and update of ATO functions in WP6 (“Automation Processes Specifications”) and, indirectly through WP6, to WP12 “Prototype development of remote control”. Thus, the timely alignment with these Work Packages is an important aspect of the definition of the user requirements. To collect external input as soon as possible, a review workshop was held with WP6 in 09/23.

## 3 FREIGHT SPECIFIC REQUIREMENTS

### 3.1 SCOPE

In this chapter 3, the defined and agreed freight specific user requirements are presented. The development and agreements have been performed as described in chapter 2.3. The user requirements are clustered according to their technical field and presented accordingly in different subchapters (chapters 3.4-3.7). The scope of the presented user requirements is as follows:

- Requirements are freight specific  
General requirements on ATO are not presented in the following unless they affect only freight specific applications.
- Requirements focus on mainline operation  
Requirements for specific applications apart from mainline operation – such as within shunting yards –, are not included and need to be developed in a second step.
- Requirements focus on ATO  
Requirements are developed for (partial) GoA4 operations (Full GoA2 + selected GoA4 functionalities) and Remote Supervision and Control (RSC)
- ATO GoA2-4 is the main target operation  
Remote Supervision and Control is not meant as target operational mode but for supervision of the train operation in GoA4 mode and remote control of the train operation in degraded mode (e.g. ATO Trackside (TS) is disrupted) or emergency mode.
- Following presumptions apply for the developed requirements:
  - Existing connection for the ETCS is GSM-R/CSD (see also chapter 3.7)
  - Operational modes apply as described in chapter 3.1.2
  - Functional components and their capability acc. to chapter 2.2.3
  - The operating environment on a partially closed system without level crossings.

For the development of the requirements, a stakeholder analysis, the description of operational states and modes as well as a (preliminary) hazard analysis are purposeful. Accordingly, they are first presented (chapters 3.1.1 to 3.1.3), before the definition of the requirements in chapters 3.3ff.

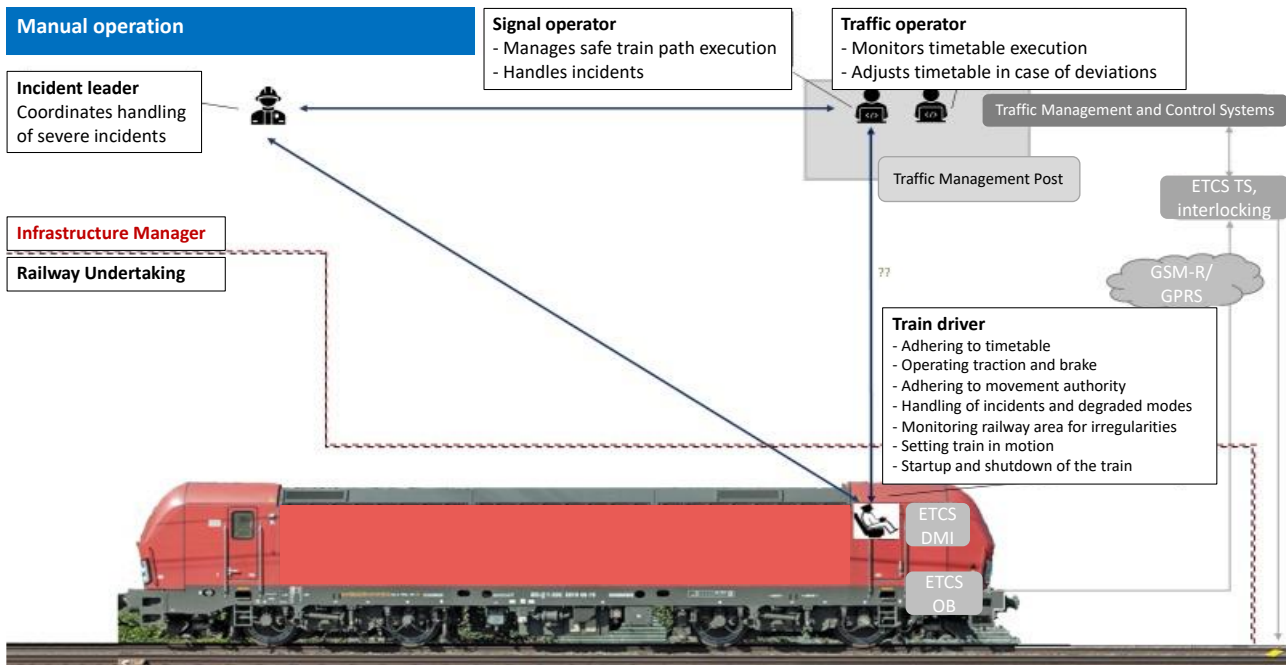
#### 3.1.1 Actors and systems

Current freight mainline operation comprises the following actors and systems.

- The **Driver** operates the train.
- The **Traffic Management Center** is the central management location for the Infrastructure Manager.
- The **Signaller / Signal Operator** manages safe train path execution and handles incidents.
- The **Traffic Operator** is responsible for timetable execution and adjusts timetables in case of deviations.
- The **Incident Manager** oversees the handling of severe incidents.
- **TMS/TCS** – Traffic Management System / Train Control Systems – is the interface between the traffic management post and ETCS trackside.
- **ETCS TS** – European Train Control System Track Side – are ATP systems, comprising systems such as the radio block centre. It shall process movement authorities and the interlocking intended to control route setting and release.

- **ETCS OB** – European Train Control System On-Board – comprises the control and command parts of ETCS. This includes the European Vital Computer which provides the logic for train protection and supervision.

Figure 7 gives a schematic overview of the actors in current operation.



**Figure 7: Current Roles and Actors. Exemplary operation.**

With ATO, new systems and actors are introduced, compared to the current state, e.g.:

- The **Remote Driving Operator(s) / RSC Operator(s)** shall supervise and control in case of degraded mode operation and / or incidents. The responsibility for testing the remote driving functionalities lies with him.
- The **ATO trackside (TS)** system provides communication between TMS/TCS and the train.
- The **ATO onboard (OB)** system shall analogously provide control to the train.

### 3.1.2 Operational modes

Here, we distinguish the following **operational modes**:

1. Normal operation
2. Disturbed Operations: delay
3. Degraded operation: rail infrastructure
4. Degraded operation: train
5. Emergency

In **Normal operation**, all train and infrastructure systems work as intended. The rail traffic is in accordance with the timetable, infrastructure is allocated accordingly.

Communication line: Driver communicates to Signal Operator.

In **Disturbed Operations: delay**, all train and infrastructure systems work as intended. Trackside conditions do not affect train run. However, the infrastructure cannot be used as intended and operation is interrupted due to delays, resulting from logistics processes. Action needs to be taken to resolve the disruption and a new path is provided to the train.

Communication lines: 1) Driver communicates to Signal Operator and 2) Traffic Operator and Signal Operator communicate on delays, within Traffic Management Post.

In ATO operation, updated journey profiles are transmitted to the affected trains.

In **Degraded Operations: infrastructure**, all train systems work as intended. However, trackside conditions do affect train run – technical malfunction, maintenance, obstacle or alike. Accordingly, the infrastructure availability is limited and cannot be used as intended. Operation is interrupted or degraded, e.g., speed restriction.

Infrastructure unavailability may be the result of incidents of all sorts and their impact on infrastructure availability may be unclear first, also leading to stranded trains.

Communication about limited infrastructure availability takes place and action is taken to solve the situation. Nevertheless, an escalation of this mode to emergency mode is possible. In ATO operation, traffic management updates the timetable / route plan as soon as possible and updated Journey Profiles are transmitted to the affected trains.

Communication lines: 1) Driver communicates to Signal Operator or vice versa and 2) Traffic Operator and Signal Operator communicate on infrastructure degradation or limitations, within Traffic Management Post.

In **Degraded Operations: train**, all infrastructure systems work as intended. Trackside conditions do not affect train run. However, the limited availability of the train, e.g., due to technical malfunction, leads to interrupted operation. Accordingly, infrastructure cannot be used at the planned time. Unplanned rerouting must consider potential limitations of track usage (e.g., train weight, electric configuration, length, and wagon profile). Communication about train limitations takes place and action is taken to solve the situation. Nevertheless, an escalation of this mode to emergency mode is possible.

Communication lines: 1) Driver communicates to Signal Operator and 2) Traffic Operator and Signal Operator communicate on train degradation, within Traffic Management Post.

In **Emergency** mode, there is an immediate threat or danger to people, animals, or the environment.

An emergency results from an unexpected situation with impact on railway operation and safety. The causes for such an incident are manifold. They might result from

- 1) the infrastructure – e.g., level crossings, tunnels, bridges, malfunctioning signalling systems or switches,
- 2) the train – lost parts, other malfunctions,
- 3) third parties or animals on / next to the tracks (trespassers, collision, accidents) or
- 4) other influences (weather, fire, power failure, derailment, malfunction of traffic management system). An incident may lead to a disruption of railway operation, even (long) after threat of danger has passed.

Stakeholders are alerted and the affected infrastructure or trajectory is closed against access or entry. The calamity will be dealt with by a specially responsible body and the planned use of rail

infrastructure is limited to minimize the consequences of the calamity. Communication about the calamity takes places and cooperated action is taken to solve the situation.

Communication lines: 1) Driver communicates to Signal Operator on emergency, 2) Signal Operator communicates to Incident Leader on emergency and 3) Traffic Operator and Signal Operator communicate on emergency, within Traffic Management Post.

For the communication lines in the various operational modes see also Figure 7.

### 3.1.2.1 Remote System Operation Operational Modes

Besides the above-described operational modes, it is especially important to define the operational modes of the remote system. Remote driving will be added as an additional operational layer along with ATO GoA2 and GoA4.

Relevant operational modes for the remote system are summarized in Table 2.

Scenario	Remote System Mode
<b>Normal operation (no degradation)</b>	Remote System is working in supervision mode
<b>ETCS-ON in Full Supervision (FS), ATO OB is degraded</b>	Remote System is in control mode (ETCS FS):  Controls the train via remote control. Remote System Trackside is HMI and Remote System Onboard controls the train same as ATO.  Speed is limited to e.g. 40 km/h
<b>ETCS-OB is in FS, but TMS/TCS of IM is degraded</b>	Remote System is in supervision mode (normal mode):  Remote System is supervising the train, Remote System Operator will request manually from Signal Operator a SS126 message (e.g., journey or segment profile) via ATO-TS. Remote System Operator will connect IM directly. No change to Remote System supervision mode.  Train is controlled via ATO OB.
<b>ETCS-OB is in FS, ATO-TS is degraded</b>	Remote System is in supervision mode (ATO-TS degraded):  Remote System supervises the train; Remote System operator manually generates a SS126 profile directly to ATO-OB  Speed is limited to e.g. 40 km/h
<b>ETCS-OB is not in FS</b>	Remote System is in control mode (ETCS-OB non FS): Remote System controls the train via ATO-OB or Remote System Onboard  Speed is limited to e.g. 40 km/h

**Table 2: Remote System operational modes [1]**



### 3.3 FREIGHT SPECIFIC GENERAL FUNCTIONAL REQUIREMENTS

In the following table, the freight specific general functional requirements are presented.

The first column gives every requirement a unique identifier. The second column indicates the obligation of the specific requirement. In the “subtopic” column, a further differentiation of the kind of the requirement is given. The requirements text describes the scope of the requirement.

ID	Obligation	Subtopic	Requirements Text
GenFun-REQ.1	Shall	General Requirements	The desks for supervision and control are located such that the RSC operator can switch between these desks within a predefined amount of time in seconds.
GenFun-REQ.2	Shall	General Requirements	RSC workstation is suitably sized to accommodate a second, standing operative.
GenFun-REQ.3	Shall	General Requirements	For each active train, the RSC HMI includes (in addition to the Train ID) the current mode of operation (Manual vs ATO vs Remote Control)
GenFun-REQ.4	Shall	General Requirements	The RSC HMI will provide a view on current and historic notifications, alerts and alarms of all relevant systems.
GenFun-REQ.5	Shall	General Requirements	Remote Control workstation will include visible feedback that the RSC System is in RSC Control mode to indicate to the RSC Operator, and colleagues at adjacent workstations - to avoid distractions during remote control driving.
GenFun-REQ.6	Shall	General Requirements	RSC HMI dialogue shall clearly indicate the status of Remote Control connection with a train.
GenFun-REQ.7	Shall	General Requirements	RSC HMI will clearly indicate the current mode of each train supervised by the respective RSC Center; either Manual, ATO or Remote Control.
GenFun-REQ.8	Shall	General Requirements	RSC workstation will accommodate an electronic logbook for recording operational information, such as instructions from the Signal Operator.
GenFun-REQ.9	Shall	General Requirements	Alerts and alarms that require an associated CCTV task automatically trigger the display of the corresponding camera stream.
GenFun-REQ.10	Shall	General Requirements	The forward-facing camera image is of suitable clarity and stability to ensure detection performance and support situation awareness at the RSC. To be tested with regard to ergonomic aspects.
GenFun-REQ.11	Shall	General Requirements	The forward facing camera footage will provide sufficient colour rendering to ensure ease of identification of hazards in the rail corridor. For example, colour signal aspects, high visibility vests. To be tested with regard to ergonomic aspects.
GenFun-REQ.12	Shall	General Requirements	RSC system is alerting the RSC user to any identified camera-feed issues impacting real-time images.
GenFun-REQ.13	Shall	General Requirements	The RSC HMI will mirror the ETCS information as shown on the ETCS DMI in the cab (e.g., ETCS levels, modes and successful and unsuccessful transitions)
GenFun-REQ.14	Shall	General Requirements	The RSC workstation will include an alarm banner listing the highest priority alerts or alarms currently 'active' across the fleet.
GenFun-REQ.15	Shall	General Requirements	The RSC alarm banner will visually differentiate between acknowledged and unacknowledged alarms.
GenFun-REQ.16	Shall	General Requirements	The RSC alarm banner will remain visible and cannot be overlayed with other windows.
GenFun-REQ.17	Shall	General Requirements	The RSC workstation will include audible indications.
GenFun-REQ.18	Shall	General Requirements	The RSC is supporting all specified modes of operation. <i>The modes of operation need to be specified for every implementation individually.</i>

ID	Obligation	Subtopic	Requirements Text
GenFun-REQ.19	Shall	General Requirements	In the mode "ATO OB is degraded" (Operating Mode 3), it will be possible for the RSC operator to control the locomotive manually and remotely via ss139 via RSC-link (public MNO).
GenFun-REQ.20	Shall	General Requirements	Onboard video and sensoric information will be send to the RSC with maximised framerate, depending on the available bandwidth.
GenFun-REQ.21	Shall	General Requirements	The HMI is suitable for the RSC operator's task, e.g. as per ISO 9241-110, §5.1.
GenFun-REQ.22	Shall	General Requirements	The HMI is self-descriptive, e.g. as per ISO 9241-110, §5.2.
GenFun-REQ.23	Shall	General Requirements	The HMI is conform to user expectations, e.g. as per ISO 9241-110, §5.3.
GenFun-REQ.24	Shall	General Requirements	The HMI is learnable, e.g. as per ISO 9241-110, §5.4.
GenFun-REQ.25	Shall	General Requirements	The HMI is controllable, e.g. as per ISO 9241-110, §5.5.
GenFun-REQ.26	Shall	General Requirements	The HMI is robust, e.g. as per ISO 9241-110, §5.6.
GenFun-REQ.27	Shall	General Requirements	The system shall provide feedback on actions entered by the RSC operator, e.g. as per ISO 9241
GenFun-REQ.28	Shall	Supervision	The RSC System enables the RSC operator to monitor the speed of the train.
GenFun-REQ.29	Shall	Supervision	The RSC System enables the RSC operator to monitor the traction effort of the train.
GenFun-REQ.30	Shall	Supervision	The RSC System enables the RSC operator to monitor the brake status of the train.
GenFun-REQ.31	Shall	Supervision	The RSC operator is able to monitor the brake percentage of the train.
GenFun-REQ.32	Shall	Supervision	The RSC operator is able to monitor the active (temporary) speed restrictions.
GenFun-REQ.33	Shall	Supervision	The RSC operator is able to monitor the movement authority on the route.
GenFun-REQ.34	Shall	Control	The system assures no two entities command the train at the same time. Accordingly, it is not possible to control the train remotely, if the train is under ATO.
GenFun-REQ.35	Shall	Control	RSC Onboard System: The "low pressure overcharge" function shall be available. E.g. another compressor to charge the brake line in the case of low pressure.
GenFun-REQ.36	Shall	Control	RSC Onboard System: The "Direction of travel" functions shall be available, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 033, 034, 035)
GenFun-REQ.37	Shall	Control	The operation of "Direction of travel" will be configurable to be similar to the controlled locomotive, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 033, 034, 035)
GenFun-REQ.38	Shall	Control	The functionality of the "Direction of travel" will have the properties e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 033, 034, 035): 3 positions Forward, Neutral, Reverse
GenFun-REQ.39	Shall	Control	RSC Onbard System: the "Combined Traction/Brake lever" functions are available e.g. as per UIC 612-0 (3.3.2.1.1, Appendix A; nr 10).
GenFun-REQ.40	Shall	Control	RSC Onbard System: "Combined Traction/Brake lever" shall be configurable to be similar to the controlled locomotive, e.g. as per UIC 612-0 (3.3.2.1.1, Appendix A; nr 10).
GenFun-REQ.41	Shall	Control	RSC will control the "Main Circuit Breaker" functions shall be available, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 017).
GenFun-REQ.42	Shall	Control	The operation of "Main Circuit Breaker" is configurable to be similar to the controlled locomotive, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 017).

ID	Obligation	Subtopic	Requirements Text
GenFun-REQ.43	Shall	Control	The "Pantograph" functions shall be available, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 016).
GenFun-REQ.44	Shall	Control	The operation "Pantograph" is configurable to be similar to the controlled locomotive, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 016).
GenFun-REQ.45	Shall	Control	The "Sanding" functions will be available, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 025)
GenFun-REQ.46	Shall	Control	The operation "Sanding" will be configurable to be similar to the controlled locomotive, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 025)
GenFun-REQ.47	Shall	Control	The "External warning horn" functions will be available, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 038).
GenFun-REQ.48	Shall	Control	The operation of "External warning horn" will be configurable to be similar to the controlled locomotive, as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 027).
GenFun-REQ.49	Shall	Control	The "Emergency Stop" functions will be available, as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 010) and Machine Directive.
GenFun-REQ.50	Shall	Control	The operation "Emergency Stop" will be configurable to be similar to the controlled locomotive, as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 010) and Machine Directive.
GenFun-REQ.51	Shall	Control	The "Technical and Diagnosis (TDD)" functions is available, e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 002 and UIC 612-03 (TDD)).
GenFun-REQ.52	Shall	Control	The operation of "Technical and Diagnosis (TDD)" will be configurable to be similar to the controlled locomotive e.g. as per UIC 612-0 (paragraph 3.3.2, Appendix A; nr 002 and UIC 612-03 (TDD)).
GenFun-REQ.53	Shall	Control	The RSC is able to switch between all cameras of the system.

**Table 3: Freight specific general functional requirements.**

### 3.4 FREIGHT SPECIFIC USER REQUIREMENTS FOR ATO GoA2-GoA4

In the following table, the freight specific requirements for ATO GoA2-4 are presented.

The first column gives every requirement a unique identifier. The second column indicates the obligation of the specific requirement. In the “subtopic” column, a further differentiation of the kind of the requirement is given. The requirements text describes the scope of the requirement.

ID	Obligation	Subtopic	Requirements Text
ATO-REQ.1	Info	01 Introduction	The specification is further specified in subtopics to: locomotive systems (GoA 2 Freight /GoA 4 Freight) and locomotive Integration Remote Supervision & Control and locomotive Integration
ATO-REQ.2	Info	01 Introduction	The ATO-TS system is provided by the infrastructure manager.
ATO-REQ.3	Shall	02 Communication	The radio module for ATO supports public Network standard to connect the ATO OB unit.
ATO-REQ.4	Shall	03 Test System Specification and Approval	The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the data from following Subset or implemented interfaces within the RSC System boundary: <ul style="list-style-type: none"> <li>- RSC Onboard - RSC Track side interface</li> <li>- RSC Onboard - Locomotive Functional Vehicle Adapter</li> <li>- RSC Onboard - Locomotive Hardwired / I/O interface</li> <li>- RSC Onboard - ATO OB interface for remote data entry of train characteristic, diagnostic and alarms</li> <li>- RSC Onboard - Diagnostic, Sensoric and Mechanical interface</li> <li>- RSC Onboard - Locomotive Diagnostic</li> <li>- RSC Onboard - Video interface (engine room, front looking, ...)</li> <li>- RSC Onboard - Rear Camera Interface (if rear camera existing on locomotive)</li> <li>- RSC Onboard - ATO OBU JRU data SS 140 sniffing</li> <li>- RSC Onboard - ETCS OBU JRU data SS 027 sniffing</li> <li>- RSC Onboard - ETCS interface (SS 130) sniffing for the jP/SP function.</li> <li>- RSC Onboard - RSC Trackside interface sniffing (SS 126)</li> <li>- RSC Onboard - RSC JRU for logging data</li> </ul>
ATO-REQ.5	Shall	03 Test System Specification and Approval	The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the data from following Subset or implemented interfaces within the ATO System boundary: <ul style="list-style-type: none"> <li>- ATO OB GoA 2 - Functional Vehicle Adapter (based on SS 139)</li> <li>- ATO OB GoA 2 - Hardwired / I/O interface</li> <li>- ATO OB GoA 4 - Functional Vehicle Adapter (based on SS 139)</li> <li>- ATO OB GoA 4 - Hardwired / I/O interface</li> <li>- ATO OB GoA 2 - ATO GoA 4 interface</li> <li>- ATO OB GoA 2 - ETCS OBU (SS 130) sniffing</li> <li>- ATO OB GoA 2/4 - RSC Trackside interface sniffing (SS 126).</li> </ul> For the JP/SP function. <ul style="list-style-type: none"> <li>- ATO OB GoA 2/4 - ATO TS Trackside interface sniffing (SS 126)</li> <li>- ATO OB GoA 2/4 - ATO OB JRU data SS 140 sniffing</li> </ul> <ul style="list-style-type: none"> <li>- Functional Vehicle Adapter - Locomotive Control System interface (Hardwired/Serial)</li> </ul>

ID	Obligation	Subtopic	Requirements Text
ATO-REQ.6	Shall	03 Test System Specification and Approval	<p>The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the data from following Subset or implemented interfaces between the ATO System and RSC System:</p> <ul style="list-style-type: none"> <li>- RSC Onboard - Locomotive Control interface based on SS 139</li> <li>- RSC Onboard - Hardwired / I/O interface to Locomotive (Control)</li> <li>- RSC Onboard - ATO OB interface for remote data entry of train characteristic</li> <li>- RSC Onboard - Diagnostic, Senoric and Mechanical interface on locomotive</li> <li>- RSC Onboard - Locomotive Diagnostic interface</li> <li>- RSC Onboard - ATO OBU JRU data SS 140 sniffing</li> <li>- RSC Onboard - ETCS OBU JRU data SS 027 sniffing</li> <li>- RSC Onboard - ATO OB - ETCS OBU interface (SS 130) sniffing</li> <li>- RSC Onboard - ATO TS interface sniffing (SS 126)</li> </ul>
ATO-REQ.7	Shall	03 Test System Specification and Approval	An HMI interface to configure the operational parameter for ATO Mode is available (additional operational parameters not transferred by SS 130 from ETCS).
ATO-REQ.8	Shall	04 Locomotive Specification and Approval	The passive locomotive must deliver the same information as required by the leading locomotive in double/multiple traction mode for the ATO. E.g. new alarm from GoA 4 implementation (fire Alarm, video, doors locked, ...) from the non-leading locomotive must come over.
ATO-REQ.9	Shall	05 Locomotive Equipment Specification	The locomotive controls the pantographs of all locomotives of the train at the request of the ETCS locomotive equipment, if the existing infrastructure e.g. Baseline 3 will support such functionality.
ATO-REQ.10	Shall	06 Vehicle integration	ATO Onboard will not exceed locomotive specific limit values.
ATO-REQ.11	Shall	06 Vehicle integration	The ATO function will determine and integrate response time of the locomotive traction and brake system based on train parameters (e.g. train composition, braked mass percentage, etc..) and adapt the freight RU traction/braking strategy accordingly.
ATO-REQ.12	Shall	06 Vehicle integration	The ATO diagnostic will be integrated within the vehicle diagnostic.
ATO-REQ.13	Shall	07 Freight specific architecture	In certain cases screw couplers can be broken or light wagons can be derailed if they are followed by heavy wagons where the applied brake force is lower.
ATO-REQ.14	Shall	07 Freight specific architecture	In case of defect brake caliper, lose wheel rims etc. the air brakes have to be switched off.
ATO-REQ.15	Shall	07 Freight specific architecture	If the wheel slide protection fails, the brakes have to be switched to P/RIC. If not possible, the brakes have to be switched off.
ATO-REQ.16	Shall	07 Freight specific architecture	Brake test shall be performed to ensure the air circulation in the system and the correct function of the brakes.
ATO-REQ.17	Shall	07 Freight specific architecture	Wirkbremsprobe: After starting of a train, a brake test with effect has to be performed. Additionally has to be performed before entering steep descends / ascends and before entering a terminus.
ATO-REQ.18	Shall	07 Freight specific architecture	Testing shall be performed if the system leaks air. Monitoring the loss of air pressure (or vacuum) over time.
ATO-REQ.19	Shall	07 Freight specific architecture	Test breaking shall be performed to remove snow and ice
ATO-REQ.20	Shall	07 Freight specific architecture	In case of entering a terminus (or similar situation), the usage of the electrical brake is only allowed in case of automatic compensation in case of failure. To be parametrizable for each country.
ATO-REQ.21	Shall	07 Freight specific architecture	Holding the train on constant speed in long descends shall be performed, avoiding overheating and overusing of break types.
ATO-REQ.22	Shall	07 Freight specific architecture	Initial breaking has to be performed with release of min. 0.4 - 0.5 bar (for min. 20 seconds) for freight trains. Applicable to heavy and long freight-trains.

ID	Obligation	Subtopic	Requirements Text
ATO-REQ.23	Shall	07 Freight specific architecture	Depending on the type of freight, the dynamic behaviour has to be taken into consideration in case of starting, driving and stopping the train.
ATO-REQ.24	Shall	07 Freight specific architecture	Applicable for heavy and long freight trains: After applying brake force or acceleration, it is necessary to wait, till the whole train is in homogenous movement.
ATO-REQ.25	Shall	07 Freight specific architecture	Applicable for heavy and long freight trains: Since every breaking action consumes air from the pressurized air reservoir, repeated breaking can lead to empty reservoirs. Between two air releases (breaking actions), there must be a filling break
ATO-REQ.26	Shall	07 Freight specific architecture	Applicable for heavy and long freight trains: If the train contains liquids, it is necessary to wait after a fast full stop at least a minute.
ATO-REQ.27	Shall	07 Freight specific architecture	Applicable for freight trains: The maximal applicable dynamic brake force value has to be controlled depending on the situation (switches, track etc.) in case of using multitraction.
ATO-REQ.28	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO function is not a safety critical system. Any safety functionality required for the ATO over ETCS to operate automatically should be managed by other safety systems, e.g. ETCS, Vital relay, ...
ATO-REQ.29	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO GoA 2 functionality and implementation is modular, expandable and evolvable.
ATO-REQ.30	Shall	08 ATO GoA 2 Freight System Specification and Approval	The Supplier delivers to the client an RSC Trackside HMI to configure the operational parameters (incl. train characteristics) (additional operational parameters not transferred by SS 130 from ETCS) of ATO OB via RSC Trackside HMI.
ATO-REQ.31	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO GoA 2 is driving in optimal driving strategy to minimize the use of train brakes and remain within the train force limits according to freight national and RU rules.
ATO-REQ.32	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO system is configurable to implement different driving styles and adhesion based on parameters to be agreed with RU.
ATO-REQ.33	Shall	08 ATO GoA 2 Freight System Specification and Approval	A user-friendly onboard HMI interface to configure the operational parameter (additional operational parameter not transferred by SS 130 from ETCS) of the ATO is available.
ATO-REQ.34	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO will perform gentle stretching of the train coupler in start (lifting).
ATO-REQ.35	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO will perform correct compressing of the train coupler for decoupling.
ATO-REQ.36	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO GoA 2 Freight is running on ETCS L1 FS.
ATO-REQ.37	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO GoA 2 Freight is running energy efficient mode. If requested via TMS the algorithm of the ATO-OB shall optimize the driving focusing on energy efficiency. (Keeping timetable is less prioritized in such a case)

ID	Obligation	Subtopic	Requirements Text
ATO-REQ.38	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO drives according to freight national and freight RU ATO driving rules, e.g., it will enforce especially driving limits such as max. acceleration. To account for differences in freight national and freight RU ATO driving rules, the system must be configurable and parameterizable. These driving rules will be determined and optimised by ATO OBU, the so called optimal driving strategy.
ATO-REQ.39	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO GoA 2 manages hill stop and start.
ATO-REQ.40	Shall	08 ATO GoA 2 Freight System Specification and Approval	Manage stop/start of a train between a downhill and uphill slope - so called "mountain bow". To avoid that a train gets stranded with insufficient traction to restart on a uphill slope, the ATO OB shall stop before of the uphill slope to allow the train to gain sufficient speed and adhesion to fully pass the uphill slope.
ATO-REQ.41	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO GoA 2 manages all locomotive brake application.
ATO-REQ.42	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO GoA 2 manages brake blending based on national and freight RU rules and driving strategy.
ATO-REQ.43	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO is capable of controlling the train with double and multiple traction units. Distributed Power formation is not part of this requirement.
ATO-REQ.44	Shall	08 ATO GoA 2 Freight System Specification and Approval	If only the leading locomotive of a double or multiple traction is equipped with ATO, the ATO is capable of controlling the train formation. E.g. in the case of double traction or multiple traction all locomotive in the formation have same traction/brake forces.
ATO-REQ.45	Shall	08 ATO GoA 2 Freight System Specification and Approval	If the ATO vehicle equipment is disturbed, the locomotive offers the driver in each driver's cab the possibility to deactivate the ATO vehicle equipment with a switch.
ATO-REQ.46	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO-OB stop optimized at ATO End of Authority ATO EoA.
ATO-REQ.47	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO on-board can operate on GoA 2 and GoA 4 (GoA 4 includes GoA 2).
ATO-REQ.48	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO on-board and the ATO trackside operate the highest system version supported by both. Backward compatibility shall be possible by allowing the ATO on-board and the ATO trackside to support several system versions.
ATO-REQ.49	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO will perform brake test before up- and downhill. If triggered by the ATO TS in case of upcoming extreme gradient.
ATO-REQ.50	Shall	08 ATO GoA 2 Freight System Specification and Approval	GoA 2 functionality is a subset of the GoA 4 functionality. E.g. GoA 2 functionalities must be also included within the GoA 4 system.
ATO-REQ.51	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO is to raise/lower the pantograph and switch automatically in neutral/powerless section.

ID	Obligation	Subtopic	Requirements Text
ATO-REQ.52	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO is to raise/lower the pantograph and switch automatically in voltage change section.
ATO-REQ.53	Shall	08 ATO GoA 2 Freight System Specification and Approval	The ATO manages the circuit breakers to avoid a driver needing to attend a train to reset the circuit breaker.
ATO-REQ.54	Shall	08 ATO GoA 2 Freight System Specification and Approval	Certain conditions (e.g. snow in winter, long and steep downhill sections) lower the performance of brakes. Counter actions have to be taken in these conditions.
ATO-REQ.55	Shall	08 ATO GoA 2 Freight System Specification and Approval	The rolling behaviour of the vehicle has to be checked after first start (Icing issues)
ATO-REQ.56	Shall	08 ATO GoA 2 Freight System Specification and Approval	The System shall perform actions to free the brakes from ice and snow.
ATO-REQ.57	Shall	08 ATO GoA 2 Freight System Specification and Approval	Trains with insufficient traction power shall be kept running before steep inclines (e.g. medium length uphill sections or ramps)
ATO-REQ.58	Shall	08 ATO GoA 2 Freight System Specification and Approval	System shall prevent icing / issues with releasing the brakes.
ATO-REQ.59	Shall	09 ATO GoA 4 Freight System Specification and Approval	Contractor delivers to the client a user friendly onboard HMI interface to configure the operational parameters (additional operational parameters not transferred by SS 130 from ETCS) of the ATO.
ATO-REQ.60	Shall	09 ATO GoA 4 Freight System Specification and Approval	ATO GoA 4 functionality and implementation is modular, expandable and evolvable.
ATO-REQ.61	Shall	09 ATO GoA 4 Freight System Specification and Approval	It shall be possible to operate in the highest Grade of Automation supported by both the ATO trackside and the ATO on-board when the ATO TS and ATO OB are in an error free situation.
ATO-REQ.62	Shall	09 ATO GoA 4 Freight System Specification and Approval	GoA 4 is performing and indicating when using sanding function. Notification will be provided to Remote System operator when in supervision mode and logged via Supervision & Diagnostic system.
ATO-REQ.63	Shall	09 ATO GoA 4 Freight System Specification and Approval	ATO-OB in GoA4 mode gives an appropriate warning sound X seconds before initiating movement. X is configurable and default is 5 s.
ATO-REQ.64	Shall	10 Operation	ATO locomotive equipment allows the data entry of operational parameters (incl. train characteristics) (standalone HMI and not integrated within the ETCS DMI) via the RSC Trackside HMI interface.
ATO-REQ.65	Shall	11 Reduced friction coefficients	A concept for the implementation and data entry of the function Reduced friction coefficients (Adhesion Management) for ATO freight trains shall be made available to the RU as customer along with the product.
ATO-REQ.66	Shall	12 Non Functional Requirements	The ATO and RSC system design is modular, expandable and evolvable.
ATO-REQ.67	Shall	12 Non Functional Requirements	The interchangeable modular building blocks shall be defined in the Logical System Architecture. A reference is provided in the Annex.
ATO-REQ.68	Shall	12 Non Functional Requirements	Completeness and quality of the specification of the system shall be proven by the supplier in a test environment prior to field testing in lab testing.

ID	Obligation	Subtopic	Requirements Text
ATO-REQ.69	Should	12 Non Functional Requirements	<p>The Supplier will deliver the full functional sequences (functional behaviour, timing constraints, limitations)</p> <p>The contractor must show that the level of specification is sufficient for creating test requirements for:</p> <ul style="list-style-type: none"> <li>- protocol tests</li> <li>- integration tests</li> <li>- functional system tests (TCMS lab)</li> <li>- field tests</li> </ul>
ATO-REQ.70	Shall	12 Non Functional Requirements	The Supplier will deliver the description of the application layer and data equal to SS 139, 119 and 121, as applicable
ATO-REQ.71	Shall	12 Non Functional Requirements	The Supplier will deliver the configuration data on all implemented communication systems in the same detail as it will be used within MVB configuration between 2 or more independent supplier.
ATO-REQ.72	Shall	12 Non Functional Requirements	<p>The interfaces to the locomotive with the ATO locomotive equipment comply to</p> <p>OCORA-40-007-Gamma_CCS_TCMS-Interface_ATO-Functionalities according to the specifications published on the OCORA website <a href="https://github.com/OCORA-Public/Publication/tree/master/00_Archive%20earlier%20Publications/01_OCORA%20Gamma%20Release">https://github.com/OCORA-Public/Publication/tree/master/00_Archive%20earlier%20Publications/01_OCORA%20Gamma%20Release</a></p>
ATO-REQ.73	Shall	12 Non Functional Requirements	<p>The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the logged data from all interfaces defined within chapter 15 - Interfaces (ID ATO-HLR.2.310.2).</p> <p>This for RSC and ATO mode. For ATO it will be available on leading locomotive.</p>
ATO-REQ.74	Shall	12 Non Functional Requirements	The System Requirement Specification must be described with strict formal methods to achieve functional correct test reference, HW and SW independent approach and plug-and-play interfaces.
ATO-REQ.75	Shall	13 Interfaces	<p>Supplier will deliver following interface specification</p> <ul style="list-style-type: none"> <li>- RSC Onboard - RSC Track side interface</li> <li>- RSC Onboard - Functional Vehicle Adapter</li> <li>- RSC Onboard - Hardwired / I/O interface</li> <li>- RSC Onboard - ATO OB interface for remote data entry of train characteristic, diagnostic and alarms</li> <li>- RSC Onboard - Diagnostic, Sensoric and Mechanical interface</li> <li>- RSC Onboard - Locomotive Diagnostic</li> <li>- RSC Onboard - Video interface (engine room, front looking, ...)</li> <li>- RSC Onboard - Rear Camera Interface (if rear camera existing on locomotive)</li> <li>- RSC Onboard - ATO OBU JRU data SS 140 sniffing</li> <li>- RSC Onboard - ETCS OBU JRU data SS 027 sniffing</li> <li>- RSC Onboard - ETCS interface (SS 130)</li> <li>- RSC Onboard - ATO TS interface sniffing (SS 126)</li> <li>- RSC Onboard - Obstacle Detection System video</li> <li>- RSC Onboard - Obstacle Detection System alarm</li> <li>- RSC Onboard - RSC JRU for logging data</li> <li>- ATO OB GoA 2 - Functional Vehicle Adapter (based on SS 139)</li> <li>- ATO OB GoA 2 - Hardwired / I/O interface</li> <li>- ATO OB GoA 4 - Functional Vehicle Adapter (based on SS 139)</li> <li>- ATO OB GoA 4 - Hardwired / I/O interface</li> <li>- ATO OB GoA 2 - ATO GoA 4 interface</li> <li>- ATO OB GoA 2 - ETCS OBU (SS 130)</li> <li>- ATO OB GoA 2/4 - RSC Trackside interface (SS 126).</li> </ul> <p>For the JP/SP function.</p> <ul style="list-style-type: none"> <li>- ATO OB GoA 2/4 - ATO TS Trackside interface (SS 126)</li> <li>- ATO OB GoA 2/4 - ATO OB JRU logging</li> <li>- Functional Vehicle Adapter - Locomotive Control System interface (Hardwired/Serial)</li> </ul>

ID	Obligation	Subtopic	Requirements Text
ATO-REQ.76	shall	13 Interfaces	<p>The Supplier will use the same System Interconnection Model equal to OSI model incl. safety &amp; security layer according to the OCORA requirements: <a href="https://github.com/OCORA-Public/Publication/blob/master/00_Archive%20earlier%20Publications/02_OCORA%20Beta%20Release/30_Program%20Documentation/OCORA-30-006-Beta_High-Level-Methodology.pdf">https://github.com/OCORA-Public/Publication/blob/master/00_Archive%20earlier%20Publications/02_OCORA%20Beta%20Release/30_Program%20Documentation/OCORA-30-006-Beta_High-Level-Methodology.pdf</a> which will be delivered to the client e.g. SS 143 and SS 147.</p> <p>Background: some protocols or CCS interfaces involve buses that are not fully OSI compliant, or use multiple serial connection technologies and gateways (e.g. MVB and Ethernet).</p> <p>It is essential that at the FFFIS level, the network, transport and application layers are independent and layered according to the OSI model.</p> <p>The Supplier hands over to the RU the discrepancies, changes, modification, gap analysis, additions or complements between the implemented and the existing standards.</p> <p>The rationale for each deviation from any of the standards shall be explained.</p>
ATO-REQ.77	Shall	14 Supervision and Diagnostic Data	The supplier provides an interface so that all generated locomotive alarms will be sent to the ATO on board (GoA4). Relevant for existing vehicle design.
ATO-REQ.78	Shall	15 Operation Conditions	The ATO and RSC system do not influence/impact other train systems (non regression).
ATO-REQ.79	Shall	15 Operation Conditions	The ATO and RSC system is not influenced/impacted by other systems of the vehicle.
ATO-REQ.80	Shall	16 Preliminary Hazard Log	The system supplier shall analyse the driver handbook and list of drivers' tasks and propose a translation of safety relevant tasks into system requirements where these had not already been identified within the requirements. Relevant for existing vehicle design.
ATO-REQ.81	Shall	08 ATO GoA 2 Freight System Specification and Approval	ATO Onboard is configurable (possible exceeding any locomotive-specific limit values e.g. like maximum acceleration, maximum tractive force, time ramps, adhesion, temperature of components etc.) according the train characteristic to ensure the loco specific execution and command rules are managed. For Adhesion management the Supplier delivers a user-friendly tool to be able to add and modify additional loco and train configuration.

**Table 4: Freight specific requirements for ATO GoA2-4.**

### 3.5 REMOTE SUPERVISION AND CONTROL (FREIGHT SPECIFIC)

In the following table, the freight specific requirements for the remote system are presented.

The first column gives every requirement a unique identifier. The second column indicates the obligation of the specific requirement. In the “subtopic” column, a further differentiation of the kind of the requirement is given. The requirements text describes the scope of the requirement.

ID	Obligation	Subtopic	Requirements Text
RSC-REQ.1	Shall	02 Communication	The radio module for Remote System Onboard supports public Network standard to connect the Remote System trackside unit.
RSC-REQ.2	Shall	02 Communication	The Remote System trackside system supports public Network standard to connect the ATO OB for - SS 126 ATO-OB/ATO-TS interface specification (FFFIS application level)
RSC-REQ.3	Shall	02 Communication	The Remote System trackside system supports public Network standard to connect the Remote System Onboard.
RSC-REQ.4	Shall	03 System Specification and Approval	The Supplier creates a RSC architecture including all interfaces to existing systems.
RSC-REQ.5	Shall	03 System Specification and Approval	The Supplier creates a RSC specification including all interfaces to existing systems.
RSC-REQ.6	Shall	03 System Specification and Approval	The system is supervising RSC System connectivity quality at all time.
RSC-REQ.7	Shall	03 System Specification and Approval	<p>The following video cameras and video streams of the system are supplied:</p> <ul style="list-style-type: none"> <li>- Front view from cab</li> <li>- In-cab view cab</li> <li>- Engine room</li> <li>- Rear cameras (if, available on the locomotive)</li> </ul> <p>The front view covers a field of view of 120 degrees horizontally and 130 degrees vertically to enable human object recognition equivalent to the naked human eye. Additionally, the front view covers 180-200 degrees horizontally in the lower half of the vertical field of vision. The in-cab view is capturing the control panel and the in-cab displays.</p>
RSC-REQ.8	Shall	03 System Specification and Approval	<p>In conjunction with the respective cameras, the following audio for the system is supplied by the supplier:</p> <ul style="list-style-type: none"> <li>- Cab</li> <li>- Engine room</li> </ul>
RSC-REQ.9	Shall	03 System Specification and Approval	The passive locomotive must deliver the same information as required by the leading locomotive in double/multiple traction mode for the RSC. E.g. new alarm from GoA 4 implementation (fire Alarm, video, doors locked, ...) from the non leading locomotive must come over.
RSC-REQ.10	Shall	03 System Specification and Approval	Video from locomotive rear camera will be streamed to RSC trackside. In the case the locomotive is equipped with rear camera.

ID	Obligation	Subtopic	Requirements Text
RSC-REQ.11	Shall	03 System Specification and Approval	The system, the ETCS, ATO and RSC equipment have a common time based on the UTC.
RSC-REQ.12	Shall	03.b Test System Specification and Approval	The test driver and RSC Operator workplace/HMI adheres to all applicable principles and rules that apply for today's operation in terms of layout, dimensions, controls and displays.
RSC-REQ.13	Shall	12 Non Functional Requirements	RSC system is able to work with the existing communication e.g. LTE and IT infrastructure.
RSC-REQ.14	Shall	12 Non Functional Requirements	RSC and ATO system are using COTS Hardware and common Operational Software e.g. Windows/Linux
RSC-REQ.15	Shall	12 Non Functional Requirements	An RSC alerts and alarms matrix is developed to identify the required alert and alarm information needed by the RSC during RSC Control and during RSC supervision, for review and input with end user representatives.
RSC-REQ.16	Shall	12 Non Functional Requirements	The RSC alerts and alarms matrix should be able to differentiate how they are represented and filtered based on a fully configurable user interface (i.e. control mode, supervision mode, by alarm, by alert, by train, by route etc.).
RSC-REQ.17	Should	13 Non Functional Requirements	The RSC HMI on trackside will display the real-time ATO operational planning, it shall be developed according to a sound Human Factors approach.
RSC-REQ.18	Shall	14 Supervision and Diagnostic Data	All (necessary) existing alarm and fault codes of the locomotive will be applied by the RSC operator. The alarm and fault codes shall be identical to their today's counterparts available to the driver.
RSC-REQ.19	Shall	14 Supervision and Diagnostic Data	All (necessary) new alarm and fault codes of new and modified systems will be applied by the RSC operator. The alarm and fault codes shall be identical to their today's counterparts available to the driver.
RSC-REQ.21	Shall	17 Remote System Specification	<p>Remote System supports the Remote Operator (Driver) to drive according to freight national and freight RU ATO driving rules, e.g., it will enforce especially driving limits such as max. acceleration.</p> <p>To account for differences in freight national and freight RU ATO driving rules, system must be configurable and parameterizable.</p> <p>Remote System will use similar driving strategy as ATO.</p>
RSC-REQ.22	Shall	17 Remote System Specification	<p>Remote Onboard is configurable according to train characteristics to ensure locomotive-specific execution and prevent locomotive-specific limits from being exceeded.</p> <p>Loco and train configuration (adding and modifying) shall be possible through a user friendly tool.</p>
RSC-REQ.23	Shall	17 Remote System Specification	ETCS emergency brake alarms are always transmitted to the Remote System Operator (Driver)
RSC-REQ.24	Shall	17 Remote System Specification	Locomotive alarms and notifications are always transmitted to the Remote System Operator (Driver)
RSC-REQ.25	Shall	17 Remote System Specification	Remote System is enabling the Remote System Operator to apply locomotive emergency brake in Remote System control mode through Remote System.

ID	Obligation	Subtopic	Requirements Text
RSC-REQ.26	Shall	17 Remote System Specification	Remote System will provide live video stream from the leading locomotive showing track ahead in sufficient detail for the operator to be able to control the train as well a video stream showing the view on current driver working space.
RSC-REQ.27	Shall	17 Remote System Specification	Remote system is able to show the front view locomotive video in case of need (request / alarm) in all modes.
RSC-REQ.28	Shall	17 Remote System Specification	Remote System will allow the Remote Operator to operate in reverse mode according to national and freight RU regulation.
RSC-REQ.29	Shall	17 Remote System Specification	Remote System is enabling the Remote System Operator to apply locomotive external warning horn in Remote System control mode.
RSC-REQ.30	Shall	17 Remote System Specification	In Remote System control mode: Remote System is monitoring the alert status of the Remote System Operator e.g. equal to vigilance system / dead man's switch.
RSC-REQ.31	Shall	17 Remote System Specification	In Remote System control mode the vigilance system / dead man's switch on locomotive is managed by the Remote System Onboard System.
RSC-REQ.32	Shall	17 Remote System Specification	All the information provided to the onboard driver will be available and displayed to the Remote System operator in Remote System control mode.
RSC-REQ.33	Shall	17 Remote System Specification	Remote System is able to receive all diagnostic information from all the operated locomotives
RSC-REQ.34	Shall	17 Remote System Specification	Locomotive diagnostic data will be available and displayed to the Remote System operator.
RSC-REQ.35	Shall	17 Remote System Specification	Video and audio (audio, when it creates benefit to the Remote System Operator) from engine room will be sent to Remote System Operator on demand. Goal is that the Remote System Operator can check if there is any abnormal sound coming from engine room, if required. As today the train driver will check the engine room visual, smelling and sound if something abnormal is ongoing with the rail system.
RSC-REQ.36	Shall	17 Remote System Specification	The Remote System is active in supervision whenever an ATO OB is in active ATO mode.
RSC-REQ.37	Shall	17 Remote System Specification	Remote System is enabling the Remote System Operator in control mode to manage the circuit breakers (set and reset) to avoid a driver needing to attend a train to reset the circuit breaker manually.
RSC-REQ.38	Shall	17 Remote System Specification	Status and actions of the remote control system in control mode shall be available on the driver's on-board HMI.
RSC-REQ.39	Shall	17 Remote System Specification	Remote System is enabling the Remote System Operator in control mode to raise/lower the pantograph and switch manually in voltage change section.
RSC-REQ.40	Shall	17 Remote System Specification	Remote System is enabling the Remote System Operator in control mode to manage the ATP isolation switch manually.
RSC-REQ.41	Shall	17 Remote System Specification	Remote System is enabling the Remote System Operator in control mode is able to manage the sanding function manually.
RSC-REQ.42	Shall	17 Remote System Specification	The Remote System operator in control mode is able to manage the "External Front Lights" function will be available, e.g. as per UIC 612-0

ID	Obligation	Subtopic	Requirements Text
			(paragraph 3.3.2, Appendix A; nr 027) on the locomotive through the Remote System.
RSC-REQ.43	Shall	17 Remote System Specification	All new alarms and fault codes of the modified and new systems necessary for the Remote system Operator shall be made available.
RSC-REQ.44	Shall	17 Remote System Specification	All alarms will be displayed on Perception System HMI and Remote system HMI
RSC-REQ.45	Shall	17 Remote System Specification	RSC System functionality and implementation is modular, expandable and evolvable.
RSC-REQ.46	Shall	17 Remote System Specification	<p>RSC System is composed of</p> <ul style="list-style-type: none"> <li>- RSC Trackside System</li> <li>- RSC Onboard - RSC Track side interface</li> <li>- RSC Onboard - Locomotive Control interface</li> <li>- RSC Onboard - Hardwired / I/O interface</li> <li>- RSC Onboard - ATO OB interface for remote data entry of train characteristic</li> <li>- RSC Onboard - Diagnostic, Sensoric and Mechanical interface</li> <li>- RSC Onboard - Locomotive Diagnostic interface</li> <li>- RSC Onboard - Video interface (engine room, front looking, ...)</li> <li>- RSC Onboard - Rear Camera Interface (if rear camera existing on locomotive)</li> <li>- RSC Onboard - ATO OBU JRU data SS 140 sniffing</li> <li>- RSC Onboard - ETCS OBU JRU data SS 027 sniffing</li> <li>- RSC Onboard - ETCS interface (SS 130)</li> <li>- RSC Onboard - ATO TS interface sniffing (SS 126)</li> <li>- RSC Onboard - RSC JRU for logging data</li> </ul>
RSC-REQ.47	Shall	17 Remote System Specification	<p>RSC System is composed of</p> <ul style="list-style-type: none"> <li>- RSC Working station trackside</li> <li>- RSC HMI on trackside</li> <li>- RSC test HMI Onboard</li> <li>- RSC Onboard</li> <li>- RSC Trackside - RSC Onboard Interface</li> <li>- RSC Trackside functions as a remote HMI is loco independent HMI in control mode</li> <li>- Diagnostic system e.g. logging box</li> <li>- Video, sensors &amp; mechanical with a data link to the RSC trackside</li> </ul>
RSC-REQ.48	Shall	17 Remote System Specification	RSC Onboard and RSC Trackside are strictly modular and connect via open standard.
RSC-REQ.49	Shall	17 Remote System Specification	The communication between RSC Onboard and Trackside is via Public Radio Network.
RSC-REQ.50	Shall	17 Remote System Specification	The RSC function is not a safety critical system. Any safety functionality required for the RSC System to operate automatically/remotely should be managed by other safety systems, e.g. ETCS, Vital relay... .

ID	Obligation	Subtopic	Requirements Text
RSC-REQ.51	Shall	17 Remote System Specification	<p>In RSC control mode real-time information, control commands and feedback on control commands are available with a latency no greater than a predefined limit value in milliseconds for the communication between RSC onboard and RSC trackside. The limit value is proposed by the RU. Limit values may be provided for each category of latency e.g. control, command, feedback of control commands, alerts latency, alarms latency etc.</p> <p>An appropriate action by the RSC System will be initiated in case the limit value is exceeded.</p>
RSC-REQ.52	Shall	17 Remote System Specification	Live camera feed is available that allows front view at up to a predefined value in meters in front of train. Limit value needs to be defined.
RSC-REQ.53	Shall	17 Remote System Specification	RSC working must have the function to indicate that the Video livestream is live and not frozen.
RSC-REQ.54	Shall	17 Remote System Specification	RSC system is logging all commands and indication in RSC Command mode.
RSC-REQ.55	Shall	17 Remote System Specification	RSC Operator is always supervising during ATO mode through RSC System.
RSC-REQ.56	shall	17 Remote System Specification	RSC system SS 126 confirm communication is possible via Public Radio Network.
RSC-REQ.57	Shall	17 Remote System Specification	RSC system operates in control mode via RSC Onboard, when locomotive is in degraded mode (degraded mode is defined in <b>this main deliverable document</b> ).
RSC-REQ.58	Shall	17 Remote System Specification	RSC System will allow the RSC Operator to drive the train in optimal driving strategy mode to minimize the use of train brake and remain within the train force limits according to freight national and RU rules.
RSC-REQ.59	Shall	17 Remote System Specification	The RSC System will allow the RSC Operator to drive the train and is able to define and implement different driving styles and adhesion based on parameters to be agreed with RU.
RSC-REQ.60	Shall	17 Remote System Specification	<p>The supplier will provide the RSC Operator the exact track location in relation to the KM Marker +/- x m of the train. The x is a configurable value. X can be set at 5 m by default.</p> <p>RU will deliver a database that provides the direct mapping of balise IDs (that are within the track for trial operation) to an exact position in the same reference system as relevant the KM markers.</p>
RSC-REQ.61	Shall	17 Remote System Specification	RSC Workstation design must comply with national and RU legal health and safety requirements and office workstation standards.
RSC-REQ.62	Shall	17 Remote System Specification	Audio from leading cab will be send to RSC Operator on demand.
RSC-REQ.63	Should	17 Remote System Specification	For the case the locomotive is equipped with rear camera. Video from locomotive rear camera will be send to RSC Operator.

ID	Obligation	Subtopic	Requirements Text
RSC-REQ.64	Shall	17 Remote System Specification	The RSC Trackside HMI shall fit this task and shall be developed according to good human factors principles. "ISO_9241-210/110 ISO_11064-5_2008- ch 6.3 ISO_11064-5_2008-A3.5 ISO_11064-5_2008-A5.2"
RSC-REQ.65	Shall	17 Remote System Specification	The system will follow standards - especially UIC 612-0, UIC 612 -1, UIC 612 -2, UIC 612 -3, UIC 612 - 01, UIC 612 -02, UIC 612 -03, UIC 612 - 04. UIC 612 -3. Wherever it makes sense in ergonomic view.
RSC-REQ.66	Shall	17 Remote System Specification	RSC working space HMI is based on touch display or mouse driven instead of softkey display solutions.
RSC-REQ.67	Shall	17 Remote System Specification	For the RSC control mode the design and layout of the RSC control workplace including the information, controls, graphical user interface is resembling a real driver desk in a way that it enhances the look and feel of driving a real train.
RSC-REQ.68	Shall	17 Remote System Specification	The layout of information on the RSC HMIs, including but not limited to the dashboard overview display, shall remain configurable, scalable and expandable by a super-user.
RSC-REQ.69	Shall	17 Remote System Specification	RSC Onboard Interface equipment complies with - Subset 139
RSC-REQ.70	Shall	17 Remote System Specification	RSC Onboard Interface equipment complies with - Subset 140 - Subset-027
RSC-REQ.71	Shall	17 Remote System Specification	The RSC Trackside HMI is configurable w.r.t the operational parameters (incl. train characteristics) (additional operational parameters not transferred by SS 130 from ETCS) of ATO OB via RSC Trackside HMI.
RSC-REQ.72	Shall	17 Remote System Specification	RSC System is indicating RSC non-stopping areas. Will deviate from ETCS non-stopping areas.
RSC-REQ.73	Shall	17 Remote System Specification	RSC System is indicating RSC inhibition areas. Will deviate from ATO inhibition areas.
RSC-REQ.74	Shall	17 Remote System Specification	In order to show to the RSC operator, the status of the locomotive, its direct surroundings and its health, video imagery, sensor statuses will be captured and gathered in order to send them to the RSC.
RSC-REQ.75	Shall	17 Remote System Specification	The locomotive transmits the operational parameter (incl. train characteristic) (additional operational parameter not transferred by SS 130 from ETCS) information to RSC.
RSC-REQ.76	Shall	17 Remote System Specification	The RSC Operator is able to use the constant speed control from modern locomotives if its available.
RSC-REQ.77	Shall	17 Remote System Specification	RSC System is enabling the RSC Operator in control mode to raise/lower the pantograph and switch manually in neutral/ powerless section.
RSC-REQ.78	Shall	17 Remote System Specification	When in Remote System control mode the Remote System Operator can engage ATO into GoA4 mode and switch to Remote System supervision mode

ID	Obligation	Subtopic	Requirements Text
RSC-REQ.79	Shall	17 Remote System Specification	When in Remote System supervision mode the Remote System Operator can disengage GoA4 mode and switch to Remote System control mode
RSC-REQ.80	Shall	17 Remote System Specification	Remote System Onboard will perform gentle stretching of the train coupler in start (lifting).
RSC-REQ.81	Shall	17 Remote System Specification	Remote System Onboard will perform correct compressing of the train coupler for decoupling.

**Table 5: Freight specific requirements for the remote system.**

### 3.6 PERCEPTION SYSTEM / OBSTACLE DETECTION

In the following table, the freight specific requirements for the perception system are presented.

The first column gives every requirement a unique identifier. The second column indicates the obligation of the specific requirement. In the “subtopic” column, a further differentiation of the kind of the requirement is given. The requirements text describes the scope of the requirement.

ID	Obligation	Section/Chapter	Requirements Text
Per-REQ.1	Shall	03 Test System Specification and Approval	The Supplier shall provide evidence, proving the perception system does not influence/impact other train systems (non regression).
Per-REQ.2	Shall	03 Test System Specification and Approval	The Supplier shall provide evidence, proving the perception system is not influenced/impacted by other systems of the vehicle.
Per-REQ.3	Shall	03 Test System Specification and Approval	The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the data from following Subset or implemented interfaces between the perception system and RSC System: - RSC Trackside - perception system
Per-REQ.4	Shall	03 Test System Specification and Approval	The perception system is configurable (in terms of coloring, transparency, thresholds for class determination, warning output to RSC operator) in real-time both during RSC supervision and RSC control mode
Per-REQ.5	Shall	03 Test System Specification and Approval	The latest minutes of video feed (exact time needs to be predefined by operator) including the superimposed graphical perception system information layer are available to the RSC operator for review via a replay function
Per-REQ.6	Shall	12 Non Functional Requirements	The perception system equipment shall be designed such that direct or indirect contact with train staff and passenger is prevented, both in normal cases and in cases of equipment failure.
Per-REQ.7	Shall	18 Perception System	The Perception System generates warnings and presents them to the Remote system operator in Remote system supervision mode
Per-REQ.8	Shall	18 Perception System	The warnings generated by the Perception System include the following events: obstacles on the track; obstacles in minimum clearance outline ("Lichttraumprofil"), obstacles close the track
Per-REQ.9	Shall	18 Perception System	The currently active configuration of the Perception system is visualized to the Remote system operator (driver). This comprises the perception system view, hardware and software configuration.
Per-REQ.10	Shall	18 Perception System	The Perception System is available to the Remote system operator as an additional layer of graphical information superimposed on the video feed
Per-REQ.11	Shall	18 Perception System	Information on current Perception System status (passive/available/active) is available to the Remote system operator.
Per-REQ.12	Shall	18 Perception System	Warnings generated by the Perception System are visually and auditorily presented to the Remote system operator
Per-REQ.13	Shall	18 Perception System	The Remote system operator can play/pause/forward/backward the video feed in the replay function
Per-REQ.14	Shall	18 Perception System	The Remote system operator can mark and add comments in the video feed in the replay function that are saved at the respective point in time in the video (tagging). Tagging is e.g., done in a copied version of the video feed.
Per-REQ.15	Shall	02 Communication	The radio module for Perception System supports public Network standard to connect the Remote system Trackside unit.

**Table 6: Freight specific requirements for the perception system.**

### 3.7 TELECOMMUNICATION

Communication of the different modules and components is crucial for the trouble-free functioning and success of ATO. However, the exact network design depends on various parameters, that might differ from case to case, as for example the equipment of the infrastructure side. Due to the complexity of the decision process, the specific characteristics of the route equipment as well as the involvement of different stakeholders, the definition of such a telecommunication network is beyond the scope of this document.

The requirements and conditions are presented below as an example for reference.

#### **ETCS connection:**

Existing connection for the ETCS is GSM-R/CSD.

#### **ATO-TS – ATO-OB connection:**

Planned implementation: Connection over public network.

Switching between the GSM-R and public network shall be done via the onboard router. However, also switching to the router for public network is considered for testing purposes e.g., not working within all tunnels.

#### **ATO-TS – ATO-OB SS 126/125:**

- - Subset-125 System Requirements Specification – TSI 2023,
- - Subset-126 ATO-OB/ATO-TS interface specification (FFFIS application level) – TSI 2023.

#### **RSC connection:**

Planned implementation: public network.

#### **Voice connections:**

Maintain existing connections. New connections have not yet been set up, but we expect that for the test the public network can be used.

The figure below shows the existing and future connections.

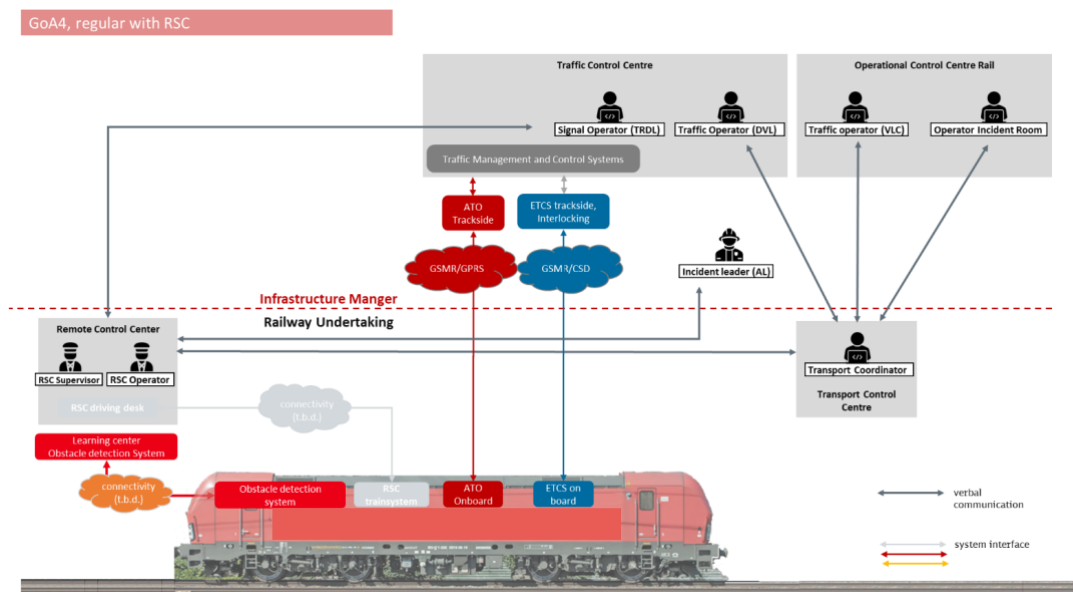


Figure 9: Current and future radio connections in an exemplary setup.

### 3.8 VEHICLE INTEGRATION

Vehicle Integration must follow OCORA-requirements.

### 3.9 TEST SYSTEM SPECIFICATION

Here, all requirements (REQ) concerning the test system are specified. It is integrated into this document as important part of development process.

The first column gives every requirement a unique identifier. The second column indicates the obligation of the specific requirement. In the “subtopic” column, a further differentiation of the kind of the requirement is given. The requirements text describes the scope of the requirement.

Please refer also to chapter “6.1.3 Annex C: Testing and validation” for use cases and operational scenarios for testing and validation purposes.

ID	Obligation	Section/Chapter	Requirements Text
Test-REQ.1	Shall	03 Test System Specification and Approval	The system can be operated in a logging mode ATO to log data for measuring the reference for the average driver
Test-REQ.2	Shall	03 Test System Specification and Approval	The system is equipped with locomotive equipment to manage ATO GoA 2 start/stop/skip on both cabs of the locomotive.
Test-REQ.3	Shall	03 Test System Specification and Approval	The system is equipped with Human Machine Interface and will display at the non active (rear) cab the same ATO information at same time as the active (front) cab.
Test-REQ.4	Shall	03 Test System Specification and Approval	The system is equipped with Human Machine Interface that will display all the RSC commands on the non active (rear) cab the same RSC information at same time as the active (front) cab.
Test-REQ.5	Shall	03 Test System Specification and Approval	The system is equipped with Human Machine Interface locomotive equipment to indicate the ATO status manual, GoA 2 or GoA 4 to external environment and will deliver the function in each ATO mode.
Test-REQ.6	Shall	03 Test System Specification and Approval	The system is equipped with Human Machine Interface locomotive equipment to indicate the RSC status to external environment and will deliver the function in RSC mode.
Test-REQ.7	Shall	03 Test System Specification and Approval	<p>The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the data from following Subset or implemented interfaces within the RSC System boundary:</p> <ul style="list-style-type: none"> <li>- RSC Onboard - RSC Track side interface</li> <li>- RSC Onboard - Locomotive Functional Vehicle Adapter</li> <li>- RSC Onboard - Locomotive Hardwired / I/O interface</li> <li>- RSC Onboard - ATO OB interface for remote data entry of train characteristic, diagnostic and alarms</li> <li>- RSC Onboard - Diagnostic, Sensoric and Mechanical interface</li> <li>- RSC Onboard - Locomotive Diagnostic</li> <li>- RSC Onboard - Video interface (engine room, front looking, ...)</li> <li>- RSC Onboard - Rear Camera Interface (if rear camera existing on locomotive)</li> <li>- RSC Onboard - ATO OBU JRU data SS 140 sniffing</li> <li>- RSC Onboard - ETCS OBU JRU data SS 027 sniffing</li> <li>- RSC Onboard - ETCS interface (SS 130) sniffing for the JP/SP function.</li> <li>- RSC Onboard - RSC Trackside interface sniffing (SS 126)</li> <li>- RSC Onboard - RSC JRU for logging data</li> </ul>

ID	Obligation	Section/Chapter	Requirements Text
Test-REQ.8	Shall	03 Test System Specification and Approval	<p>The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the data from following Subset or implemented interfaces within the ATO System boundary:</p> <ul style="list-style-type: none"> <li>- ATO OB GoA 2 - Functional Vehicle Adapter (based on SS 139)</li> <li>- ATO OB GoA 2 - Hardwired / I/O interface</li> <li>- ATO OB GoA 4 - Functional Vehicle Adapter (based on SS 139)</li> <li>- ATO OB GoA 4 - Hardwired / I/O interface</li> <li>- ATO OB GoA 2 - ATO GoA 4 interface</li> <li>- ATO OB GoA 2 - ETCS OBU (SS 130) sniffing</li> <li>- ATO OB GoA 2/4 - RSC Trackside interface sniffing (SS 126).</li> </ul> <p>For the JP/SP function.</p> <ul style="list-style-type: none"> <li>- ATO OB GoA 2/4 - ATO TS Trackside interface sniffing (SS 126)</li> <li>- ATO OB GoA 2/4 - ATO OB JRU data SS 140 sniffing</li> </ul> <p>- Functional Vehicle Adapter - Locomotive Control System interface (Hardwired/Serial)</p>
Test-REQ.9	Shall	03 Test System Specification and Approval	<p>The supplier will deliver an open interface, tool, software and documentation to enable a RU user to access and understand in a user friendly way the data from following Subset or implemented interfaces between the ATO System and RSC System:</p> <ul style="list-style-type: none"> <li>- RSC Onboard - Locomotive Control interface based on SS 139</li> <li>- RSC Onboard - Hardwired / I/O interface to Locomotive (Control)</li> <li>- RSC Onboard - ATO OB interface for remote data entry of train characteristic</li> <li>- RSC Onboard - Diagnostic, Sensoric and Mechanical interface on locomotive</li> <li>- RSC Onboard - Locomotive Diagnostic interface</li> <li>- RSC Onboard - ATO OBU JRU data SS 140 sniffing</li> <li>- RSC Onboard - ETCS OBU JRU data SS 027 sniffing</li> <li>- RSC Onboard - ATO OB - ETCS OBU interface (SS 130) sniffing</li> <li>- RSC Onboard - ATO TS interface sniffing (SS 126)</li> </ul>
Test-REQ.10	Shall	03 Test System Specification and Approval	<p>perception system functionalities for test systems can be considered as non safety &amp; security certified. However, for commercial operation exhaustive CSM-RA/Hazard analysis according European regulation needs to be carried out to confirm which, if any, functions do need to be implemented with a safety &amp; security category.</p>
Test-REQ.11	Shall	03 Test System Specification and Approval	<p>The system and components comply with the Rail System and industry standards such as using components which are fire protected, electromagnetic compatibility, cabling requirements, mechanical fatigue, mechanical static loads, Cyber security etc.</p>
Test-REQ.12	Shall	03 Test System Specification and Approval	<p>The supplier will set up a requirement capture process to capture all the applicable standards e.g. EMC, Fired protection, ... and provide RU the result of the requirement capture process. The supplier shall deliver the necessary documentation to RU for the proof of railway system certification of the installed components e.g. EMC, fire protection, ...</p>
Test-REQ.13	Shall	03 Test System Specification and Approval	<p>The test system is equipped with Human Machine Interface and will display at the non active (rear) cab the same ATO information at same time as the active (front) cab.</p>
Test-REQ.14	Shall	03 Test System Specification and Approval	<p>The system is supervising perception system - RSC Trackside System connectivity quality at all time.</p>
Test-REQ.15	Shall	4 Test System Specification and Approval	<p>The test driver and RSC Operator workplace/HMI adheres to all applicable principles and rules that apply for todays operation in terms of layout, dimensions, controls and displays.</p>
Test-REQ.16	Shall	5 Test System Specification and Approval	<p>Existing or new installed antennas on the locomotive will not lead to any interference regarding electromagnetic or other. The supplier will deliver the proof according to the freight national safety authority (ILT) Electro Magnetic Compatibility rules.</p>

ID	Obligation	Section/Chapter	Requirements Text
Test-REQ.17	Shall	12 Non Functional Requirements	Completeness and quality of the specification of the system shall be proven by the supplier in a test environment prior to field testing in lab testing.
Test-REQ.18	Shall	12 Non Functional Requirements	The perception system equipment shall be designed and installed in such a way that it shall not cover the air inlets of the front hatch.
Test-REQ.19	Shall	12 Non Functional Requirements	If the perception system equipment for demonstration purposes will be mounted on the bracket of the middle step, free space after installation of perception system equipment shall comply with EN 16116-1. Additional space has to be provided for operation of air cocks and screw coupling.
Test-REQ.20	Shall	12 Non Functional Requirements	The mounting of the perception system outside the Locomotive shall be within the bounds of the reference profile for kinematic gauge according to EN 15273.
Test-REQ.21	Shall	12 Non Functional Requirements	The design and installation of the perception system shall not obstruct the light beams of the head and tail lights of the locomotive in accordance with TSI LOC&PAS articles 4.2.7. and TSI OPE articles 4.2.2.1, 4.2.2.1.2, 4.2.2.1.3.
Test-REQ.22	Shall	12 Non Functional Requirements	The perception system shall be installed in such manner that it shall not interfere in any task of the staff on board.
Test-REQ.23	Shall	12 Non Functional Requirements	The perception system shall be installed in such manner that staff has complete, unobstructed physical access to the Emergency exit in the locomotive
Test-REQ.24	Shall	12 Non Functional Requirements	The perception system shall be installed in such manner that staff will not trip over components, parts, products which belong to the perception system in or outside the locomotive
Test-REQ.25	Shall	12 Non Functional Requirements	The perception system shall be installed in such manner that it shall not reach high temperatures which could distract the staff during operation or other activities in or outside the locomotive
Test-REQ.26	Shall	12 Non Functional Requirements	The perception system shall be installed in such manner that it shall not create obstructing vibrations which could distract the staff during operation or other activities in or outside the locomotive.
Test-REQ.27	Shall	12 Non Functional Requirements	The perception system shall be installed in such manner that maintenance staff has complete unobstructed access to all items on which service checks or corrective maintenance or preventive maintenance is to be performed.

**Table 7: Freight specific requirements for test specification.**

### 3.10 SUPERVISION AND DIAGNOSTIC DATA

In the following, supervision and diagnostic data is presented which is needed for remote supervision and control (RSC) operation.

The first column gives every requirement a unique identifier. The second column indicates the obligation of the specific requirement. The "Process data" column describes the scope of the data to be provided. The Kind of data transfer to RSC contains the attributes "event-driven", "high data rate" or "low data rate".

ID	Obligation	Process Data (from Locomotive interface to RSC)	Kind of data transfer to RSC
<b>01 General Information</b>			
ATO-SD.1.1	shall	Locomotive number	event-driven
ATO-SD.1.2	shall	Train number	event-driven
ATO-SD.1.3	shall	GPS position latitude	high data rate
ATO-SD.1.4	shall	GPS position longitude	high data rate
ATO-SD.1.5	should	GPS position altitude	high data rate
ATO-SD.1.6	should	GPS Source (Which subsystem provides the information)	high data rate
ATO-SD.1.7	shall	Speed	high data rate
ATO-SD.1.8	should prio	Total Locomotive mileage (km)	low data rate
ATO-SD.1.9	shall	train weight	event-driven
ATO-SD.1.10	should prio	Component test overdue	event-driven
ATO-SD.1.11	should	Indicator for imminent shut down of the locomotive	event-driven
ATO-SD.1.12	shall	Maintenance mode activated	event-driven
ATO-SD.1.13	shall	Direction of travel drivers active cab 1/3	event-driven
<b>02 Currents / Voltages / Energy</b>			
ATO-SD.1.14	should prio	Counter of the events of the too high catenary voltage in AC and DC operation	event-driven
ATO-SD.1.15	should prio	Counter of catenary low voltage events in AC and DC operation	event-driven
ATO-SD.1.16	should prio	Counter of the events of the too high catenary current in AC and DC operation	event-driven
<b>03 Pantograph</b>			
ATO-SD.1.17	shall	Pantograph AC1 is raised (Locomotive specific)	event-driven
ATO-SD.1.18	shall	Pantograph AC2 is raised (Locomotive specific)	event-driven
ATO-SD.1.19	shall	Pantograph DC1 is raised (Locomotive specific)	event-driven
ATO-SD.1.20	shall	Pantograph DC2 is raised (Locomotive specific)	event-driven
ATO-SD.1.21	shall	System voltage identification (Locomotive specific)	event-driven
ATO-SD.1.22	should prio	All Pantographs are down (Locomotive specific)	event-driven
<b>04 Auxiliary operations</b>			
ATO-SD.1.23	shall	Main compressor is switched on	event-driven
ATO-SD.1.24	shall	Auxiliary compressor is switched on	event-driven
ATO-SD.1.25	should prio	Sanding in direction of travel F1	event-driven
ATO-SD.1.26	should prio	Sanding in direction of travel F2	event-driven

ID	Obligation	Process Data (from Locomotive interface to RSC)	Kind of data transfer to RSC
<b>05 Fan</b>			
ATO-SD.1.27	should prio	Frequency for component MRL low	event-driven
ATO-SD.1.28	should prio	FMLx on/off	event-driven
ATO-SD.1.29	should prio	KTLx on/off	event-driven
ATO-SD.1.30	should prio	TrL on/off	event-driven
ATO-SD.1.31	should prio	MRL low on/off	event-driven
ATO-SD.1.32	should prio	MRL high on/off	event-driven
ATO-SD.1.33	should prio	Braking resistor fan on/off	event-driven
<b>06 Operating times</b>			
ATO-SD.1.34	should	Locomotive operating time	low data rate
ATO-SD.1.35	should	Hours of speed > 2 km/h	low data rate
<b>07 Brake</b>			
ATO-SD.1.36	shall	Brake pressure bogie 1 (C-Druck)	high data rate
ATO-SD.1.37	shall	Brake pressure bogie 2 (C-Druck)	high data rate
ATO-SD.1.37b	shall	Brake pressure bogie 3...n (C-Druck) - if applicable	high data rate
<b>08 Temperature values</b>			
ATO-SD.1.38	should prio	Actual value FMx temperature	medium data rate
ATO-SD.1.39	should prio	Actual value temperature converter x	medium data rate
ATO-SD.1.40	should prio	Actual value temperature ASGx	medium data rate
ATO-SD.1.41	should prio	Actual value of water temperature SRx	medium data rate
ATO-SD.1.42	should prio	Actual value HBU transformer A temperature	medium data rate
<b>09 Water pressure</b>			
ATO-SD.1.44	should prio	Actual value water pressure SRx	medium data rate
<b>10 Locomotive Data</b>			
ATO-SD.1.44	shall	Traction and brake effort	high data rate
ATO-SD.1.45	should prio	Line current AC and DC	high data rate
ATO-SD.1.46	should prio	Line voltage AC and DC	high data rate

**Table 8: Supervision and Diagnostics Data.**

## 4 READING GUIDE

The main goal of this deliverable is to provide freight specific user requirements for the use in FP2 R2DATO. The user requirements can be found in the main chapter 3. The requirements are categorized by their application and further parameters so that the user can quickly overlook the subset of interest to her.

The requirements as presented in this document are the basis for further discussions in FP2 R2DATO. However, as an additional working document, the requirements are provided in a separate table (Annex A). In the sheet, a filtering of the requirements is possible which makes their usage handier. But since such a file is not document proof, this main document remains the only reference for further discussions.

The definition of use cases and of a preliminary hazard log was beyond the scope of this Task 5.5. As an indicative example, they were provided by DB Cargo and can be found in the Annexes for further use as best case examples.

For the methodology of this deliverable please refer to chapter 2.

## 5 CONCLUSIONS

In this deliverable, freight specific user requirements are presented. They were composed by the involved Railway Undertakings, refined, and consolidated. The developed list is the main basis for further discussions of Freight RU and the suppliers of the assets and components, especially for further collaboration within this project FP2 R2DATO. The requirements shall be used to verify and validate the design and demonstrator outcome for freight against all defined requirements herein.

In the further course of FP2 R2DATO, the implementation of the freight specific user requirements will initiate further discussion. The results of these discussions build the ground for future projects. Especially, the definition of a common set of use cases, test and validation cases and hazard logs remains as open points for future projects. In addition, the scope of the requirements needs to be extended beyond mainline operation, e.g., for shunting yards. Altogether, the introduction of ATO as a commercial product poses a great challenge to the whole railway ecosystem. For its implementation, the cooperation of all actors, the railway transport and railway infrastructure companies, the research bodies, and politics, is crucial.

## REFERENCES

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- [4] FP2-R2DATO, 2023, D5.1 – Documentation of use cases for automating functions. Work package internal working document.
- [5] Documentation and evaluation of GoA2 freight demonstrator test results in specified testing scenarios, proposal of next steps.

## 6 ANNEXES

### 6.1.1 Annex A: Freight Specific user requirements index

The requirements are given as additional information in the separate File: “FP2-T5.5-D-DBA-007-02-Annex\_A”.

### 6.1.2 Annex B: Requirements to Safety, Security and Quality (Plan & Concept) & Preliminary Hazard Log

For internal purposes, DB Cargo developed an informative “Preliminary Hazard Log” as informative baseline for its suppliers. Since such a hazard log is important for the development of freight specific user requirements and required by CENELEC, the hazard log is provided as an example. Accordingly, it is meant as additional information to the freight specific user requirements of T5.5. The lists have not been changed by T5.5.

The project workflow is structured, organized, and executed on the basis of the life cycle model (V-Model) of the CENELEC standard EN 50126:2018-10 or equal quality, with the aim of ensuring an efficient working method for the project teams at the supplier side and at RU side. This is understood to mean fast decision-making processes that bring about economic solutions considering function - costs - timeframe.

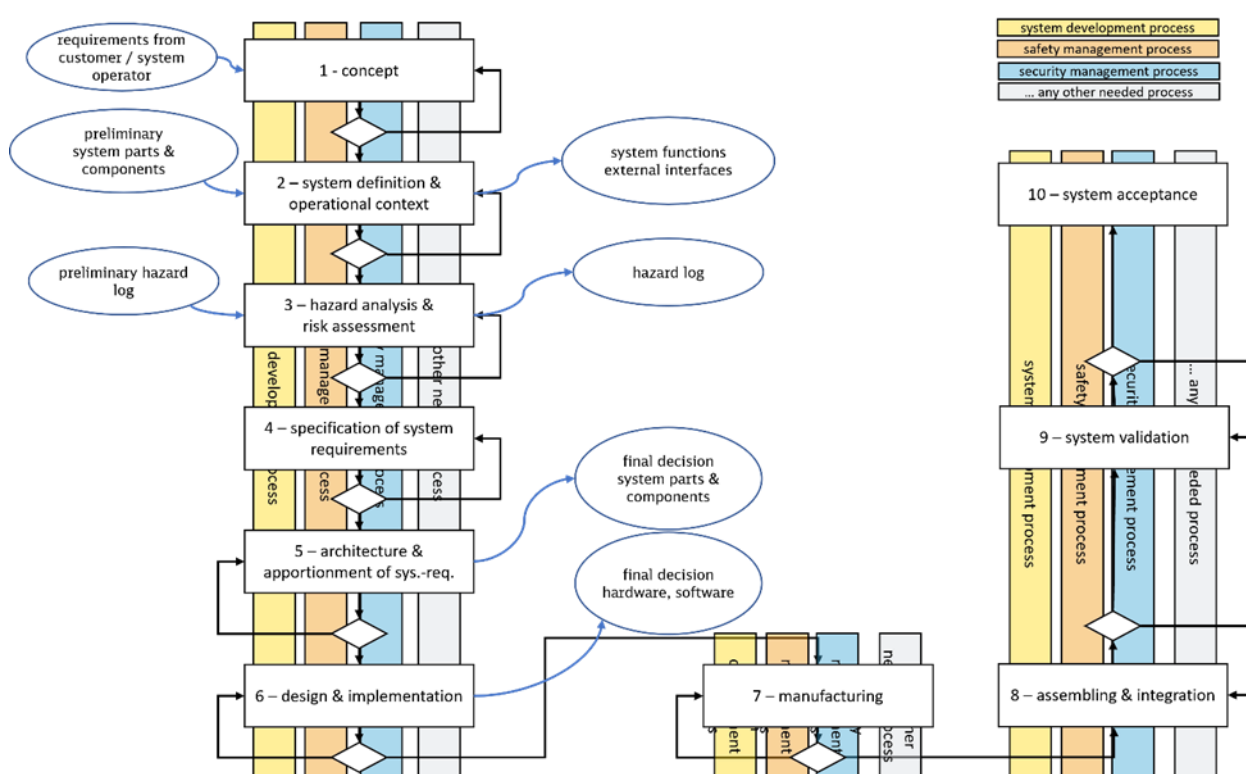


Figure 10: Overlay of the lifecycle stages with the individual management and development processes in the project

The life cycle phases according to the mentioned standard are shown unchanged in Figure 10; phases 11 and 12 have been deliberately omitted. The parallel management and development activities are organized in several processes in the project. Currently, the following three processes are envisaged (colored boxes):

1. System development process
2. Management process for functional safety
3. Management process for security
4. Quality management process (as integrated basement of the three above mentioned)

The transition from one lifecycle phase to the next phase takes only place if, at the quality gate or milestone (shown as a diamond in the picture), all process owners involved can agree to the transition on the basis of their work results in the respective phase. This is to avoid conflicting results from the processes or incomplete requirements between the individual processes.

The first table shows potential technical hazards, while the second table focuses on human factor related hazards.

Category	Hazard	Cause
Ensure safe train movement	Passing EoA	GoA2: driver does not (timely) recognize slippery track
Ensure safe train movement	Passing EoA	ATO system does not (timely) recognize slippery track
Ensure safe train movement	Passing EoA	Wrong train data has been entered at SoM: train length, brake percentage, braking category, etc.
Ensure safe train movement	Brake failure	ATO behavior causes repeatedly braking and depleting the presurred air faster than the compressor can correct, resulting in an air pressure to low to initiate a braking
Ensure safe train movement	Passing EoA	remote control overriding ETCS
Ensure safe train movement	Train not compatible with conv. Network	Unaathorized train driver drives trial locomotive in unauthorized section of network
Ensure safe train movement	Train not compatible with conv. Network	GoA2: (Part of) ETCS (onboard or onside) on the route becomes unavailable or is disturb during a run. Train must reroute to conventional lines
Ensure safe train movement	Train not compatible with conv. Network	GoA2: (Part of) ETCS (onboard or trackside) the route becomes unavailable during a run. Train must reroute to conventional ATP lines e.g. with ATB equipment.
Ensure safe train movement	Train not compatible with conv. Network	ATO: (Part of) the route becomes unavailable during a run. Train must reroute to conventional lines
Prevent collisions with persons / obstacles leads to collision	Overspeed when remote controlled	insufficient information/overview/camera footage for the RSC operator
Prevent collisions with persons / obstacles	Driving towards a danger ( <b>EoA in ETCS</b> ) when remote controlled	insufficient information/overview/camera footage for the RSC operator
Prevent collisions with persons / obstacles	Persons/objects on track	GoA2: Object(s) on (adjacent) track are not noticed by driver

Category	Hazard	Cause
Prevent collisions with persons / obstacles	Persons/objects on track	ATO: Object(s) on (adjacent) track are not noticed by ATO/ODS system
Prevent collisions with persons / obstacles	Persons/objects on track	ATO: Object(s) on (adjacent) track faultly signalled by ATO system (false positive)
Prevent collisions with persons / obstacles	Persons/objects on track	Train driver from train on adjacent track is outside his train
Prevent collisions with persons / obstacles	Persons/objects on track	Person or animal on track
Prevent collisions with persons / obstacles	Persons on track	Staff on track think the loco might not start moving (because it's unstaffed or because they think they're seen)
Prevent collisions with persons / obstacles	Persons/objects on track	Maintenance personnel on track
Prevent hazards related to emergency situations	Overspeed or driving towards a danger	GSM-R General Alarm Call from dispatcher or other trains is not processed by ATO
Prevent hazards related to emergency situations	Overspeed or driving towards a danger	Procedure to take over Locomotive in emergency situation (e.g. ATO system locked in) is not implemented
Prevent hazards related to emergency situations	Overspeed or driving towards a danger	No way to take over Locomotive in emergency situation (e.g. ATO system locked in)
Prevent hazards resulting from procedure failures	ATO and RSC are too sensitive and lead to too much false positive alarms	RSC Operator resets or isolates functions, incorrectly
Prevent hazards resulting from procedure failures	Deviation from processes	Not all relevant driver tasks are properly translated to the technical system, like brake handling, lights management, failure handling, observations to be made, ...
Prevent hazards resulting from procedure failures	Deviation from processes	RSC operator is not following the ProRail Use Cases
Prevent hazards resulting from procedure failures	Distraction of driver	Drivers getting used to ATO / GoA2: they incorrectly may expect certain actions to be automatic when manually operating a train
Prevent hazards resulting from procedure failures	Distraction of driver	Driver on the locomotive gives control inputs while ATO is in operation
Prevent hazards resulting from procedure failures	Distraction of driver	Driver gets disturbed by test output or obstacle detection system alarms
Prevent hazards resulting from procedure failures	Distraction of driver	Driver gets disturbed by non essential personnel on train
Prevent hazards resulting from procedure failures	Distraction of driver	Driver leaves the train when stopped by ATO or ... . After leaving the train the train starts moving because the problem gets solved "train rollaway" Train runs unstaffed from then

Category	Hazard	Cause
Prevent hazards resulting from procedure failures	Distraction of driver	GoA2 Driver on the locomotive gives control inputs while ATO is in operation
Prevent hazards resulting from procedure failures	Distraction of RSC operator	RSC Operator gives control inputs while ATO is in operation
Prevent hazards resulting from procedure failures	Dangerous fault at locomotive	RSC system does not detect various train problems (e.g. brake defect, sounds, smells, vibrations)
Prevent hazards resulting from procedure failures	Incorrect transition	Incorrect transition from manual $\Leftrightarrow$ GoA /ATO operation (transitions must occur correctly and at the right time)
Prevent hazards resulting from procedure failures	Incorrect transition	Incorrect transition manual $\Leftrightarrow$ GoA operation (transitions must occur correctly and at the right time)
Prevent hazards resulting from procedure failures	RSC operator responsible for multiple trains at the same time	Confusion/errors in communication between RSC remote operator and dispatcher, as operator is responsible for multiple trains at the same time
Prevent hazards resulting from procedure failures	RSC operator responsible for multiple trains at the same time	Too high workload for RSC remote operator if multiple ATO-trains require attention simultaneously
Prevent hazards resulting from procedure failures	Two locomotives on different tracks	RSC commands wrong locomotive
Prevent hazards resulting from procedure failures	Two locomotives on different tracks	testdriver SR in wrong locomotive
Prevent hazards resulting from procedure failures	Security at locomotive insufficient	Unauthorised people can enter the locomotive (requirement not formulated)
Prevent hazards resulting from security breaches	Security at remote center insufficient	Unauthorised people can enter the remote center (requirement not formulated)
Prevent hazards resulting from security breaches	Security at train insufficient	Unauthorised people can manipulate the train (requirement to replace the functions of the driver not properly formulated) <i>(Remark bs: analyse what is done by the staff in the terminal and what does the driver. May be some driver functions have to be taken over by stationary staff instead by ATO-system)</i>
Prevent hazards resulting from security breaches	Security in connections (any of them in ATO and RSC system) insufficient	Test driver does not realise in time a security breach
Prevent hazards resulting from track failures	Overspeed or driving towards a danger	GoA2: General (adverse) track conditions not recognized by driver (e.g. broken overhead line, damaged track, other irregularities) on own or adjacent track
Prevent hazards resulting from track failures	Overspeed or driving towards a danger	ATO: General (adverse) track conditions not recognized by ATO (e.g. broken overhead line, damaged track, other irregularities) on own or adjacent track

Category	Hazard	Cause
Prevent hazards resulting from track failures	Overspeed or driving towards a danger	GoA4: General (adverse) track conditions not recognized by ATO (e.g. broken overhead line, damaged track, other irregularities) on own or adjacent track
Prevent hazards resulting from track failures	Wrong position of switch (points)	GoA2: driver does not notice wrong position of switch
Prevent hazards resulting from track failures	Wrong position of switch (points)	GoA4: ATO system does not notice wrong position of switch (points)
Prevent hazards resulting from train failures	Hot box alarm is not recognized	Hot box alarm, normally to driver shall get to RSC, RSC shall take appropriate action or alarm should go direct to ATO and this does not work correctly
Prevent hazards resulting from train failures	Catenary melts down	ATO applies full traction in case train is stranded.
Prevent hazards resulting from train failures	Dangerous fault at locomotive	RSC operator wrongly overrides alarm from locomotive
Prevent hazards resulting from train failures	Dangerous fault at locomotive	RSC operator get wrong feedback from TCMS
Prevent hazards resulting from train failures	Dangerous fault at locomotive	GoA2: driver does not detect various train problems (e.g. brake defect, sounds, smells, vibrations)
Prevent hazards resulting from train failures	Dangerous fault at locomotive	Train is involuntary switched to ATO mode when driving SR
Prevent hazards resulting from train failures	Dangerous fault at locomotive	ATO system does not detect various train problems (e.g. brake defect, sounds, smells, vibrations)
Prevent hazards resulting from train failures	Deviation from processes	ATO System is not following the ProRail Use Cases
Prevent hazards resulting from train failures	Exceed maximum speed	ATO reacts insufficiently/too late to envisaged/intended speed profile. Like: Train accelerates too soon when leaving shunting yard Speeding of the last wagon when passing switch 2303B
Prevent hazards resulting from train failures	Train breaks or derails due to in train forces	ATO behavior causes (repeatedly) pulling/braking and initiates high forces over couplers in the train
Prevent hazards resulting from train failures	Incorrect transition	ATO does not apply correct actions for track conditions at Voltage Change-over
Prevent hazards resulting from train failures	Incorrect transition	ATO does not apply correct actions for track conditions at Phase Lock
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	SR: driver is not able to override RSC operator commands
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	SR: insufficient information/overview/camera footage for the RSC operator

Category	Hazard	Cause
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	remote control providing faulty commands to TCMS
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	ATO interferes (with commands) with driver during manual operation
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Driver does not (timely) recognize system not working properly
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	RSC: driver does not (timely) recognize system not working properly
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Isolated ATO system has effect on other system (wayside or on the Locomotive)
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Inactive ATO system (ready in stand-by) has effect on other system (wayside or on the Locomotive)
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Active ATO system has other effect than intended on other system (wayside or on the Locomotive)
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Isolated RSC system has effect on other system (wayside or on the Locomotive)
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Inactive RSC system (ready in stand-by) has effect on other system (wayside or on the Locomotive)
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Active RSC system has other effect than intended on other system (wayside or on the Locomotive)
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Interface to ETCS OB unit has other effect than intended on other system (wayside or on the Locomotive)
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	Driver unable to make ATO system immediately inactive
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	ATO system might lock-in in a rare state
Prevent hazards resulting from train failures	Overspeed or driving towards a danger	RSC system might lock-in in a seldom state
Prevent train put in operation with failure	Exceed maximum speed	Wrong <b>ETCS</b> train data has been entered at SoM: train length, brake percentage, braking category, etc.
Prevent train put in operation with failure	Exceed maximum speed	Wrong <b>ATO</b> train data has been entered at SoM: journey profile, etc.
Prevent train put in operation with failure	Train 'escapes' the route	Route path is set wrong (or not) but train starts
Onboard Computer	System Onboard Computer errors	System too slow or too often causing errors, leading to bad availability and to capacity reduction on route.
Locomotive Control	Driving strategy not according national and DB C rules	RSC OB or ATO apply higher electro-dynamic braking forces than allowed ahead of a switch in GoA2, GoA4 or RSC

Category	Hazard	Cause
ATO Locomotive Control	Driving strategy not according national and DB C rules	ATO and RSC OB do not apply brake blending (combination of dynamic, direct and airbrake) according to national and local regulation of the RU and IM and track environment and topology.
ATO Locomotive Control	Driving strategy not according national and DB C rules	ATO does not apply brake and accelerating correct with liquid cargo and e.g. will be pushed over a red signal
ATO Locomotive Control	Driving strategy not according national and DB C rules	ATO is not correctly considering the longitudinal forces of the train within the driving strategy.
ATO Locomotive Control	Driving strategy not according national and DB C rules	ATO is not considering the dynamic system of the train set e.g., mass-damper within the driving strategy.
External System interfacing	No visual indication of train to oncoming traffic	No lighting or insufficient outside lighting
External System interfacing	Disturbing of external systems	Locomotive high beam head light not changed to low beam when required oncoming locomotives or road traffic near the railway line
External System interfacing	Not warning of external systems	Not blowing the horn or bells, when required under the rules of the railway system.
External System interfacing	Test staff exits train to inspect status	Train starts moving with one or more staff members in its path
Reduced Friction on railway	Adhesion factor provided by ATO-TS in the Journey Profile Packet (JPP) to the ATO OB inappropriate for specific area	RSC Operator is unaware of local conditions and does not provide slippery track warning to the ATO system
Systematic failure	ATO train characteristic entered wrong	ATO system will perform wrong driving strategy
Systematic failure	Allocate safe functions to ATO System	ATO and RSC system are today not specified as safe system. Safety functions needs to be considered and mitigated by safe system.
Systematic failure	Allocate safe functions to RSC System	ATO and RSC are not considered as safe system. Safety functions needs to be considered and mitigated by safe system. E.g., RSC under ETCS non FS needs to be analyzed within the project.
Detection of Hot Box or Hot Wheel	No reaction of Hot Box or Hot Wheel	ATO or RSC are not considering Hot Box or Hot Wheel detection and reaction in time
Generic Hazard	Human is not anymore on the locomotive	Locomotive suffers damage (mechanical or electric equipment (beginning of fire, ...)) and now it will take time for a driver to mitigate the hazard.

**Table 9: Preliminary Hazard List DB Cargo Project [DB Cargo]**

Human factor risk	Potential Hazard
Risk that RSC Operator has insufficient awareness of the Train surrounds and personnel in vicinity (e.g. joining/ leaving the train) prior to initiating remote control train movements.	Risk of harm for Test Crew in the event of an unexpected movement during the trial.  Risk of harm to Crew or Maintainers in the commercial phase.
Risk that a latent ATO mode selection leads to unexpected train movements - particularly with systems under test.	Risk of harm for Test Crew in the event of an unexpected movement during the trial.  Risk of harm to Crew or Maintainers in the commercial phase.
Risk that train serviceability is not maintained during the trial phase. Locomotive may be provided by the system supplier or may be taken out of 'normal' maintenance regimes for the duration of the trial.	Potential for asset damage or safety incident
Risk that an RSC Operator makes an error during ETCS SoM, 1) being less familiar with the train (not having direct visibility of the consist) and 2) potentially performing multiple SoM tasks across several trains entering service.	Potential for asset damage or safety incident
Unclear if the RSC Remote Control driver will have sufficient visibility/ awareness of lineside information, which may remain relevant in some manual driving tasks (e.g. within the Yard).  RSC Remote Control driving (a less immersive driving experience, performed in a fragmented fashion and creating a less 'complete' route knowledge will create heightened dependence on the ETCS (in-cab) information. A more focused external field of view (fixed camera) may also impact awareness/perception of external cues.	Increased likelihood that lineside signals or signage in the Yard could be missed; may increase potential for low-speed derailment or collision.
Safety risk for a local Driver joining or leaving the train. Particularly during transfer of control procedures.	
Risk of secondary harm to RSC staff witnessing collision with an obstacle. I.e. risk that ODS alerts staff in the control room who then collectively view a collision, exposing them to a workplace trauma.	
Risk of asset-damage if brake-release failures are not detected in a timely fashion.  Unclear if systems will be able to assist in detection of brake-release failure in an ATO-failure scenario.	Increased likelihood of brake failures or reduced braking efficiency if the remote-control operator is unaware of a brake-release failure.
Risk that the Operator may activate ATO for the wrong train (selection error).	Unexpected movement of a train due to selection error.
Risk that ATO train movements begin prior to receiving permission to commence - due to an available movement authority (the route being set) without necessarily confirming readiness with the Signal Operator.	Operational disruption.

Risk of RSC user distraction (e.g. not vigilant or not present at the control desk), particularly during OS and SR ETCS modes.	May lead to asset damage or safety incidents, e.g. low speed collision or derailment, if the RSC user is not vigilant.
Risk that the RSC user has less feedback to prove successful horn operation.	May lead to a delayed horn signal in response to a hazard.
Risk of stopping the train when not clear of the preceding points due to incomplete route knowledge and/or decreased awareness of lineside information/markers.	Potential for conflicting movements.
Risk of blurring safety responsibilities during the trial phase if direct communications are established between RSC and the Signal Operator.	
Risk of inadvertent controller operation at the RSC - e.g. knocking the desktop controls.	Unexpected train movements. Potentially undetected for some time if the RSC user does not realise they are in remote control mode.
Task requirements for Remote Control need further clarity in different failure modes; for example 1) where ETCS is in OS/SR mode; 2) where ETCS movement authority is available for Remote Control Driving; 3) where a procedural movement authority is required for Remote Control Driving; 4) where ATO failure could feasibly affect GoA2 or GoA4 functions, but not both.	Further safety considerations may be identified subsequently.
Incomplete handover or misunderstanding during handover could lead to ineffective or delayed RSC intervention, impacting operations.	Impact to operations if RSC is not effective in supervising the fleet.
Risk of error cross-checking train serviceability information with the correct train.	Potential for a train to be entered into service (remotely) which does not meet minimum operating standards.
Risk of a latent system issue going undetected if the alerts and alarms are not clearly presented.	Impact to operations if RSC is not effective in supervising the fleet.
Risk of ineffective fault rectification if remote stakeholders (RSC and Helpdesk) do not achieve a shared and complete understanding of train system issues.	Two remote actors (RSC and Helpdesk) will require clear information and a shared view of the information in order to accurately conduct fault identification and rectification.
Risk of reduced safety margins if the Remote Control operator is unaware of a latent failure in a safety function e.g. Obstacle detection malfunction, camera feed frozen, etc.	Remote control operator may not be alerted to a hazard in the corridor.
Risk that a verbal movement authority is exceeded (e.g. because a route is set that provides a greater ETCS movement authority than the authority intended by the Signal Operator).	Disrupted operations.  Should be no safety outcome whilst the movement is supervised by ETCS.
Risk of exceeding a degraded mode movement authority during ETCS failure	Potential for a safety incident if the remote-control operator inadvertently exceeds a verbal or administrative movement authority.

**Table 10: Preliminary Hazard List Human Factors DB Cargo Project [DB Cargo]**

### 6.1.3 Annex C: Testing and validation

For internal purposes, DB Cargo developed “use cases and operational scenarios for testing and validation purposes” for its suppliers. Since such scenarios and use cases are important for the development of freight specific user requirements it is provided as an example. Accordingly, it is meant as additional information to the freight specific user requirements of T5.5. The lists have not been changed by T5.5.

The first table shows the use cases, while the operational scenarios are presented in the second table. These are provided as an example.

Use Case	Description
Train Composition and System Start	pre-operational tests of the trainset and startup of ATO system
Train Composition and System Start	pre-operational tests of the trainset and startup of RSC system
Input train data, Request and Handshake of JP/SP and MA	input of relevant train data in the ETCS system, request and handshake of Journey & Segment-Profile, request of MA. ATO-OB startup
Run train functional correct according ATO Freight driving strategy	ATO-OB is functionally able to run the freight train according to functional correct driving strategy
Control the train functionally correct via the RSC system	RSC operator is functionally able to control the train via the RSC system interface and according to the RSC freight driving strategy.
Update of JP/SP - ATO TS	The JP/SP is changed in the ATO-OB by ATO-TS according to new route, timetable, speed area restriction for energy saving, etc.
Update of JP/SP - RSC Trackside	The JP/SP is changed by RSC according to new route, timetable, speed area restriction, etc.
ATO-OB stops functionally correct at stopping point	According to JP/SP conditions, ATO-OB is stopping functionally correct the train in front of ETCS End of Authority.
RSC Operator stops functionally correct at stopping point	RSC Operator is stopping functionally correct the train in front of ETCS End of Authority (procedure)
Loss of ATO-connection	ATO-OB loses it connection to ATO-TS and runs until end of JP
ETCS end section - ATO disengage	Entry of shunting yard, ATO stopping point has to X meters before end section. Handover of ATO to manual must be provided.
RSC requests handover from ATO to RSC	RSC is requesting handover from ATO to RSC
RSC requests handover to ATO-OB	RSC operator requests control back to ATO GoA4
Hill start / stop in ATO operation	ATO starts on a hill. ATO stops on a hill
Hill start in RSC operation	Train starts in RSC Uphill and downhill slope.  To avoid that a train become to a stand with insufficient traction to re-start on a uphill slope, the RSC operator shall stop in rear of an uphill slope to allow the train to gain sufficient speed to fully passe the uphill slope.
Neutral / Powerless Section in ATO mode	out of SP information, ATO-OB is operating the train through neutral / powerless section and is requesting TCMS actions

Use Case	Description
Neutral / Powerless Section handled by RSC	out of SP information, the RSC operator is able to functionally operate the train through neutral / powerless section and is requesting TCMS actions (procedural test)
Balise / Signal error in ATO mode	ATO will signal ETCS is no longer FS. ATO will disengage. RSC Shall receive an alarm and RSC will take over.
Basic RSC control test, communication, and access	The RSC operator and the test driver will receive positive confirmation that system is communicating and functioning correctly.
Detection of slippery tracks	ATO/TCMS detecting slippery tracks
Adhesion Management	Driver changes ETCS adhesion factor during run. GoA2 receives and follows new adhesion rules.
Adhesion Management by ATO-TS	ATO-TS changes adhesion factor in JP and ATO-OB adapts driving strategy.
Voltage changeover	ATO is operating the train through voltage changeover remarked in SP
Voltage changeover	RSC operator is functionally able to operate the train through voltage changeover remarked in SP (procedural test)
Report arrival on destination	ATO-OB is reporting end of JP via ATO-TS
Loss of catenary while operating in ATO-mode	During ATO GoA4-mode, the train loses catenary voltage, ATO requests a handover to RSC emergency
Loss of catenary while operating in RSC-mode	During RSC control mode the train loses catenary voltage, alarm is raised, and RSC operator follows procedure / regulation.
Detection and reaction to emergencies in GoA4 mode	The ATO System will follow the national emergency regulation for the route react according to the regulation design on fire e.g. don't stop in tunnels in case of fire, ...
Disabling / operating SIFA <sup>1</sup> in RSC operation	
Operating of horn in ATO GoA4	According to provided information automatic function in GoA4
Operating of horn in RSC operation	
Sanding in GoA4	If slippery tracks are detected, the train activates sanding by braking or accelerating
Sanding in RSC operation	If slippery tracks are detected, the RSC-operator activates sanding by braking or accelerating
Train starts automatically on L1 balise/induction loop and in release speed after signal clearing	Train starts automatically on L1 balise / induction loop and in release speed after signal clearing
Signal clearing while in braking process due to stop signal, restart with release speed	Signal clearing while in braking process due to stop signal, restart with release speed
Train braking after spontaneous shifting of signal to stop signal	Train braking after spontaneous shifting of signal to stop signal

<sup>1</sup> Sifa is short for Sicherheitsfahrerschaltung, German for "safety driving circuit". It is usually a pedal and/or large press button, which monitors the alertness of the driver. The driver has to repeatedly press a button after a fixed interval; if they fail to do so, the train will carry out an emergency stop.

Use Case	Description
Manual start after stop signal without L1 Balise or induction Loop connection	Manual start after stop signal without L1 Balise or induction Loop connection
Connection loss of ATO-ETCS interface	If ATO loses the connection to ETCS, ATO will disengage
Connection loss of ATO-TCMS interface	If ATO loses the connection to TCMS, ATO will disengage
Connection loss of TCMS-RSC interface	If the train loses the connection to the RSC, it shall stop the train.
off/on-boarding of personnel on ATO operated train	Test driver is able to determine the ATO mode of the train and is able to use the ATO/RSC override outside switch to allow for off/on boarding
off/on-boarding of personnel on RSC operated train	RSC is able to determine the RSC mode of the train and is able to use the ATO/RSC override outside switch to allow for off/on boarding
Deviations from stopping point	ATO-OB indicates when there are deviations on the stopping point.
Reverse mode while in RSC operation	RSC operator is able to activate reverse mode in case of overrunning a stopping point
Emergency stop by RSC operator	Operating in RSC control mode, the RSC operator is requesting an emergency stop of the train
Connection Test ATO-OB <> ATO-TS	Basic test of communication interface and handshake between ATO-TS and ATO-OB
ATO-OB sends the status report along SS126 to ATO-TS	ATO-OB gives ATO-TS several information along SS126 status report about ongoing train run
ATO-OB informs ATO-TS via SS126 if SP data is incorrect	If Segment Profile Data is invalid, ATO-OB informs ATO-TS via Status Report along Subset-126
Routing-Error	According to SS126, if JP is not matching the MA from ETCS, ATO disengages.
ATO-OB outside ATO-TS along valid JP/SP	If the train leaves the ATO JP section, the train driver needs to takeover manually. If the driver drives back into the JP section, the ATO is able to use the valid JP again.
change of train number during trial	A change of planning train number during train run automatically requests an updated JP/SP of ATO-OB to ATO-TS
train data change ATO-TS <> ATO-OB	Change of train data in ATO-TS JP/SP, will be implemented in the ATO -OB
audible warning traction brake lever in ATO mode	If the Traction Brake Lever is moved to traction the command Shall be ignored and the ATO on-board Shall react according to SS125 requirements
Change Stopping point skip > stop	Stopping Point characteristics are changed from "Stopping Point Skip" to "Stopping Point Stop" by ATO-TS. ATO-OB stops at the concerning TP. ATO-OB follows SS125 requirements
ATO train hold	In Stopping point characteristics, "Train hold" is being executed by ATO-TS. ATO-OB Shall not be able to depart as long as an JP update without "Train hold" occurs.
stopping point skip	The following Stopping point is being skipped by the driver and ATO-OB doesn't stop per SS125 requirements

Use Case	Description
alarm brake low pressure	When pressure is low in the brake system, an alarm is occurring.
light indicators automatic driving mode	when the train is operating in ATO, outside ATO light indicators are switched on
Locomotive system regulates ATO-OB commands when they exceed locomotive specific limits.	In case ATO-OB is requesting commands out of locomotive-specific limit values (e.g. maximum speed, maximum acceleration), the vehicle will regulate the limits according to design specifications.
ATO-TS operated by RSC operator	RSC TS is able to send SS126 messages to ATO-OB
Alarm test RSC	test of several alarms applying in RSC TS HMI by degraded loco functions.
JP/SP updates by RSC operator	several updates of the JP (timing points, stopping point, skip, etc.) are executed by the RSC operator in ATO GoA4
ETCS emergency stop in RSC mode, handling test	During emergency stop applied by ETCS, RSC-OB does not give any further commands. Afterwards, RSC operator is able to restart train journey after ETCS emergency stop in RSC control mode.
braking on turnout	When driving on a turnout, maximum dynamic braking force to be applied has to be considered
brake-test before slope gradient	Before a slope gradient occurs, ATO is executing a simple brake-test (e.g. reducing speed about 10 km/h and test train reaction)
Use of Public Network ATO instead of GSM-R	Testing the ATO system with public network instead of GSM-R
Optimization of ATO OB - Target total energy consumption improvement min. 15%	ATO Onboard total energy consumption in a run comparing to the reference driver
Optimization of ATO OB - accuracy on adhering to the timing points - max. 15%	SS 126 Journey profile timing point for the ATO OB optimization will be measured via the - accuracy on adhering to the timing points over a designated trip
Optimization of ATO OB - number of train brake interactions target 15 % better than manual driver.	number of ATO Onboard brake application comparing to the reference driver
ATO-OB stops optimized at ATO stopping point.	According to JP/SP conditions, ATO-OB is stopping optimized the train in front of ETCS End of Authority.
ATO inhibition zone	Train in ATO approaching an inhibition zone, train stops before the zone. Train is unable to engage ATO if it is in inhibition zone.
RSC inhibition zone	Train in RSC control mode, approaching an inhibition zone, train stops before the zone. Train is unable to engage RSC if it is in inhibition zone.
ATO GoA2 manages start and stop in "Uphill and downhill slope"	Uphill and downhill slope. To avoid that a train comes to a stand with insufficient traction to re-start on a uphill slope, the ATO OB shall stop in rear of an uphill slope to allow the train to gain sufficient speed to fully pass the uphill slope.

Use Case	Description
ATO operates light in ATO GoA4	According to provided information automatic function in GoA4
RSC manages circuit braker	The RSC operator manages the circuit breakers (set and reset) to avoid a driver needing to attend a train to reset the circuit breaker manually.
ATO manages circuit braker	The ATO-OB manages the circuit breakers (set and reset) to avoid a driver needing to attend a train to reset the circuit breaker manually.

**Table 11: Use cases for testing and validation purposes for freight ATO [DB Cargo]**

Scenario	Description	Output
Basic Trainrun "Green wave"	basic train run on whole line without any planned ETCS-MA restriction	Successful run without stop
Basic Trainrun "Red wave"	basic train run on whole line with several planned ETCS-MA restrictions	Successful run with stop
Premature departure	train run with premature departure from starting point	data for energy usage and adherence to TP
Delayed departure	train run with delayed departure from starting point (achieve max punctuality)	data for energy usage and adherence to TP
Mode-changing train run I	train run with premature departure from starting point, delayed operation from stopping point	proof of ATO-optimisation execution
Mode-changing train run II	train run with delayed departure from starting point, normal operation from stopping point	proof of ATO-optimisation execution
TMS-execution train run	train run with two directly approached trainsets with delays and speed restrictions, test of TMS-execution	test of TMS-optimisation execution
emergency scenarios	train run with emergency scenarios	test of GoA4 & RSC

**Table 12: Operational scenarios for testing and validation purposes for freight ATO [DB Cargo]**

#### 6.1.4 Annex D: Freight national driving rules

Here, some of the requirements will be mentioned as example for national driving rules. These need to be implemented as further refinement of the requirements mentioned in the following but are too specific for the general purpose of this document.

The requirements that need to be refined regarding freight national driving rules are:

- ATO-REQ.31
- ATO-REQ.38
- RSC-REQ.21
- RSC-REQ.58
- Test-REQ.16

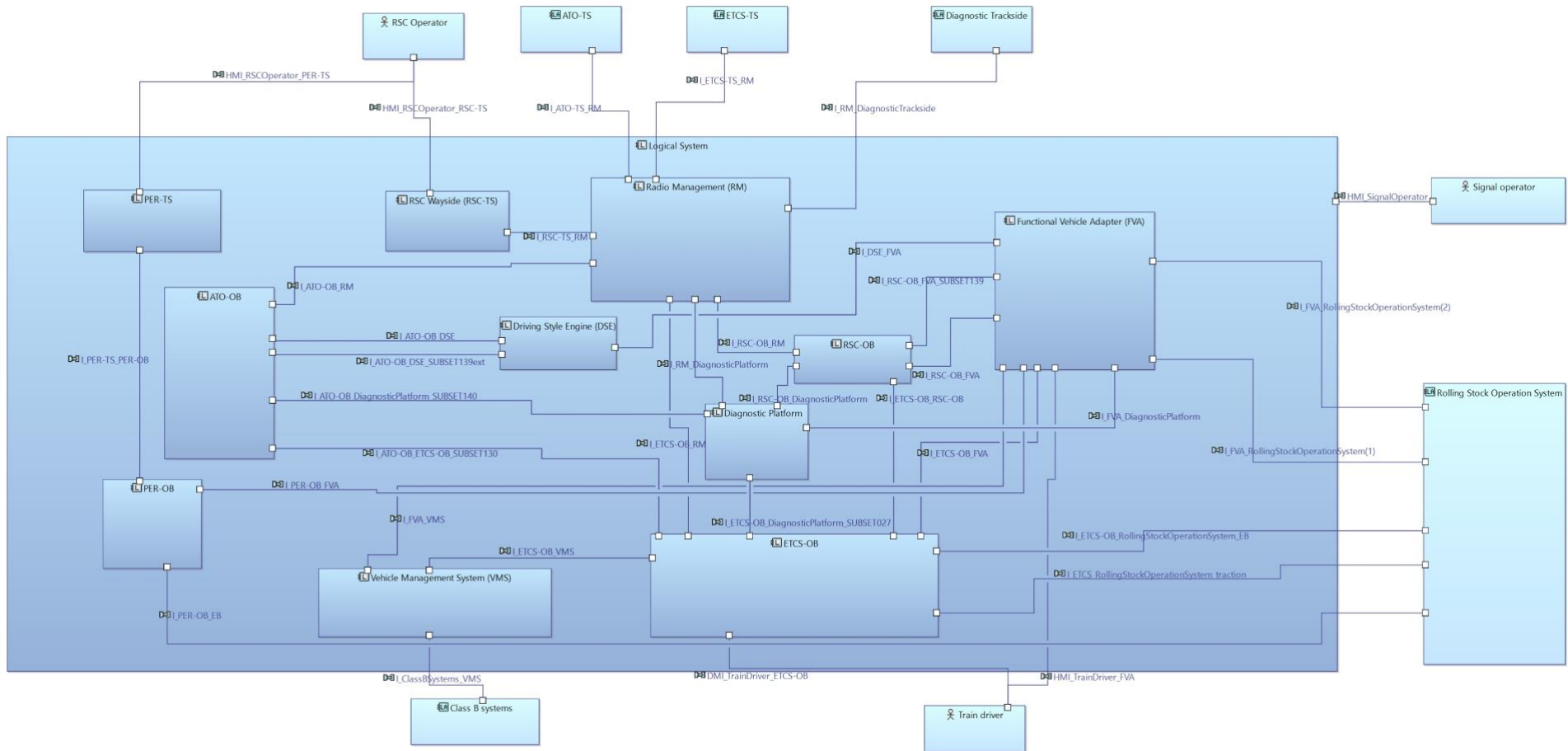
ID	Subtopic	Requirements Text
Nat-REQ.1	Freight specific architecture	Start a freight train on even track (no ascending or descending gradient)
Nat-REQ.2	Freight specific architecture	In cases, where icing of brakes is noticed, all brakes have to be controlled of being released.
Nat-REQ.3	Freight specific architecture	Accelerate a freight train from 40 km/h to 100 km/h
Nat-REQ.4	Freight specific architecture	Brake a freight train from 100 km/h to 40 km/h
Nat-REQ.5	Freight specific architecture	Decelerate a freight train while driving over a switch which is in deflecting position
Nat-REQ.6	Freight specific architecture	Stop a freight train on even track (no ascending or descending gradient)
Nat-REQ.7	Freight specific architecture	Trains with insufficient traction power shall be kept running before steep inclines (e.g. medium length uphill sections or ramps)
Nat-REQ.8	ATO GoA2-4	Unexpected event has occurred. Defined actions have to be taken ("Sofortmassnahmen")
Nat-REQ.9	ATO GoA2-4	Unexpected event has occurred. Train has to be stopped, defined actions to be taken.
Nat-REQ.10	ATO GoA2-3	In steep descends, there are additional driving rules to be followed to prevent derailling.
Nat-REQ.11	Freight specific architecture	Using the Sägezahn-Methode
Nat-REQ.12	Freight specific architecture	Using the Reguliermethode

**Table 13: Freight national driving rules.**

### 6.1.5 Annex E: Architecture and System

DB Cargo developed additional information for a better understanding of the proposed system design requirements and to provide an overview of existing standards, systems, and interfaces and the proposed architecture. Accordingly, it is meant as additional information to the freight specific user requirements of T5.5.

*For better readability, the architecture is shown in landscape orientation on the next page followed by the description of the Actors, Components, and Interfaces.*



**Figure 11: Reference for freight specific architecture**

## Actors

ID	SA1
System	ATO-TS: Module and interface to be provided by Infrastructure Manager (IM)
Description	<p>These modules shall be provided by the Infrastructure Manager (IM). The function of the modules is to generate a journey profile plus segment profile (SS-126) based on the IM timetable planning via TMS or if required by the RSC and send to the ATO Onboard.</p> <p>The ATO-TS function is according to SS-125, using interface according to SS-126.</p>
Applied Standards	SS-126 ATO over ETCS (latest version)

ID	SA2
System	ETCS Track Side: Module and interface to be provided by IM
Description	<p>These modules shall be provided by ProRail. The function of the modules is to communicate between the RBC and ETCS OBU via ETCS SS-26 standard.</p>
Applied Standards	SS-26 ERA Standard

ID	SA3
System	Train Driver
Description	<p>A person capable and authorised to drive trains, including locomotives, shunting locomotives, work trains, maintenance railway vehicles or trains for the carriage of passengers or goods by rail in an autonomous, responsible, and safe manner.</p>
Applied Standards	ERA_ERTMS_015560

ID	SA4
System	RSC Operator
Description	<p>A person responsible for monitoring a train's operation, capable of remotely supervising and control the train.</p>
Applied Standards	Standards for Remote Operator working environment, regulation and guidance needs to be defined.

ID	SA5
System	Class B Systems
Description	National automated train protection system – no STM.
Applied Standards	No standard defined yet for Class B.

ID	SA6
System	Diagnostic Trackside
Description	<p>The diagnostic trackside component can access the stored data from the onboard diagnostics platform (LC10). The trackside system will be able to store the data offline and has the capability to analyse and visually display the data for an operator.</p> <p>Stored data on the diagnosis platform (LC10) can be rather large considering if the number of locomotive increases. Therefore, the system shall be configurable to retrieve only information that is required and able to be downloaded via the available data communication. Data can be used for e.g. condition based maintenance.</p>
Applied Standards	No standard defined yet.

ID	SA7
System	Signal Operator
Description	Performer in charge of the route setting of trains/shunting movements and of issuing instructions to drivers.
Applied Standards	Existing standards for today's operation. For ATO no standards defined yet.

ID	SA8
System	Rolling Stock Operation System
Description	The Rolling Stock Operation System represents a collection of functionalities of on-board systems which are external to the system of interest. This includes the Train Control Management System and other control systems, e.g., door control, traction control, or braking control, and can be specific to the class from the supplier of the rolling stock; but it interacts with the system of interest over standardized interfaces.
Applied Standards	For ETCS and ATO GoA 2 Subset-139, -147, -119 latest version and new interface for e.g., GoA 4 operation.

## Components

ID	LC1
System	Remote Control Onboard/ Diagnostic Coupler (to RSC): sending diagnostic messages to the RSC.
Description	<p>Remote Supervision &amp; Control</p> <p>The Remote Control Onboard will translate the communicated data:</p> <p>Between RSC and ATO-OB (SS-126 data) to support ATO when ATO-TS is degraded; Between RSC and Locomotive Interface to support “remote control”.</p> <p>Information to the JRU:</p> <p>Other Locomotive functions needed in case of remote control instead of ATO GOA4 (fallback).</p> <p>Remote Diagnostic (Remote Diagnostic)</p> <p>The diagnostic coupling shall gather and pass all necessary monitoring and diagnostic data to the RSC. Necessary data includes generic diagnostic information plus all additional information needed to evaluate the tests (excluding obstacle detection information which is communicated directly).</p> <p>At least all diagnostic information that a driver has on the cab will be sent to the RSC. The Diagnostic Coupling shall also collect the images of the cameras in the leading cabin in the locomotive.</p> <p>The images shall be sent to track side with a maximized FPS (Frames per second), depending on the available bandwidth.</p>
Applied Standards	<p>RSC:</p> <p>SS-126 ATO over ETCS (latest version); SS-139/147 ATO over ETCS (latest version) ZWS/ZDS/ZMS interface; SS-140/147: ATO OB – JRU; SS-027: ETCS OBU – JRU</p> <p>Remote Diagnostic:</p> <p>SS-027 ETCS OBU – JRU; SS-140/147 ATO OB – JRU; To be standardized</p>

ID	LC2
System	FVA: Functional Vehicle Adapter
Description	One important goal of this solution is to provide on the one hand a common solution for adapting functions to existing Vehicle Design and on the other hand to use the advantage of highly matured legacy automatic driving and braking control systems - <b>see chapter 2.2.3</b> Freight Automation subsystems
Applied Standards	First specification delivered by OCORA.

ID	LC3
System	ETCS Onboard
Description	Existing or adapted ETCS – ATO interface. An interface shall be added to the existing ETCS.
Applied Standards	SS-119 ETCS – Train Interface Unit; SS-121 ETCS – DMI; SS-027 ETCS – JRU; SS-130/147 – ETCS OBU – ATO OBU

ID	LC4
System	RSC Trackside
Description	The modes and functionalities are defined in the operational concept, chapter 3.1.2.
Applied Standards	SS-126 ATO over ETCS (latest version); To be standardized

ID	LC5
System	PER-OB (Perception Onboard)
Description	The Perception Onboard subsystem is responsible for using sensors and cameras on the train to gather and analyse data about the immediate environment.
Applied Standards	No standard defined yet.

ID	LC6
System	PER-TS (Perception Trackside)
Description	The Perception Trackside subsystem is a trackside management system for the Perception Onboard component (LC5). It provides an HMI for an RSC Operator to see and investigate alarms, monitors the status of the onboard system and configures adjustments by super-user.
Applied Standards	No standard defined yet.

ID	LC7
System	Radio Management (RM)
Description	The Radio Management subsystem is responsible for managing data and handling communication between the onboard and trackside components for ATO, Diagnostics, ETCS, and RSC. It's a bearer independent Management System.
Applied Standards	No standard defined yet.

ID	LC8
System	ATO-OB (Automatic Train Operation – Onboard)
Description	The sub-system and set of automated non-safety-related driver functions, depending on the grade of automation.
Applied Standards	For GoA 2: SS -139 ATO over ETCS if applicable; ZWS/ZDS/ZMS interface; SS-126 GoA 4 parts; SS-121/147 ATO over ETCS, if applicable (GoA4); SS-125 ATO over ETCS; SS-126 ATO over ETCS; SS -139 ATO over ETCS For GoA 4: No standard defined yet.

ID	LC9
System	DSE: Driving Style Engine
Description	<p>A freight train set composition incl. the coupler and wagons with different types of loads must be understood as dynamic control of a spring-mass-damper system – <b>see chapter 2.2.3</b> Freight Automation subsystems.</p> <p>The DSE module has two main components addressing these constrains:</p> <ul style="list-style-type: none"> <li>a) A driving strategy component that computes an optimal driving strategy for the configured train compliant to national rules and the environment. This component should only fulfil basic integrity functions to compute an optimal driving strategy to reach a target. Therefore, this component can execute algorithms to optimise and configure the driving style.</li> <li>b) A supervision component that is developed independently* from component (a). It ensures that the requested control commands from the computed driving strategy do not lead to any unsafe situation, i.e., too high in train forces that could result into coupler breakages. This function would have a certain vitality and therefore uses a more coarse model with less configurable parameters to verify its functions.</li> </ul> <p>* With independently it is referred to a different team and algorithms to ensure compliance to railway SW guideline,s like EN 50128.</p>
Applied Standards	No European standards existing yet.
ID	LC10
System	Diagnostic Platform
Description	<p>The Diagnostic Platform is responsible for real-time data collection from various on-board systems. The main purpose is to store nonvital information that is used by other systems for offline or real time data analysis.</p> <p>This component does not replace the JRU function and is not designed as a vital component.</p>
Applied Standards	No standard defined yet.

ID	LC11
System	Vehicle Management System (VMS)
Description	<p>This subsystem manages the selection of:</p> <ul style="list-style-type: none"> <li>a) the automated train protection system (ETCS or Class B), and</li> <li>b) the train control commands source for the functional vehicle adapter.</li> </ul> <p>This selection will ensure that the locomotive is controlled by</p> <ul style="list-style-type: none"> <li>a. the local driver (Manual) and the ATO or RSC cannot send control commands via the FVA,</li> <li>b. the ATO, or</li> <li>c. the remote driver via the RSC functions.</li> </ul>
Applied Standards	No standard defined yet.

## Interfaces

ID	I1
System	HMI_TrainDriver_FVA
Description	This interface represents the interactions between the train driver and the functional vehicle adapter.
Applied Standards	No standard defined yet.

ID	I2
Interface	HMI_TrainDriver_ETCS-OB
Description	This interface represents the interactions between the train driver and the ETCS-DMI.
Applied Standards	<p>For ETCS and ATO GoA 2 Subset 121 and CR 1238.</p> <p>For ATO GoA 4 no standard defined yet.</p>

ID	I3
Interface	I_PER-TS_PER-OB
Description	This interface handles the transmission of information from the onboard component of the Perception system to the trackside component.
Applied Standards	No standard defined yet.

ID	I4
Interface	I_PER-OB_FVA
Description	This interface handles communication between the Perception Onboard component and the Functional Vehicle Adapter.
Applied Standards	No standard defined yet.

ID	I5
Interface	I_PER-OB_RollingStockOperationSystem_EB
Description	This interface handles commands from the on-board component of the Perception system to the emergency brakes.
Applied Standards	No standard defined yet.

ID	I6
Interface	I_ETCS-OB_RollingStockOperationSystem_EB
Description	This interface handles ETCS commands to the emergency brake system.
Applied Standards	No standard defined yet.

ID	I7
Interface	I_ETCS_RollingStockOperationSystem_traction
Description	This interface handles ETCS commands to cut off traction, to traction control subsystems.
Applied Standards	No standard defined yet.

ID	I8
Interface	I_FVA_RollingStockOperationSystem(2)
Description	This interface represents the open I/O interface to train control systems out of the system of interest and the functional vehicle adapter.
Applied Standards	No standard defined yet.
ID	I9
Interface	HMI_RSCOperator_PER-TS
Description	This interface handles the interactions between the RSC Operator and the trackside component of the Perception system.
Applied Standards	No standard defined yet.

ID	I10
Interface	HMI_RSCOperator_RSC-TS
Description	This interface handles the interactions between the RSC Operator and the trackside component of the RSC system.
Applied Standards	No standard defined yet.

ID	I11
Interface	I_DSE_FVA
Description	This interface is transmitting all commands and information between DSE – FVA.
Applied Standards	No standard defined yet.

ID	I12
Interface	I_ATO-OB_DSE
Description	This interface is transmitting all commands and information between DSE and the ATO Onboard for supervision & controlling the driving style rules.
Applied Standards	No standard defined yet.

ID	I13
Interface	I_ATO-OB_DSE_SUBSET139ext
Description	This interface handles communication between the DSE and the ATO Onboard that will need to be added to SS-139.
Applied Standards	No standard defined yet.

ID	I14
Interface	I_ETCS-OB_FVA
Description	This interface handles communication between the ETCS onboard component and the Functional Vehicle Adapter.
Applied Standards	No standard defined yet.

ID	I15
Interface	I_FVA_VMS
Description	This interface handles communication between the Functional Vehicle Adapter and the Vehicle Management System.
Applied Standards	No standard defined yet.

ID	I16
Interface	I_FVA_DiagnosticPlatform
Description	This interface handles communication between the Functional Vehicle Adapter and the Vehicle Management System.
Applied Standards	No standard defined yet.

ID	I17
Interface	I_FVA_RollingStockOperationSystem(1)
Description	This interface represents the open vehicle bus interface to train control systems external to the system of interest.
Applied Standards	No standard defined yet.

ID	I18
Interface	I_RSC-OB_FVA
Description	This interface handles communication between the RSC Onboard and the Functional Vehicle Adapter.
Applied Standards	No standard defined yet.

ID	I19
Interface	I_RSC-OB_FVA_SUBSET139
Description	This interface handles communication between the RSC Onboard and the Functional Vehicle Adapter as defined in Subset-139.
Applied Standards	SS-139 + new data

ID	I20
Interface	I_ETCS-OB_RSC-OB
Description	This interface handles communication between the ETCS Onboard and the RSC Onboard.
Applied Standards	SS-130

ID	I21
Interface	I_ETCS-OB_RM
Description	This interface handles communication from the ETCS Onboard to the ETCS Trackside through the Radio Management subsystem.
Applied Standards	GSM-R Standard. Maybe later FRMCS.

ID	I22
Interface	I_ETCS-OB_DiagnosticPlatform_SUBSET027
Description	This interface handles the communication between the ETCS Onboard and the Diagnostic Platform regarding juridical recording.
Applied Standards	SS-027

ID	I23
Interface	I_ETCS-OB_VMS
Description	This interface handles communication between the ETCS Onboard and the Vehicle Management System.
Applied Standards	No standard defined yet.

ID	I24
Interface	I_ClassBSystems_VMS
Description	This interface handles communication between the Vehicle Management System and National Train Protection systems.
Applied Standards	No standard defined yet.

ID	I25
Interface	I_RSC-OB_DiagnosticPlaform
Description	This interface handles communication between the RSC Onboard and the Diagnostic Platform.
Applied Standards	No standard defined yet.

ID	I26
Interface	I_RM_DiagnosticPlatform
Description	This interface handles communication from the Diagnostic Platform to the trackside Diagnostic component through the Radio Management system.
Applied Standards	No standard defined yet.

ID	I27
Interface	I_RSC-OB_RM
Description	This interface handles communication from the RSC Onboard to the RSC Wayside through the Radio Management system.
Applied Standards	No standard defined yet.

ID	I28
Interface	I_RM_DiagnosticTrackside
Description	This interface handles communication from the trackside Diagnostic component to the Diagnostic Platform through the Radio Management system.
Applied Standards	No standard defined yet.

ID	I29
Interface	I_ETCS-TS_RM
Description	This interface handles the communication from the ETCS Trackside to the ETCS Onboard through the Radio Management subsystem.
Applied Standards	No standard defined yet.

ID	I30
Interface	I_ATO-TS_RM
Description	This interface handles the communication from the ATO Trackside to the ATO Onboard through the Radio Management subsystem.
Applied Standards	No standard defined yet.

ID	I31
Interface	I_RSC-TS_RM
Description	This interface handles the communication from the RSC Trackside to the RSC Onboard through the Radio Management subsystem.
Applied Standards	No standard defined yet.

ID	I32
Interface	HMI_SignalOperator
Description	This interface represents the interaction between the Signal Operator and the system of interest.
Applied Standards	No standard defined yet.