RCA

System Needs Analysis

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1 Preamble

1.1 Release Information

Basic document information:

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Support and Feedback:

For feedback, or if you have trouble accessing the material, please contact rca@eulynx.eu.

1.3 Disclaimer

No disclaimer defined.

1.4 Purpose

The purpose of this document is the system needs analysis for System RCA. The system needs analysis determines the overall functionality for performing safe and efficient railway operation. It is performed on the level of RCA that comprises trackside and on-board functionality. This is a deliberate decision, as the end-to-end functionality of the entire System needs to be known in order to successfully design the track-side part of RCA in laster stages of the project. This is true especially taking future developments like GoA4 operation into account, that will require much tighter integration of track side and on-board functionality.

See the release notes (RCA.Doc.5) for further elaboration.

The system needs analysis includes the following aspects:

- Definition of the RCA system boundary and the actors interacting with the system
- Definition of the RCA system functions which are necessary to achieve the RCA system capabilities
- Definition of the RCA system capabilities and how the RCA system functions are used to achieve them

This document is currently only valid for a subset of all the foreseen capabilities, and this subset is defined in the system capabilities section. Furthermore, not all possible features related to the system capabilities are currently in scope of this document.

The system functions are decomposed into logical functions in RCA.Doc.81.

2 Version history

Version	Date	Author	Description
0.4	2022-04-26	Dr. Oliver Lemke	First release.
1.0	2022-09-30	Dr. Oliver Lemke	Updates originated from development of functional decomposition.
1.1	2022-10-19	Dr. Oliver Lemke	Minor formal changes.

3 References

Reference ID	Name	Document ID	Version
1	RCA Terms and Abstract Concepts	RCA.Doc.14	1.0
2	European Union Agency for Railways - European Rail Traffic Management System- Driver Machine Interface	ERA_ERTMS_015560	3.6.0
3	System Requirement Specification	SUBSET-026	3.6.0
4	FIS for the RBC/RBC Handover	SUBSET-036	3.2.0
5	Train Interface FFFIS	SUBSET-119	1.1.0
6	ATO-OB / TCMS FFFIS	SUBSET-139	0.0.22

4 Instructions for reading

The diagrams in this documents are following the ARCADIA method and the syntax of the Capella modelling language. Details on the interpretation of the diagrams are explained in the document "RCA.Doc.60 Explanation of ARCH Process, Methods, Rules".

Please be aware:

- of the limitations of the current state of this document in content and maturity and also the defined scope. See release notes (RCA.Doc.5) for more information.
- that this document is not yet a complete system definition in terms of EN 50126-1. This document is only intended to show how model based content can be serialised into a readable document structure and to display the current content of the model.

5 System objectives

System limitations are defined in a feature tree according to RCA.Doc.80 System Feature Definition.

6 System description

6.1 System boundary

In this chapter, the system boundary is defined by the following aspects:

- A system context diagram, showing the system, all actors and the interfaces between system and actors.
- Enumeration of all actors, definition of the attributes of each actor.
- Interface context diagrams of all interfaces showing:
    - The functions allocated to system and actor relevant for this particular interface.
    - The functional exchanges between these functions allocated to this particular interface.

- Tables with attributes for each interface
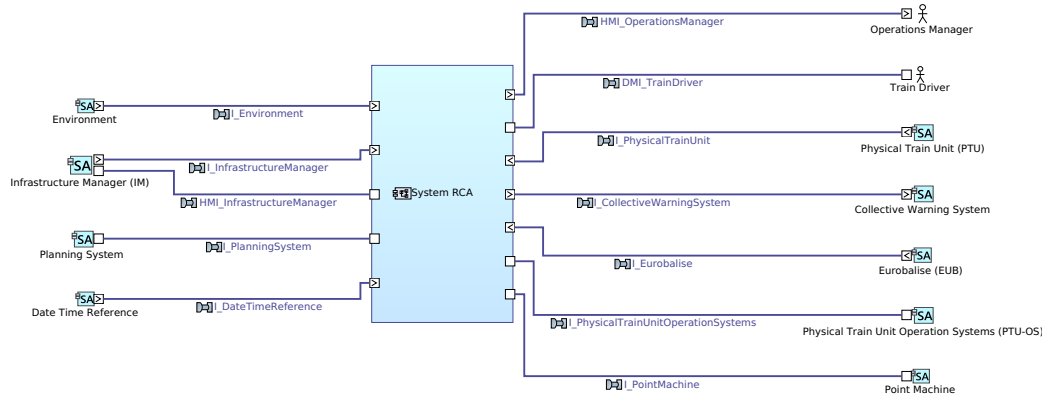
Figure 1: Context of System RCA

6.1.1 Actors

6.1.1.1 Point Machine

Attribute	Content
Name	Point Machine
Description	Point Machine is a device, which can drive movable parts of field elements (e.g. point blades) to a required position. Such a field element may be equipped with more than one Point Machine.
Type	External system
Rationale	The movement of point switch rails is already provided by long-established technologies and is not going to be significantly changed due to the automation of the railway operation and is not part of the development scope. Hence, this entity has been defined as an actor.
Involved system capabilities	01: Set point to position required by mission
Allocated actor functions	Exert force on one switch rail actuation mount point Sense+Observe the position of switch rail on one point machine

Attribute	Content
Interfaces	I_PointMachine

6.1.1.2 Infrastructure Manager (IM)

Attribute	Content
Name	Infrastructure Manager (IM)
Description	Infrastructure Manager means any body or firm responsible for establishing, operating, and maintaining railway infrastructure, including the management of all relevant infrastructure data, traffic management, and control-command and signalling in alignment with key term definition in Directive 2012/34/EU. The functions of the Infrastructure Manager on a network or part of a network may be allocated to different bodies or firms.
Type	External system
Rationale	The infrastructure manager as an organisational role cannot be part of the system. Hence, the infrastructure manager has been defined as an actor.
Involved system capabilities	87: Activate map data
Allocated actor functions	Provide map data - STUB Command the authorisation of one version of map data
Interfaces	HMI_InfrastructureManager I_InfrastructureManager

6.1.1.3 Train Driver

Attribute	Content
Name	Train Driver
Description	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. Source: Directive 2007/59/EC of the European Parliament and of the Council
Type	Human Actor
Rationale	The Train Driver as person cannot be part of the system. Hence, the Train Driver has been defined as an actor.
Involved system capabilities	09: Move one train unit 11: Prepare departure of train unit

Attribute	Content
Allocated actor functions	Command the requested state of all doors of one train unit
	Authorise the departure of one train unit
	Decide about intervention into train unit movement
Interfaces	DMI_TrainDriver

6.1.1.4 Collective Warning System

Attribute	Content
Name	Collective Warning System
Description	Collective Warning System represents the devices which actuate the required warning state provided by System RCA to the track workers. Warnings are given audibly and optically. The warning devices are located at the track and are forming one collective warning system to cover the respective warning area.
Type	External system
Rationale	Collective Warning Systems are widely established in the railway domain and the actual design and functionality of the warning devices of the Collective Warning Systems will not change with RCA. Only the control of the activation and warning state will be optimised within RCA. Hence, the collective warning system has been defined as an actor.
Involved system capabilities	66.1: Start warning authorised trackside persons of approaching train unit
	66.2: Stop warning authorised trackside persons of approaching train unit
Allocated actor functions	Control+Execute the warning state for all warning devices within one warning area
Interfaces	I_CollectiveWarningSystem

6.1.1.5 Operations Manager

Attribute	Content
Name	Operations Manager
Description	The Operations Manager represents a person responsible for the railway operation of the System in a given geographic area. This person is part of the Infrastructure Management entity. The Operations Manager supervises the normal operation performed automatically by Planning System and manages specific actions that cannot be executed automatically.
Type	Human Actor
Rationale	The Operations Manager as a human actor role cannot be part of the system. Hence, the Operations Manager has been defined as an actor.
Involved system capabilities	01: Set point to position required by mission

Attribute	Content
Allocated actor functions	Observe the state of the railway - STUB
Interfaces	HMI_OperationsManager

6.1.1.6 Physical Train Unit Operation Systems (PTU-OS)

Attribute	Content
Name	Physical Train Unit Operation Systems (PTU-OS)
Description	Physical Train Unit Operation Systems represents all on-board subsystems not in RCA and OCORA scope, including the Train Control and Management System (TCMS) and hard-wired electrical and electronical components that are necessary for the operation of the Physical Train Unit, but are not likely to change due to the development of System RCA or OCORA.
Type	External system
Rationale	As the PTU-OS intentionally represents technical components outside of the RCA scope, it has to be an actor.
Involved system capabilities	09: Move one train unit 11: Prepare departure of train unit 15: Respond autonomously to object on or near the line 85: Provide navigation data of train unit
Allocated actor functions	Control the sounding state of horn Control the traction and brake effort of one train unit Sense+Observe the state of all doors of one train unit Control the required state of all doors of one train unit Observe the train integrity state of one physical train unit Observe the intended movement direction relative to the front end of the train unit
Interfaces	I_PhysicalTrainUnitOperationSystems

6.1.1.7 Physical Train Unit (PTU)

Attribute	Content
Name	Physical Train Unit (PTU)
Description	Physical Train Unit (PTU) is physically existent, driveable and made up of a single or an ordered sequence of Physical Consists coupled together.
Type	External system

Attribute	Content
Rationale	The physical train unit represents the physical aspects of a train unit, that are defined as not being part of the development scope. Hence, this entity is defined as an actor.
Involved system capabilities	09: Move one train unit 11: Prepare departure of train unit 85: Provide navigation data of train unit
Allocated actor functions	Actuate+Plant movement behaviour of one train unit Actuate+Plant behaviour of all doors of one train unit
Interfaces	I_PhysicalTrainUnit

6.1.1.8 Planning System

Attribute	Content
Name	Planning System
Description	Planning System provides functionality for preparing and optimising the entire schedule within an Area of Control. This schedule will be represented by Missions for Train Units. Missions are provided to System RCA where they enable command and control of traffic operations. System RCA provides the current operation state to the Planning System as feedback.
Type	External system
Rationale	Depending on the individual needs of IMs, planning systems can be vastly different regarding functional scope and complexity. Therefore, it is not possible for RCA to define exactly one planning system fulfilling the entire bandwidth of requirements of all IMs. Hence, the planning system is intentionally excluded from the development scope and is defined as an actor.
Involved system capabilities	01: Set point to position required by mission 09: Move one train unit 11: Prepare departure of train unit 65.1: Create warning area 66.1: Start warning authorised trackside persons of approaching train unit 85: Provide navigation data of train unit 87: Activate map data

Attribute	Content
Allocated actor functions	Control the plan for all missions in one area of control Control the plan for warning areas over time for all tracks in one area of control Control the life-cycle of map data - STUB Control the plan for restriction areas over time for all tracks in one area of control
Interfaces	I_PlanningSystem

6.1.1.9 Date Time Reference

Attribute	Content
Name	Date Time Reference
Description	Date Time Reference is the system/organisation that provides reference of date and time to System RCA.
Type	External system
Rationale	Date and time should be provided by an official source like a metrology institute, which cannot be part of the system. Hence, Date Time Reference has been defined as an actor.
Involved system capabilities	None
Allocated actor functions	Provide date and time reference
Interfaces	I_DateTimeReference

6.1.1.10 Environment

Attribute	Content
Name	Environment
Description	Environment represents the external physical environment the System RCA operates in. It is a source for environmental conditions, localisation references like landmarks or dedicated electromagnetic signals and also for possible obstacles impeding the railway operation.
Type	External system
Rationale	By definition the environment cannot be part of the system. Hence, it has been defined as an actor.
Involved system capabilities	15: Respond autonomously to object on or near the line 85: Provide navigation data of train unit
Allocated actor functions	Contains physical objects Has physical dimensions and limits
Interfaces	I_Environment

6.1.1.11 Eurobalise (EUB)

Attribute	Content
Name	Eurobalise (EUB)
Description	A transponder, mounted on the track, which can communicate with a train passing over it, compliant to the ERTMS/ETCS specifications.
Type	External system
Rationale	The current assumption is, that the Eurobalise (EUB) will be used primarily for location references and will be conceptually unchanged. Hence, it does not need to be inside the development scope of RCA and is defined as an actor.
Involved system capabilities	85: Provide navigation data of train unit
Allocated actor functions	Transmit eurobalise static information
Interfaces	I_Eurobalise

6.1.2 Interfaces

This chapter defines the interfaces between System RCA and the actors. Each interface is defined by an allocation of functions to the system and to the actor as well as the functional exchanges crossing over this interface.

6.1.2.1 DMI_TrainDriver

This interface is constrained to be specified according to ERA ERTMS 015560 including the future ATO display information.
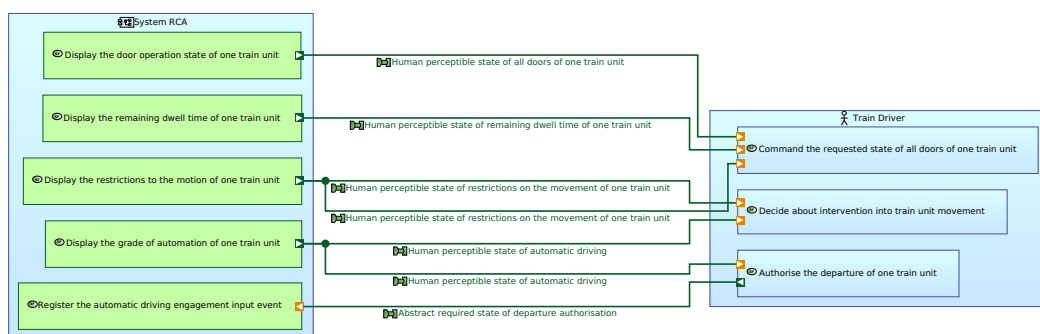
Figure 2: Interface Context of DMI_TrainDriver

Attribute	Content
Name	DMI_TrainDriver
Source	System RCA
Target	Train Driver

Attribute	Content
System RCA incoming allocated functional exchanges	Abstract required state of departure authorisation **Exchange Items:** • DMI_engage_event

System RCA outgoing allocated functional exchanges	Human perceptible state of restrictions on the movement of one train unit
	Exchange Items:
	
	    • movement_authority_indication
	
	Human perceptible state of automatic driving
	Exchange Items:
	
	    • automatic_driving_state_indication
	
	Human perceptible state of remaining dwell time of one train unit
	Exchange Items:
	
	    • remaining_dwell_time_indication
	
	Human perceptible state of restrictions on the movement of one train unit
	Exchange Items:
	
	    • movement_authority_indication
	
	Human perceptible state of all doors of one train unit
	Exchange Items:
	
	    • door_operation_state_indication
	
	Human perceptible state of automatic driving
	Exchange Items:
	
	    • automatic_driving_state_indication

6.1.2.2 HMI_InfrastructureManager

This interface is not constrained by existing standards and can be developed according to the needs elicited.
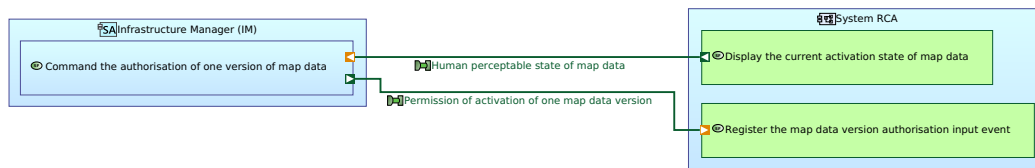
Figure 3: Interface Context of HMI_InfrastructureManager

Attribute	Content
Name	HMI_InfrastructureManager
Source	Infrastructure Manager (IM)
Target	System RCA
System RCA incoming allocated functional exchanges	Permission of activation of one map data version **Exchange Items:** • map_data_authorisation_command
System RCA outgoing allocated functional exchanges	Human perceptable state of map data **Exchange Items:** • map_data_state_indication

6.1.2.3 HMI_OperationsManager

This interface is not constrained by existing standards and can be developed according to the needs elicited.
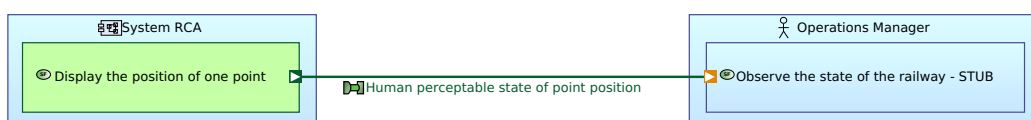
Figure 4: Interface Context of HMI_OperationsManager

Attribute	Content
Name	HMI_OperationsManager
Source	System RCA
Target	Operations Manager
System RCA incoming allocated functional exchanges	None

Attribute	Content
System RCA outgoing allocated functional exchanges	Human perceptible state of point position **Exchange Items:** • point_position_indication

6.1.2.4 I_CollectiveWarningSystem

This interface is not constrained by existing standards and can be developed according to the needs elicited.
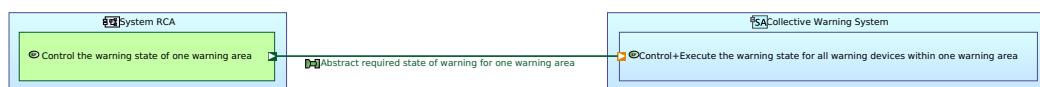
Figure 5: Interface Context of I_CollectiveWarningSystem

Attribute	Content
Name	I_CollectiveWarningSystem
Source	System RCA
Target	Collective Warning System
System RCA incoming allocated functional exchanges	None
System RCA outgoing allocated functional exchanges	Abstract required state of warning for one warning area **Exchange Items:** • warning_area_warning_requirement

6.1.2.5 I_DateTimeReference

This interface is not constrained by existing standards and can be developed according to the needs elicited.
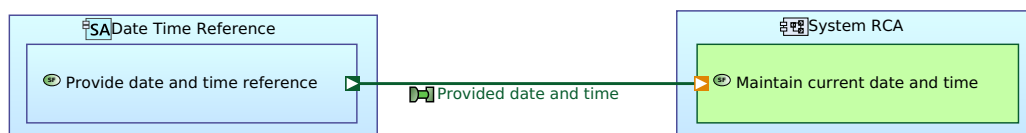

Figure 6: Interface Context of I_DateTimeReference

Attribute	Content
Name	I_DateTimeReference
Source	Date Time Reference
Target	System RCA

Attribute	Content
System RCA incoming allocated functional exchanges	Provided date and time **Exchange Items:** • date_and_time_definition
System RCA outgoing allocated functional exchanges	None

6.1.2.6 I_Environment

This interface by characteristic cannot be constrained or standardised.
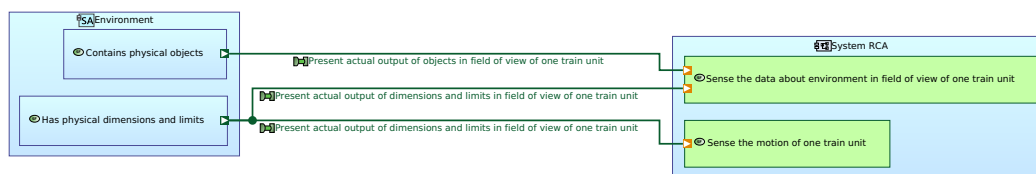
Figure 7: Interface Context of I_Environment

Attribute	Content
Name	I_Environment
Source	Environment
Target	System RCA

System RCA incoming allocated functional exchanges	Present actual output of dimensions and limits in field of view of one train unit
	Exchange Items:
	
	   • physical_dimensions_and_limits_presence
	
	Present actual output of objects in field of view of one train unit
	Exchange Items:
	
	   • physical_objects_presence
	
	Present actual output of dimensions and limits in field of view of one train unit
	Exchange Items:
	
	   • physical_dimensions_and_limits_presence

System RCA outgoing allocated functional exchanges	None

6.1.2.7 I_Eurobalise

This interface is constrained to be specified according to ERTMS/ETCS SUBSET-036 and ERTMS/ETCS SUBSET-026.

Figure 8: Interface Context of I_Eurobalise

Attribute	Content
Name	I_Eurobalise
Source	System RCA
Target	Eurobalise (EUB)
System RCA incoming allocated functional exchanges	Transmitted balise data **Exchange Items:** • eurobalise_telegram
System RCA outgoing allocated functional exchanges	None

6.1.2.8 I_PhysicalTrainUnit

This interface by characteristic cannot be constrained or standardised.
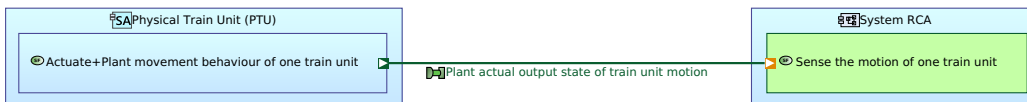
Figure 9: Interface Context of I_PhysicalTrainUnit

Attribute	Content
Name	I_PhysicalTrainUnit
Source	System RCA
Target	Physical Train Unit (PTU)
System RCA incoming allocated functional exchanges	Plant actual output state of train unit motion **Exchange Items:** • physical_train_unit_behaviour_presence
System RCA outgoing allocated functional exchanges	None

6.1.2.9 I_PhysicalTrainUnitOperationSystems

This interface is constrained to be specified according to ERTMS/ETCS SUBSET-119, upcoming SUBSET-139 and needs to be aligned with OCORA and other European initiatives.
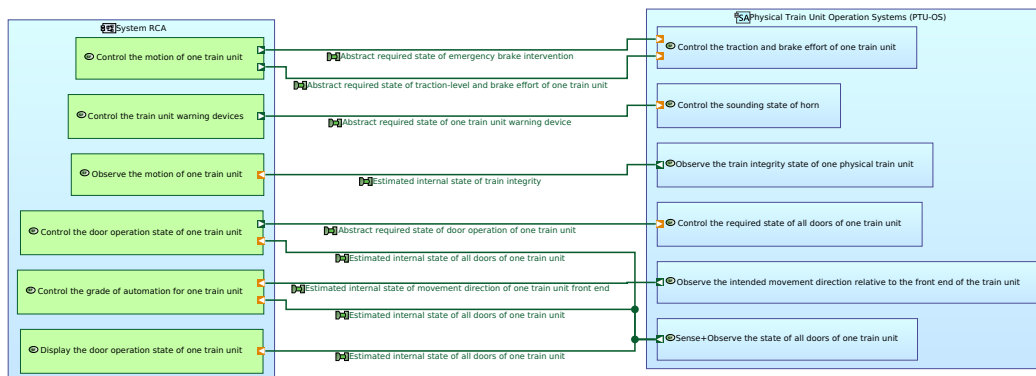
Figure 10: Interface Context of I_PhysicalTrainUnitOperationSystems

Attribute	Content
Name	I_PhysicalTrainUnitOperationSystems
Source	System RCA
Target	Physical Train Unit Operation Systems (PTU-OS)

System RCA incoming allocated functional exchanges	Estimated internal state of all doors of one train unit
	Exchange Items:
	
	    • all_doors_state_observation
	
	Estimated internal state of all doors of one train unit
	Exchange Items:
	
	    • all_doors_state_observation
	
	Estimated internal state of train integrity
	Exchange Items:
	
	    • train_unit_integrity_state_estimation
	
	Estimated internal state of all doors of one train unit
	Exchange Items:
	
	    • all_doors_state_observation
	
	Estimated internal state of movement direction of one train unit front end
	Exchange Items:
	
	    • train_unit_front_end_movement_direction_intention

Attribute	Content

System RCA outgoing allocated functional exchanges	Abstract required state of emergency brake intervention
	Exchange Items:
	
	   • emergency_brake_requirement
	
	Abstract required state of one train unit warning device
	Exchange Items:
	
	   • audible_warning_device_requirement
	
	Abstract required state of traction-level and brake effort of one train unit
	Exchange Items:
	
	   • relative_traction_braking_effort_level_requirement
	
	Abstract required state of door operation of one train unit
	Exchange Items:
	
	   • door_operation_state_requirement

6.1.2.10 I_PlanningSystem

This interface is not constrained by existing standards and can be developed according to the needs elicited.

Figure 11: Interface Context of I_PlanningSystem

Attribute	Content
Name	I_PlanningSystem
Source	Planning System
Target	System RCA

System RCA incoming allocated functional exchanges	Abstract required state of missions in one area of control
	Exchange Items:
	
	  • mission_requirement
	
	Abstract required state of missions in one area of control
	Exchange Items:
	
	  • mission_requirement
	
	Abstract required state of missions in one area of control
	Exchange Items:
	
	  • mission_requirement
	
	Abstract required state of warning areas in one area of control
	Exchange Items:
	
	  • warning_area_requirement
	
	Abstract required state of missions in one area of control
	Exchange Items:
	
	  • mission_requirement
	
	Abstract required state of missions in one area of control
	Exchange Items:
	
	  • mission_requirement
	
	Abstract required state of missions in one area of control
	Exchange Items:
	
	  • mission_requirement
	
	Abstract required state of restriction areas in one area of control - STUB
	Exchange Items:
	
	  • restriction_area_requirement_STUB

Attribute	Content

System RCA outgoing allocated functional exchanges	Estimated internal position state of point
	Exchange Items:
	
	  • point_position_estimation
	
	Estimated internal motion state of one train unit
	Exchange Items:
	
	  • train_unit_navigation_data_estimation
	
	Reported state of map data
	Exchange Items:
	
	  • map_data_state_observation
	
	Defined actual motion state plan over time
	Exchange Items:
	
	  • motion_state_over_time_plan
	
	Defined actual state of one warning area
	Exchange Items:
	
	  • warning_area_actual_definition
	
	Defined actual state of restriction area - STUB
	Exchange Items:
	
	  • restriction_area_actual_definition_STUB

6.1.2.11 I_PointMachine

This interface is constrained to be specified according to the existing 4-wire electrical point-machine interface.
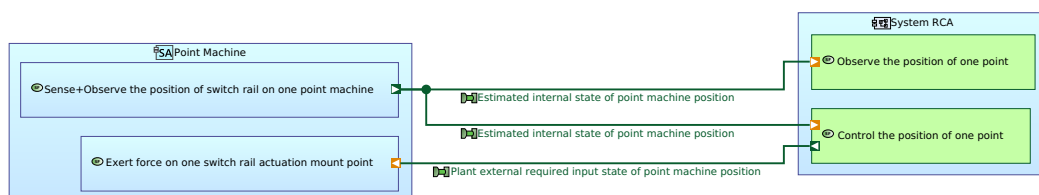
Figure 12: Interface Context of I_PointMachine

Attribute	Content
Name	I_PointMachine
Source	System RCA
Target	Point Machine

System RCA incoming allocated functional exchanges	Estimated internal state of point machine position
	Exchange Items:
	
	   • point_machine_position_estimation
	
	Estimated internal state of point machine position
	Exchange Items:
	
	   • point_machine_position_estimation

System RCA outgoing allocated functional exchanges	Plant external required input state of point machine position **Exchange Items:** • point_machine_actuation_requirement

6.1.2.12 I_InfrastructureManager

This interface is not constrained by existing standards and can be developed according to the needs elicited.

Figure 13: Interface Context of I_InfrastructureManager

Attribute	Content
Name	I_InfrastructureManager
Source	Infrastructure Manager (IM)
Target	System RCA
System RCA incoming allocated functional exchanges	Provided map data **Exchange Items:** • map_data_definition
System RCA outgoing allocated functional exchanges	None

6.2 System Limitations

To be released in future version of this document.

6.3 System capabilities

In this chapter, all system capabilities provided by the system are described by the following aspects:

- A capability context diagram, showing the relationship between system capabilities under consideration, other system capabilities and actors.
- List of the attributes of the system capability.
- System functional chain diagram, showing how the system capability will be realised by the system functions.

6.3.1 01: Set point to position required by mission
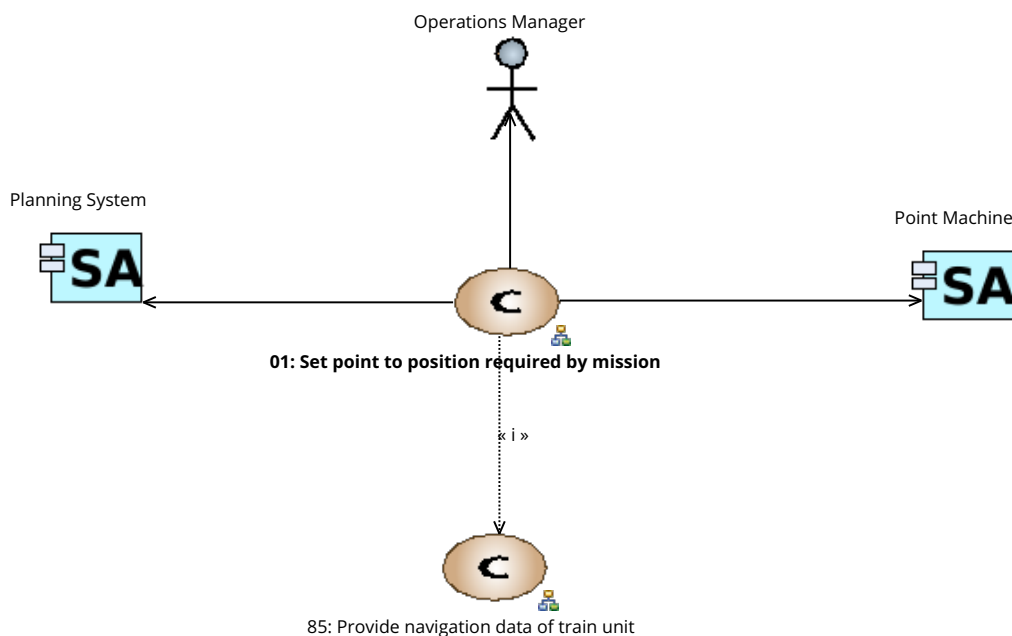
Figure 14: [CC][AMOD-138] 01: Set point to position required by mission [Single System capability context]

Attribute	Content
Name	01: Set point to position required by mission
Description	The Planning System requires the System RCA to set one point to a position needed for execution of one Mission. System RCA is therefore providing control commands to the Point Machine and status information to the Operations Manager.
Pre-condition	All Point Machines of one Point are in Controllable and observable state AND one Move Segment in the Mission extends over this Point AND Point is not in the required position state to execute the Mission related concepts.

Attribute	Content
Post-condition	(All Point Machine of one Point are in the required position state to execute the Move Segment (Success) OR At least one Point Machine of one Point is not in the required position state to execute the Move Segment (Alternative)) AND All Point Machines of one point are in Stopped AND current point_position_estimation is indicated to Operations Manager AND current point_position_estimation is provided to Planning System.
Involved actors and external systems	Operations Manager Planning System Point Machine
Involved functions	**allocated to system:** Maintain map data Display the position of one point Control the position of one point Observe the position of one point Observe the motion of one train unit Maintain current date and time Control the motion of one train unit Control the life-cycle of one restriction area - STUB **allocated to actor:** Control the plan for all missions in one area of control Exert force on one switch rail actuation mount point Sense+Observe the position of switch rail on one point machine Observe the state of the railway - STUB
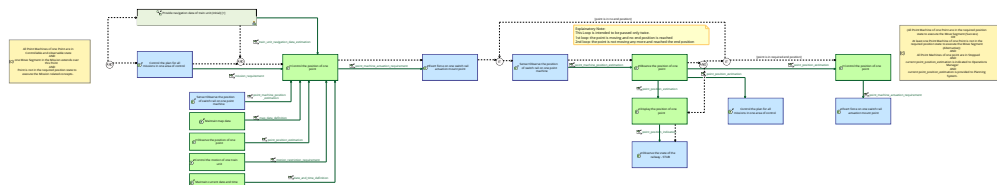
Figure 15: [SFCD][AMOD-059] Set point to position required by mission [Initial system functional chain description]

6.3.2 09: Move one train unit
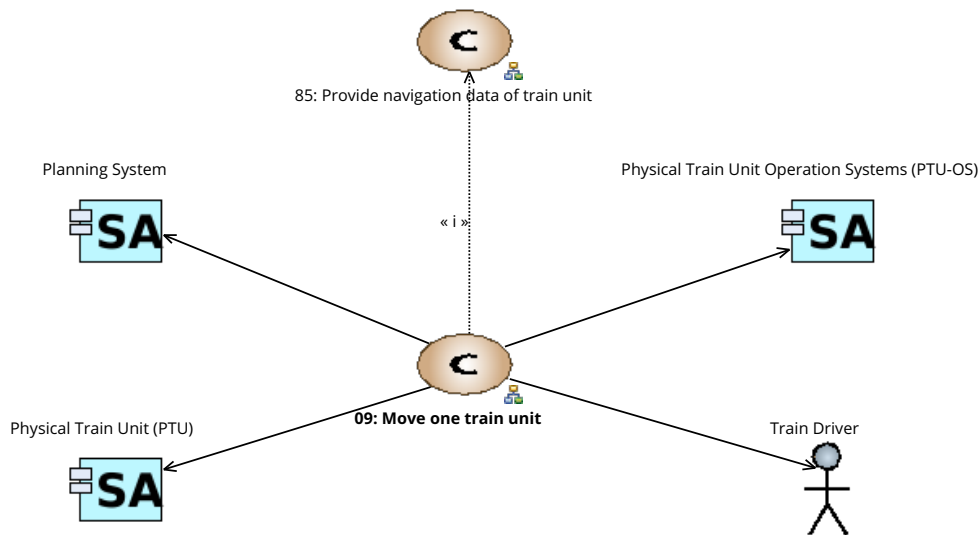
Figure 16: [CC][AMOD-138] 09: Move one train unit [Single system capability context]

Attribute	Content
Name	09: Move one train unit
Description	The Planning System requires the System RCA to move one Train Unit across a sequence of Mission Segments by providing control commands to Physical Train Unit Operation Systems (PTU-OS) and information to the Train Driver.
Pre-condition	According to Physical Train Unit Operation Systems (PTU-OS), the Physical Train Unit is technically able to execute required movement AND there are neither technical nor operational restrictions conflicting with the required Train Unit movement AND AutomaticDrivingOperationalState = Engaged
Post-condition	Physical Train Unit (PTU) has stopped at the next required Stop Segment AND Planning System is informed about the train_unit_navigation_data_estimation and motion_state_over_time_plan AND AutomaticDrivingOperationalState is in state Available
Involved actors and external systems	Train Driver Planning System Physical Train Unit Operation Systems (PTU-OS) Physical Train Unit (PTU)

Attribute	Content
Involved functions	**allocated to system:** Control the motion of one train unit Maintain current date and time Observe the motion of one train unit Display the restrictions to the motion of one train unit Control the grade of automation for one train unit Maintain map data Display the grade of automation of one train unit Maintain train unit configuration data **allocated to actor:** Control the traction and brake effort of one train unit Control the plan for all missions in one area of control Decide about intervention into train unit movement Actuate+Plant movement behaviour of one train unit
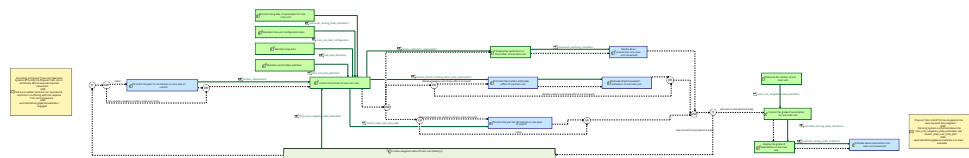
Figure 17: [SFCD][AMOD-059] Move one train unit (GoA2)[Initial system functional chain description]

6.3.3 11: Prepare departure of train unit
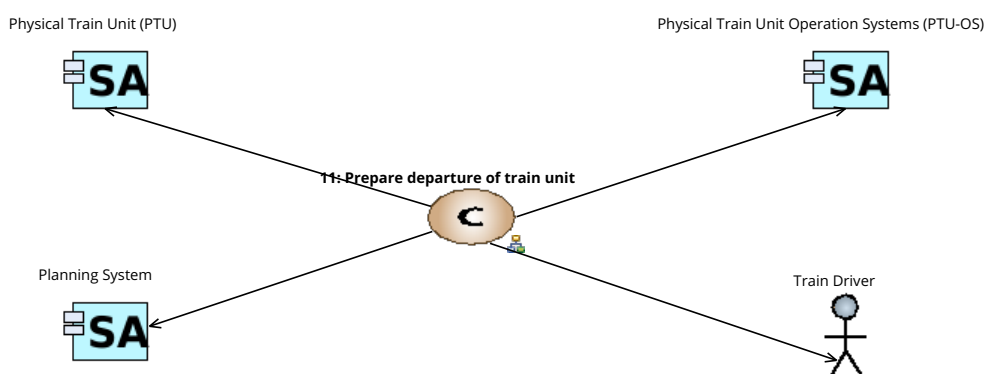
Figure 18: [CC][AMOD-138] 11: Prepare departure of train unit [Single system capability context]

Attribute	Content
Name	11: Prepare departure of train unit

Attribute	Content
Description	The Planning System requires the System RCA to prepare the departure of one Train Unit by providing control commands to Physical Train Unit Operation Systems (PTU-OS) and information to the Train Driver and Train Attendant, so that the next Move Segment can be started as planned.
Pre-condition	Grade of Automation (GoA) is in the required state AND AutomaticDrivingOperationalState is in state Available AND Physical Train Unit (PTU) is in state standstill AND Train Unit ready to perform next Move Segment AND Doors are in state not all closed and locked
Post-condition	AutomaticDrivingOperationalState is in state Engaged AND Doors are all closed and locked
Involved actors and external systems	Train Driver Physical Train Unit Operation Systems (PTU-OS) Planning System Physical Train Unit (PTU)

Attribute	Content
Involved functions	**allocated to system:** Control the motion of one train unit Register the automatic driving engagement input event Display the grade of automation of one train unit Control the grade of automation for one train unit Display the door operation state of one train unit Display the restrictions to the motion of one train unit Display the remaining dwell time of one train unit Maintain current date and time Maintain map data Observe the motion of one train unit Control the door operation state of one train unit Maintain train unit configuration data Observe the free space of the track in the field of view of one train unit **allocated to actor:** Command the requested state of all doors of one train unit Authorise the departure of one train unit Actuate+Plant behaviour of all doors of one train unit Sense+Observe the state of all doors of one train unit Control the required state of all doors of one train unit Observe the intended movement direction relative to the front end of the train unit Control the plan for all missions in one area of control

Figure 19: [SFCD][AMOD-059] Prepare departure of train unit (GoA2)[Initial system functional chain description]
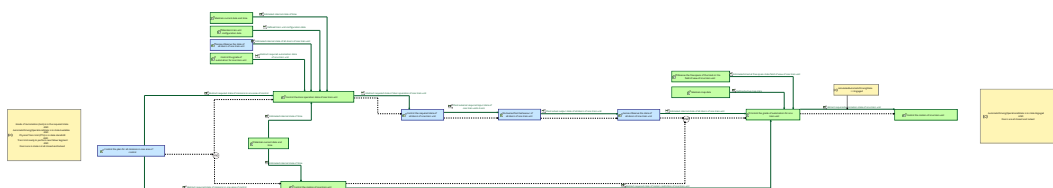
Figure 20: [SFCD][AMOD-059] Prepare departure of train unit (GoA4)[Initial system functional chain description]

6.3.4 15: Respond autonomously to object on or near the line

Environment   Physical Train Unit Operation Systems (PTU-OS)

15: Respond autonomously to object on or near the line
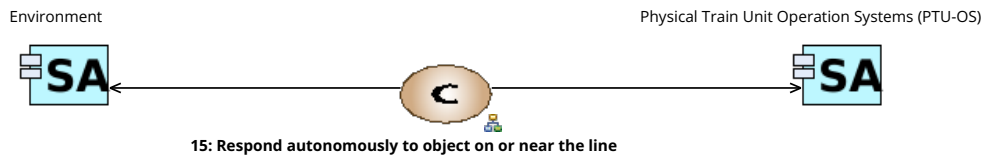
Figure 21: [CC][AMOD-138] 15: Respond autonomously to object on or near the line [Single system capability context]

Attribute	Content
Name	15: Respond autonomously to object on or near the line
Description	The Infrastructure Manager and Railway Undertaking (RU) requires the System RCA to respond autonomously to objects on or near the line by issuing control commands to Physical Train Unit Operation Systems (PTU-OS), so that the current Move Segment can be safely executed.
Pre-condition	At least one physical object is present on or near the line ahead of one Physical Train Unit (PTU).
Post-condition	The affected Physical Train Unit (PTU) is in a safe state (hazardous situation was mitigated or present object did not cause hazardous situation) OR the collision with an obstacle occured with lower severity (impact) OR the collision with an obstacle occured with full impact without mitigation.
Involved actors and external systems	Physical Train Unit Operation Systems (PTU-OS) Environment
Involved functions	**allocated to system:** Sense the data about environment in field of view of one train unit Observe the free space of the track in the field of view of one train unit Observe the motion of one train unit Control the motion of one train unit Control the train unit warning devices Control the life-cycle of one restriction area - STUB Maintain map data Maintain current date and time **allocated to actor:** Contains physical objects Has physical dimensions and limits Control the traction and brake effort of one train unit Control the sounding state of horn
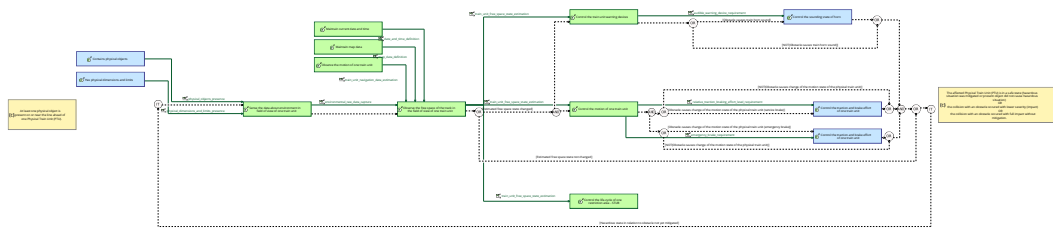
Figure 22: [SFCD][AMOD-059] Respond autonomously to object on or near the line [Initial system functional chain description]

6.3.5 65.1: Create warning area

Planning System

65.1: Create warning area
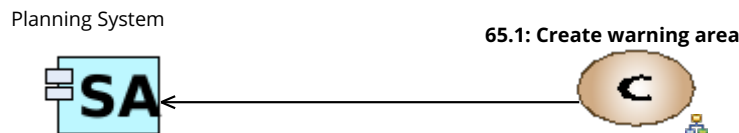
Figure 23: [CC][AMOD-138] 65.1: Create warning area [Single system capability context]

Attribute	Content
Name	65.1: Create warning area
Description	The Planning System requires the System RCA to create a warning area.
Pre-condition	The Warning Area is not yet created in System RCA.
Post-condition	The Warning Area is created in System RCA.
Involved actors and external systems	Planning System
Involved functions	**allocated to system:** Control the life-cycle of one warning area Maintain current date and time Maintain map data **allocated to actor:** Control the plan for warning areas over time for all tracks in one area of control
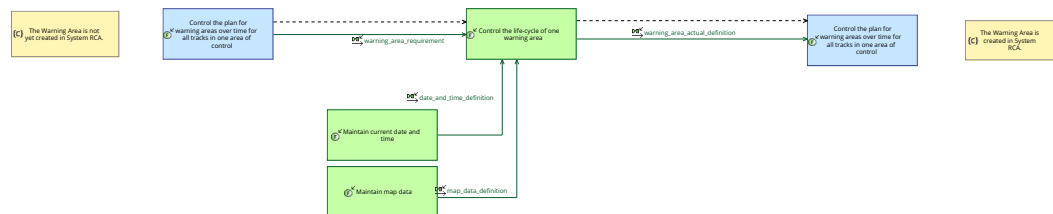
Figure 24: [SFCD][AMOD-059] Create warning area [Initial system functional chain description]

6.3.6 66.1: Start warning authorised trackside persons of approaching train unit
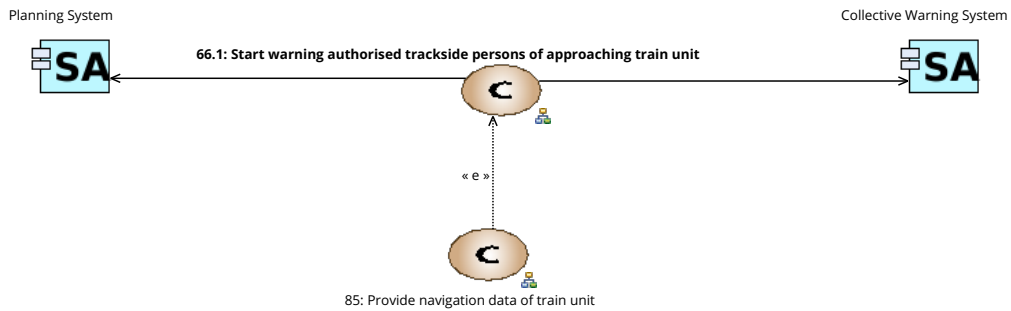
Figure 25: [CC][AMOD-138] 66.1: Start warning authorised trackside persons of approaching train unit [Single system capability context]

Attribute	Content
Name	66.1: Start warning authorised trackside persons of approaching train unit
Description	The position of the Physical Train Unit (PTU) requires the System RCA to command the activation of the warning to Authorised Trackside Person of approaching Train Units by issuing control commands to the Collective Warning System.
Pre-condition	A Warning Area is in state activated AND the Collective Warning System is in state actived AND a warning for Warning Area is in state not actived.
Post-condition	Warning for Warning Area is in state activated.
Involved actors and external systems	Collective Warning System Planning System
Involved functions	**allocated to system:** Control the warning state of one warning area Sense the motion of one train unit Control the life-cycle of one warning area Maintain map data Maintain current date and time Observe the motion of one train unit **allocated to actor:** Control+Execute the warning state for all warning devices within one warning area Control the traction and brake effort of one train unit Control the plan for all missions in one area of control

Figure 26: [SFCD][AMOD-059] Start warning authorised trackside persons of approaching train unit [Initial system functional chain description]

6.3.7 66.2: Stop warning authorised trackside persons of approaching train unit

Collective Warning System

66.2: Stop warning authorised trackside persons of approaching train unit

« i »

85: Provide navigation data of train unit

Figure 27: [CC][AMOD-138] 66.2: Stop warning authorised trackside persons of approaching train unit [Single system capability context]
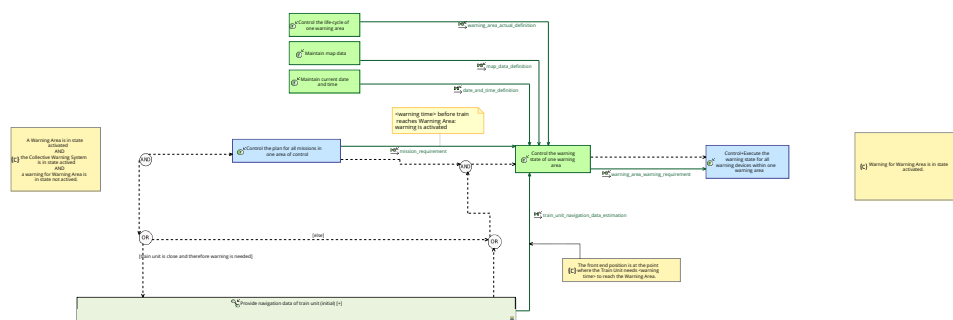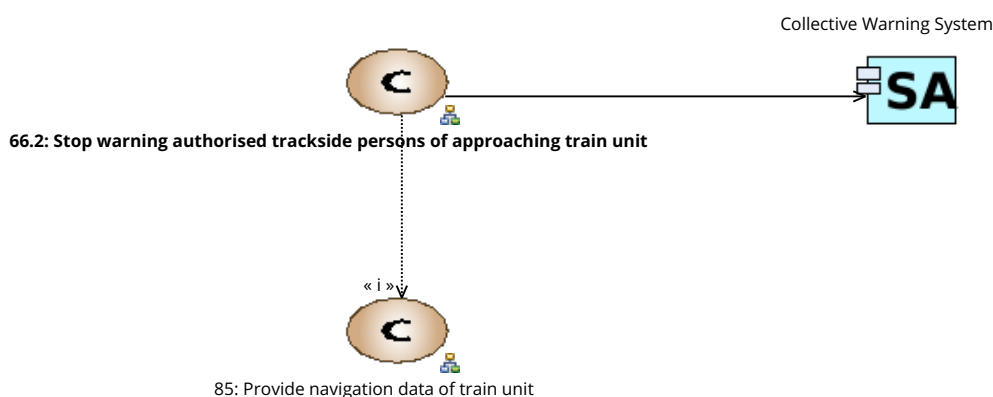
Attribute	Content
Name	66.2: Stop warning authorised trackside persons of approaching train unit
Description	The position of the Physical Train Unit (PTU) requires the System RCA to command the deactivation of the warning to Authorised Trackside Person of approaching Train Units by issuing control commands to the Collective Warning System.
Pre-condition	Warning for Warning Area is in state activated.
Post-condition	Warning for Warning Area is in state not activated.
Involved actors and external systems	Collective Warning System
Involved functions	**allocated to system:** Control the warning state of one warning area **allocated to actor:** Control+Execute the warning state for all warning devices within one warning area
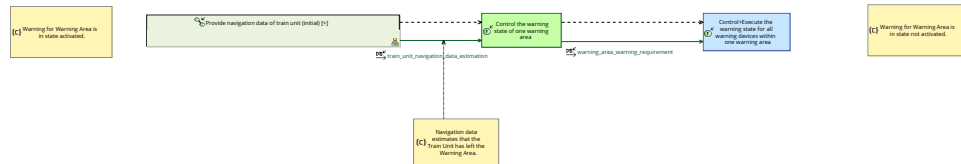
Figure 28: [SFCD][AMOD-059] Stop warning authorised trackside persons of approaching train unit [Initial system functional chain description]

6.3.8 85: Provide navigation data of train unit
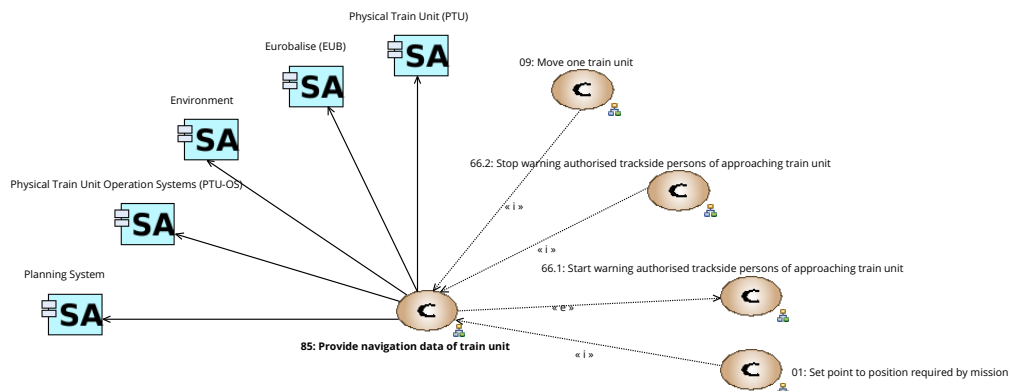
Figure 29: [CC][AMOD-138] 85: Provide navigation data of train unit [Single System capability context]

Attribute	Content
Name	85: Provide navigation data of train unit
Description	The Infrastructure Manager (IM) requires the System RCA to provide navigation data of the physical train unit.
Pre-condition	Navigation data of the Physical Train Unit (PTU) has changed significantly.
Post-condition	New changed Physical Train Unit (PTU) navigation data has been provided
Involved actors and external systems	Environment Planning System Eurobalise (EUB) Physical Train Unit (PTU) Physical Train Unit Operation Systems (PTU-OS)

Attribute	Content
Involved functions	**allocated to system:** Sense the data of one eurobalise Observe the motion of one train unit Maintain train unit configuration data Maintain map data Sense the motion of one train unit Observe the position of one point **allocated to actor:** Transmit eurobalise static information Observe the train integrity state of one physical train unit Control the plan for all missions in one area of control Actuate+Plant movement behaviour of one train unit Has physical dimensions and limits Observe the intended movement direction relative to the front end of the train unit
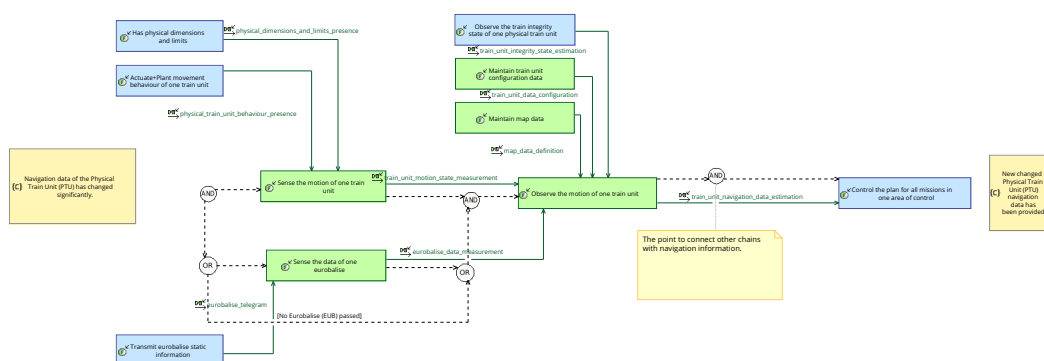
Figure 30: [SFCD][AMOD-059] Provide navigation data of train unit [Initial system functional chain description]

6.3.9 87: Activate map data

Infrastructure Manager (IM)   Planning System

87: Activate map data
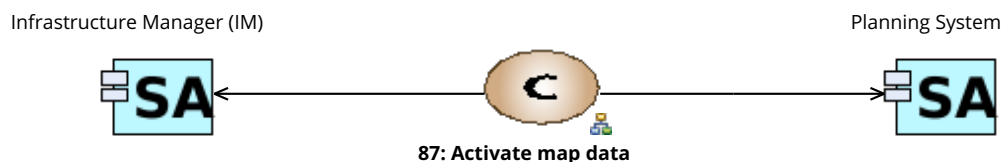
Figure 31: [CC][AMOD-138] 87: Activate map data [Single system capability context]

Attribute	Content
Name	87: Activate map data
Description	The Infrastructure Manager requires the System RCA to activate Map Data so that the system is able to operate on the currently correct version of Map Data.

Attribute	Content
Pre-condition	New version of Map Data from Infrastructure Manager is in state Ready for Activation AND New version of Map Data is present in the Planning System
Post-condition	New version of Map Data is in state Activated
Involved actors and external systems	Planning System Infrastructure Manager (IM)
Involved functions	**allocated to system:** Control the active version of map data Control the motion of one train unit Display the current activation state of map data Maintain current date and time Maintain map data Observe the motion of one train unit Control the life-cycle of one restriction area - STUB Register the map data version authorisation input event **allocated to actor:** Provide map data - STUB Command the authorisation of one version of map data Control the life-cycle of map data - STUB Control the plan for restriction areas over time for all tracks in one area of control
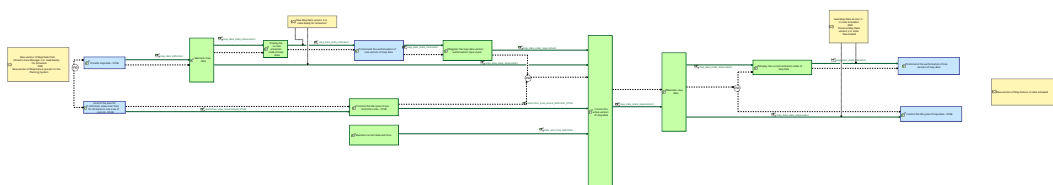
Figure 32: [SFCD][AMOD-059] Activate map data [Initial system functional chain description]

6.4 System Functions

In this chapter, all system functions defined for the system are described by the following aspects:

- List of the attributes of the system function.
- A functions context diagram, showing the relationship between the system function under consideration and other functions, including the functional exchanges.

6.4.1 Control the active version of map data

Attribute	Content
Name	Control the active version of map data

Attribute	Content
Description	This function controls which version of map data is to be activated and correspondingly provided by the function Maintain map data at any given point in time. In addition, this function also controls the transitions between different versions of Map Data.
Rationale	Map data is a central configuration asset, as a lot of functionality is dependent on it. Also, changes to map data are frequent compared to system's life cycle and highly mission critical from safety, security and business risk perspective. A reliable solution is hence an important contributor to the project goals. Therefore this function needs to be inside the development scope and inside the system boundary.
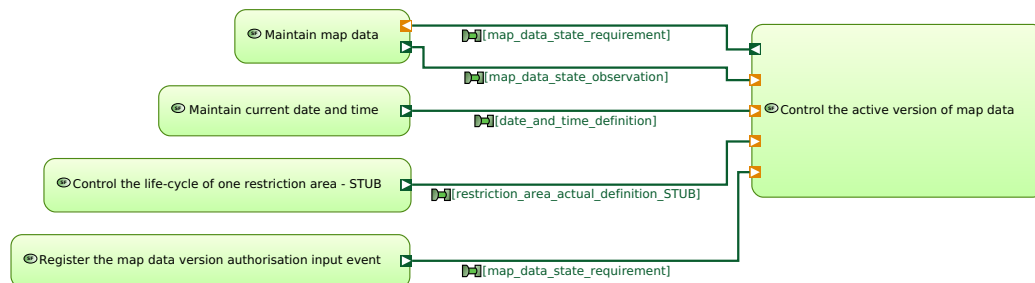
Figure 33: Context of Control the active version of map data

Input	Rationale	From
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to evaluate time constraints of map data activation.	Maintain current date and time
Reported state of map data **Exchange Items:** • map_data_state_observation	To be able to evaluate the current state of map data against the required state of map data.	Maintain map data

Input	Rationale	From
Defined actual state of restriction area - STUB **Exchange Items:** • restriction_area_actual_definition_STUB	To be able to check, if a usage restriction area has been set up around the track area affected by the map update. Map data shall only be updated, if movement of trains is effectively disabled in the affected track area. The update of the Map Data during on-going operations within system RCA is safety critical. To allow a safe and deterministic update of the Map Data, the concerned Map Data section must be protected. The specific track state over the track area has to ensure that, no train movements are performed in the concerned Map Data section during the Update process. Train runs on the unchanged part of the Map Data should however not been affected by the Map Data update in order to provide an improved availability. Refer to RCA goal G7 (Improved performance), Q2 (which leads to the required high availability), RCA.Doc.48, Realisation of RCA Goals.	Control the life-cycle of one restriction area - STUB
Permission of activation of one map data version **Exchange Items:** • map_data_state_requirement	To be able to detect, when a human actor has triggered the update of map data.	Register the map data version authorisation input event

Output	To
Abstract required state of map data **Exchange Items:** • map_data_state_requirement	Maintain map data

6.4.2 Control the door operation state of one train unit

Attribute	Content
Name	Control the door operation state of one train unit
Description	This function controls the door operation state for one train unit, as a combination of the required door position state and the general automation state of the train unit. I.e. the function controls, if the doors need to be open or closed on a particular side of the train unit and if this state needs to be achieved automatically or with help from the driver.
Rationale	To achieve fully automatic driving, controlling the door operation state of train units is needed. The decision making on the door operation state requires inputs from inside the system, hence it is sensible to also facilitate the control inside the system. Also, automation of door operating state control is needed to enable the re-use of older rolling stock. Therefore this function needs to be inside the development scope and inside the system boundary.
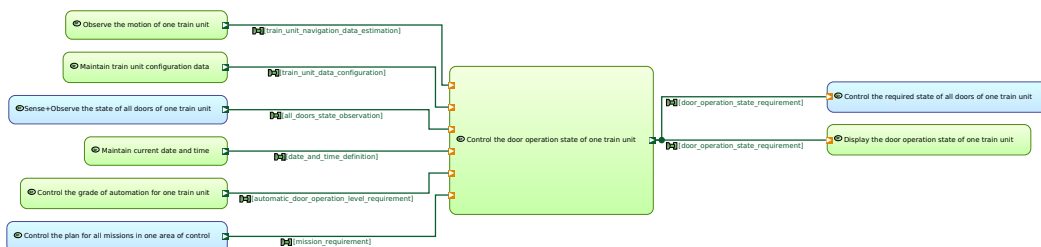
Figure 34: Context of Control the door operation state of one train unit

Input	Rationale	From
Defined train unit configuration data **Exchange Items:** • train_unit_data_configuration	To be able to consider information of available door operation states for that particular train unit.	Maintain train unit configuration data

Input	Rationale	From
Estimated internal state of all doors of one train unit **Exchange Items:** • all_doors_state_observation	To be able to consider the observed state of the train unit's doors and compare to the required state.	Sense+Observe the state of all doors of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to control tim triggered-aspects of door control, e.g. closing the doors before departure.	Maintain current date and time
Abstract required automation state of one train unit **Exchange Items:** • automatic_door_operation_level_requirement	To be able to derive the required door automation state from the actual train unit automation state.	Control the grade of automation for one train unit
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	To be able to derive mission related parameters of door control, e.g. on which side boarding shall be performed and when a train unit needs to depart.	Control the plan for all missions in one area of control
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	To be able to consider position related aspects of door-control, e.g. to compare the actual position of the Train Unit with door operation information in the mission valid for a specific station.	Observe the motion of one train unit

Output	To
Abstract required state of door operation of one train unit **Exchange Items:** • door_operation_state_requirement	Control the required state of all doors of one train unit
Abstract required state of door operation of one train unit **Exchange Items:** • door_operation_state_requirement	Display the door operation state of one train unit

6.4.3 Control the grade of automation for one train unit

Attribute	Content
Name	Control the grade of automation for one train unit
Description	This function controls the grade of automation of one train unit, i.e. this function defines authoritatively the grade of automation of one train unit at any given point in time.
Rationale	The control of the grade of automation of train units is one of the key functionalities to achieve the goal of automatic railway operation. Risk, performance and business considerations require a technical solution for this functionality. Therefore this function needs to be inside the development scope and inside the system boundary.

Figure 35: Context of Control the grade of automation for one train unit

Input	Rationale	From
Estimated internal state of all doors of one train unit **Exchange Items:** • all_doors_state_observation	To be able to consider the actual state of the Train Unit's doors before e.g. engaging automatic driving.	Sense+Observe the state of all doors of one train unit
Estimated internal state of movement direction of one train unit front end **Exchange Items:** • train_unit_front_end_movement_direction_intention	*None*	Observe the intended movement direction relative to the front end of the train unit
Abstract required state of departure authorisation **Exchange Items:** • DMI_engage_button_state	To be able to trigger the engagement of automatic driving by the start command of the driver.	Register the automatic driving engagement input event
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	To be able to consider the current position of the train unit for changes in the grade of automation.	Observe the motion of one train unit
Defined active map data **Exchange Items:** • map_data_definition	To be able to map the information from the mission to the actual position of the train unit.	Maintain map data

Input	Rationale	From
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	To be able to consider, if a permission to move the train unit has been granted.	Control the motion of one train unit
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	To be able to consider different grades of automation along the mission of the Train Unit.	Control the plan for all missions in one area of control
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation	To be able to decide whether a reaction to an obstacle is needed or not, e.g if the automatic departure needs to be suppressed, if an obstacle is detected.	Observe the free space of the track in the field of view of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to consider the current time in time-based decisions, e.g. coming from the mission definition.	Maintain current date and time

Output	To
Abtract required automation state of one train unit **Exchange Items:** • automatic_driving_state_calculation	Display the grade of automation of one train unit
Abtract required automation state of one train unit **Exchange Items:** • automatic_driving_state_calculation	Control the motion of one train unit
Abstract required automation state of one train unit **Exchange Items:** • automatic_door_operation_level_requirement	Control the door operation state of one train unit
Abtract required automation state of one train unit **Exchange Items:** • automatic_door_operation_level_requirement	Display the door operation state of one train unit

6.4.4 Control the life-cycle of one restriction area - STUB

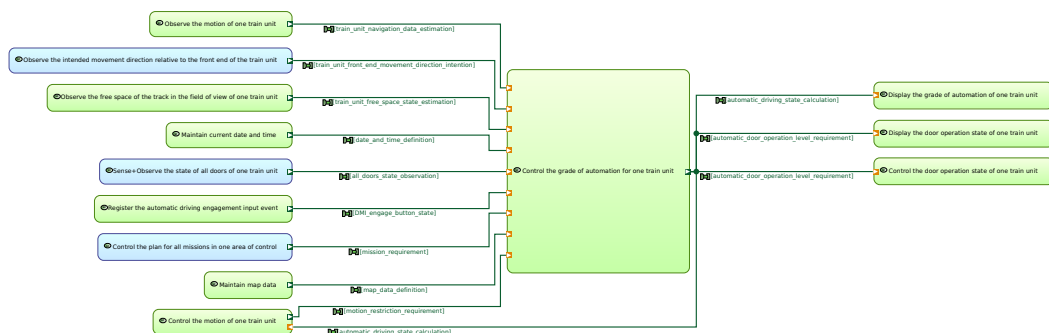| Attribute	Content
Name	Control the life-cycle of one restriction area - STUB
Description	This function controls the creation of, changes to and removal of one restriction area in the area of control to limit the usage of the infrastructure. This function is currently an unfinished stub.
Rationale	Controlling the life-cycle of restriction areas is a key element for assuring the safety of operations in non-regular or degraded situations. Risk, performance and business considerations require a technical solution for this functionality. Therefore this function needs to be inside the development scope and inside the system boundary.

Figure 36: Context of Control the life-cycle of one restriction area - STUB

Input		Rationale	From
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation		To be able to consider detected obstacles to create a usage restriction area.	Observe the free space of the track in the field of view of one train unit
Abstract required state of restriction areas in one area of control - STUB **Exchange Items:** • restriction_area_requirement_STUB		To be able to create usage restriction areas according to planning from the planning system.	Control the plan for restriction areas over time for all tracks in one area of control
Output		**To**	
Defined actual state of restriction area - STUB **Exchange Items:** • restriction_area_actual_definition_STUB		Control the active version of map data	
Defined actual state of restriction area - STUB **Exchange Items:** • restriction_area_actual_definition_STUB		Control the plan for restriction areas over time for all tracks in one area of control	

6.4.5 Control the life-cycle of one warning area

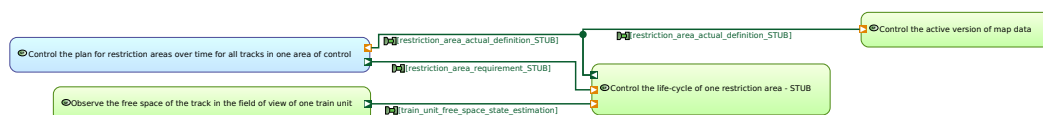| Attribute	Content
Name	Control the life-cycle of one warning area
Description	This function controls the creation of one warning area for track workers in the area of control.
Rationale	Controlling the life-cycle of warning areas is a key element for assuring the safety of track workers on or near the line and also for optimising the management of warning areas. Risk, performance and business considerations require a technical solution for this functionality. Therefore this function needs to be inside the development scope and inside the system boundary.
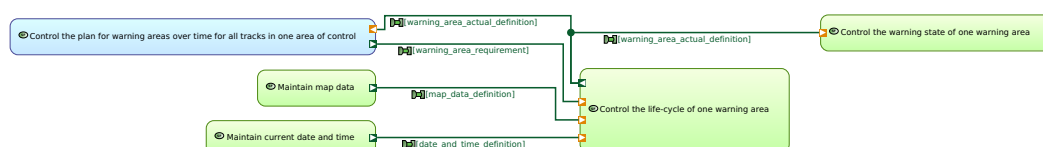
Figure 37: Context of Control the life-cycle of one warning area

Input	Rationale	From
Abstract required state of warning areas in one area of control **Exchange Items:** • warning_area_requirement	To be able to create and remove warning areas according to the plan of the planning system.	Control the plan for warning areas over time for all tracks in one area of control
Defined active map data **Exchange Items:** • map_data_definition	To be able to map planned warning areas to the topology.	Maintain map data
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to create or remove warning areas according to time criteria in the plan from the planning system.	Maintain current date and time

Output		To
Defined actual state of one warning area **Exchange Items:** • warning_area_actual_definition		Control the plan for warning areas over time for all tracks in one area of control
Defined actual state of one warning area **Exchange Items:** • warning_area_actual_definition		Control the warning state of one warning area

6.4.6 Control the motion of one train unit

Attribute	Content
Name	Control the motion of one train unit
Description	This function controls the motion of one train unit by using the mission from the planning system as reference input. It safely restricts and supervises the motion of one train unit to prevent hazardous situations in all grades of automation and automatically drives the train unit in higher grades of automation.

Attribute	Content
Rationale	To fulfil the non-functional requirements (especially safety, reliability, availability and performance) of controlling the motion states of train units, a technical solution to this functionality is inevitably required. Furthermore ,high grades of automation also require a technical realisation of this functionality. Also, this functionality is an fundamental principle of fully automatic railway operation. Therefore, this function needs to be inside the development scope and inside the system boundary.

Figure 38: Context of Control the motion of one train unit

Input	Rationale	From
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation	To be able to restrict the motion of a train unit to a safe location in front of an obstacle and to prevent a collision with obstacles.	Observe the free space of the track in the field of view of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to execute the mission according to the time constraints defined therein.	Maintain current date and time
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	To be able to control the motion of the Train Unit according to the mission plan of the planning system, all missions as input are needed. This functions filters for the relevant mission.	Control the plan for all missions in one area of control

Input	Rationale	From
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	To be able to consider the actual position of this train unit in the control decisions for the train unit, and also to take the position of all other train units into account to avoid train collisions.	Observe the motion of one train unit
Abtract required automation state of one train unit **Exchange Items:** • automatic_driving_state_calculation	To be able to control the motion state of the train unit according to the current grade of automation, e.g. to actively control the motion in higher grade vs. pure supervision in lower levels, the required automation state is needed.	Control the grade of automation for one train unit
Defined active map data **Exchange Items:** • map_data_definition	To be able to map current train position and mission requirement as well as process all relevant topology parameters (e.g. maximum permitted speed), map data is needed.	Maintain map data
Defined train unit configuration data of one train unit **Exchange Items:** • train_unit_data_configuration	To be able to take limitations of the train unit into account, e.g. top speed, lauding gauge and energy supply, train unit configuration data is needed.	Maintain train unit configuration data

Input	Rationale	From
Abstract required state of motion restriction of one train unit (reflexive) **Exchange Items:** • motion_restriction_requirement	To be able to take the permitted movements of other train units into account to avoid simultaneous granting movement permission into a track area already granted to some other train unit.	Duplicated instance of function 'Control the motion of one train unit'

Output	To
Abstract required state of emergency brake intervention **Exchange Items:** • emergency_brake_requirement	Control the traction and brake effort of one train unit
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	Display the restrictions to the motion of one train unit
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	Control the position of one point
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	Control the grade of automation for one train unit
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	Observe the free space of the track in the field of view of one train unit
Abstract required state of motion restriction of one train unit (reflexive) **Exchange Items:** • motion_restriction_requirement	Duplicated instance of function 'Control the motion of one train unit'

Output	To
Abstract required state of traction-level and brake effort of one train unit **Exchange Items:** • relative_traction_braking_effort_level_requirement	Control the traction and brake effort of one train unit
Defined actual motion state plan over time **Exchange Items:** • motion_state_over_time_plan	Control the plan for all missions in one area of control

6.4.7 Control the position of one point

Attribute	Content
Name	Control the position of one point
Description	This function controls the position of one point by using the mission from the planning system as reference input. It sets the point to the correct position needed for the mission at the correct point in time. Controlling the required point position state is done safely to prevent hazardous situations.
Rationale	To fulfil the non-functional requirements (especially safety, reliability, availability and performance) of controlling the position state of a point, a technical solution to this functionality is inevitably required. Also, this functionality is a fundamental principle of automatic railway operation. Therefore, this function needs to be inside the development scope and inside the system boundary.
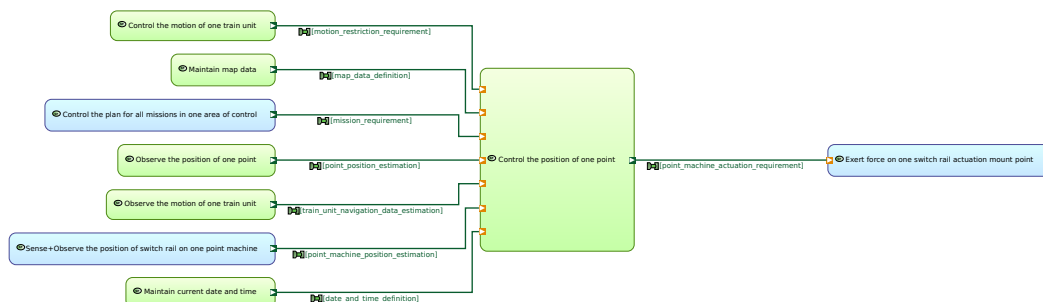
Figure 39: Context of Control the position of one point

Input	Rationale	From
Defined active map data **Exchange Items:** • map_data_definition	To be able to match the current position of train units to the extent of the point to avoid setting a point while a train unit is on it.	Maintain map data

Input	Rationale	From
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	To be able to derive the required state of the point necessary for the mission.	Control the plan for all missions in one area of control
Estimated internal state of point position **Exchange Items:** • point_position_estimation	To be able to compare the required position of the point according to the mission to the actual position of the point.	Observe the position of one point
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	To be able to match the current position of train units to the extent of the point to avoid setting a point while a train unit is on it.	Observe the motion of one train unit
Estimated internal state of point machine position **Exchange Items:** • point_machine_position_estimation	To be able to control the exact motion of the point machine according to the constraint of using the electrical 4-wire interface.	Sense+Observe the position of switch rail on one point machine
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to set the point position at the correct time as required by the mission.	Maintain current date and time
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	To be able to check, if a granted movement is extending over this point and hence locking it against position changes. There is one input of this type for this function per train unit in the area of control.	Control the motion of one train unit

Output	To
Plant external required input state of point machine position **Exchange Items:** • point_machine_actuation_requirement	Exert force on one switch rail actuation mount point

6.4.8 Control the train unit warning devices

Attribute	Content
Name	Control the train unit warning devices
Description	This function determines, based on the assessment of the free space state in front of a train unit, if the warning device like the train horn needs to be activated to warn an obstacle (e.g. person) on or near the line. Operational rules and EN 15153-1:2020-03 are taken into account.
Rationale	To fulfil the non-functional requirements (especially safety, reliability, availability and performance) of fully automatic railway operation, the system needs to fulfil the task of warning obstacles (e.g. persons) on or near the line of an approaching train unit. Therefore, this function needs to be inside the development scope and inside the system boundary.
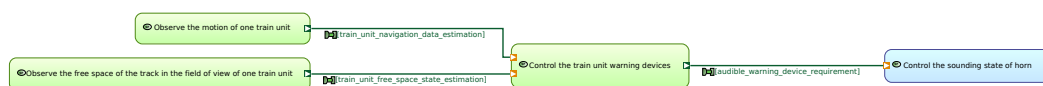
Figure 40: Context of Control the train unit warning devices

Input	Rationale	From
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation	To be able to decide whether a reaction to an obstacle is needed or not.	Observe the free space of the track in the field of view of one train unit

Input	Rationale	From
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	To be able to relate the position of an obstacle to the actual position of the train unit so that an assessment of the situation can be performed.	Observe the motion of one train unit

Output		To
Abstract required state of one train unit warning device **Exchange Items:** • audible_warning_device_requirement		Control the sounding state of horn

6.4.9 Control the warning state of one warning area

Attribute	Content
Name	Control the warning state of one warning area
Description	This function controls for any point in time, if warning devices for a Warning Area need to issue a warning for track workers or not, depending on the position of train units and planned missions.
Rationale	To fulfil the non-functional requirements (especially safety, reliability, availability and performance) for warning of track workers, a technical solution to the control aspect of this functionality is inevitably required. Also, the calculation of the optimal point in time for issuing a warning is better done centrally inside the System RCA based on all available information. Therefore, this function needs to be inside the development scope and inside the system boundary.

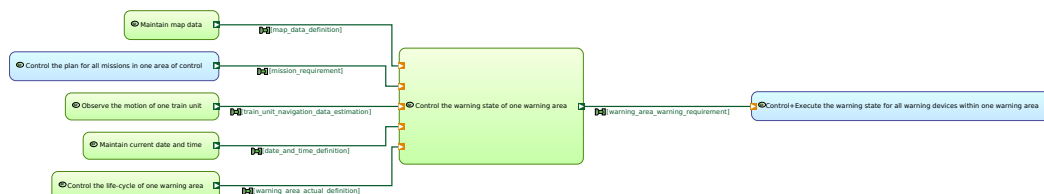**Figure 41: Context of Control the warning state of one warning area**

Input	Rationale	From
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	To be able to consider all planned missions that are using the tracks in the warning area.	Control the plan for all missions in one area of control
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	To be able to precisely activate the warning devices at the correct pre-warning time by knowing the time at which the train has reached a location that is equivalent to the required pre-warning time.	Observe the motion of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to precisely activate the warning devices at the correct pre-warning time.	Maintain current date and time
Defined actual state of one warning area **Exchange Items:** • warning_area_actual_definition	To be able to consider the actual status of the warning area for controlling the required state.	Control the life-cycle of one warning area
Defined active map data **Exchange Items:** • map_data_definition	To be able to match the estimated position of train units to the extent of the Warning Area.	Maintain map data

Output	To
Abstract required state of warning for one warning area **Exchange Items:** • warning_area_warning_requirement	Control+Execute the warning state for all warning devices within one warning area

6.4.10 Display the current activation state of map data

Attribute	Content
Name	Display the current activation state of map data
Description	This function displays the current activation state of the Map Data on the HMI for the Infrastructure Manager by rendering the system internal state into a human readable format.
Rationale	*None*
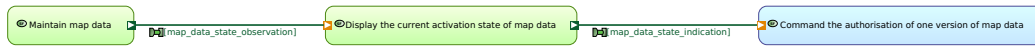
Figure 42: Context of Display the current activation state of map data

Input	Rationale	From
Reported state of map data **Exchange Items:** • map_data_state_observation	To be able to display the current activation state to a human actor, this internal state is needed.	Maintain map data

Output	To	
Human perceptable state of map data **Exchange Items:** • map_data_state_indication	Command the authorisation of one version of map data	

6.4.11 Display the door operation state of one train unit

Attribute	Content
Name	Display the door operation state of one train unit
Description	This function indicates the door operation state of one train unit on the DMI for the Driver by rendering the system internal state into a human readable format
Rationale	It has been defined that the DMI between the system and the driver shall be realised according to the ERA_ERTMS_015560, hence all internal states must be displayed according to this subset. This includes the door operation state of the train unit. Furthermore, the improvement of the integration of the DMI into the system is part of the development task. Therefore this function needs to be inside the development scope and inside the system boundary.

Figure 43: Context of Display the door operation state of one train unit

Input	Rationale	From
Abstract required state of door operation of one train unit **Exchange Items:** • door_operation_state_requirement	To be able to display the required state of the door operation to a human actor, this internal state is needed.	Control the door operation state of one train unit
Estimated internal state of all doors of one train unit **Exchange Items:** • all_doors_state_observation	To be able to display the estimated (i.e. current actual) state of the doors to a human actor, this internal state is needed.	Sense+Observe the state of all doors of one train unit
Abtract required automation state of one train unit **Exchange Items:** • automatic_door_operation_level_requirement	To be able to display the general automation state of the train unit to a human actor, this internal state is needed.	Control the grade of automation for one train unit

Output	To
Human perceptible state of all doors of one train unit **Exchange Items:** • door_operation_state_indication	Command the requested state of all doors of one train unit

6.4.12 Display the grade of automation of one train unit

Attribute	Content
Name	Display the grade of automation of one train unit
Description	This function displays the current grade of automation of one train unit on the DMI for the Train Driver by rendering the system internal state into a human readable format.

Attribute	Content
Rationale	It has been defined that the DMI between the system and the driver shall be realised according to the ERA_ERTMS_015560, hence all internal states must be displayed according to this subset. This includes the door operation state of the train unit. Furthermore, the improvement of the integration of the DMI into the system is part of the development task. Therefore this function needs to be inside the development scope and inside the system boundary.

Figure 44: Context of Display the grade of automation of one train unit

Input	Rationale	From
Abtract required automation state of one train unit **Exchange Items:** • automatic_driving_state_calculation	To be able to display the required automation state of the train unit to the driver, this internal state is needed.	Control the grade of automation for one train unit

Output	To
Human perceptible state of automatic driving **Exchange Items:** • automatic_driving_state_indication	Authorise the departure of one train unit
Human perceptible state of automatic driving **Exchange Items:** • automatic_driving_state_indication	Decide about intervention into train unit movement

6.4.13 Display the position of one point

Attribute	Content
Name	Display the position of one point
Description	This function displays the position of one point on the HMI for the Operations Manager by rendering the system internal state into a human readable format.
Rationale	*None*
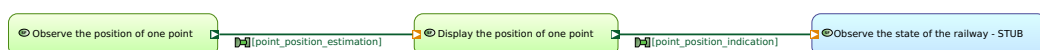
Figure 45: Context of Display the position of one point

Input	Rationale	From
Estimated internal state of point position **Exchange Items:** • point_position_estimation	To be able to display the position state of one point to a human actor, this internal state is needed.	Observe the position of one point

Output		To
Human perceptable state of point position **Exchange Items:** • point_position_indication		Observe the state of the railway - STUB

6.4.14 Display the remaining dwell time of one train unit

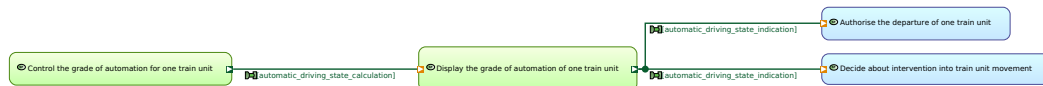| Attribute	Content
Name	Display the remaining dwell time of one train unit
Description	This functions displays the remaining dwell time on the DMI for the Train Driver by rendering the system internal state into a human readable format.
Rationale	It has been defined that the DMI between the system and the driver shall be realised according to the ERA_ERTMS_015560, hence all internal states must be displayed according to this subset. This includes the door operation state of the train unit. Furthermore, the improvement of the integration of the DMI into the system is part of the development task. Therefore this function needs to be inside the development scope and inside the system boundary.

Figure 46: Context of Display the remaining dwell time of one train unit

Input	Rationale	From
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	To be able to display the remaining dwell time, the information on all mission plans is needed. The display functions filters the correct mission.	Control the plan for all missions in one area of control
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to display the dwell time as a relative time, the actual time is needed.	Maintain current date and time

Output	To
Human perceptible state of remaining dwell time of one train unit **Exchange Items:** • remaining_dwell_time_indication	Command the requested state of all doors of one train unit

6.4.15 Display the restrictions to the motion of one train unit

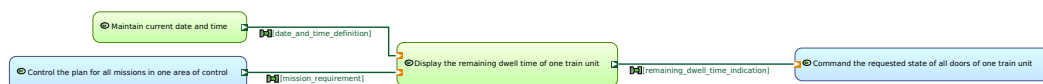| Attribute	Content
Name	Display the restrictions to the motion of one train unit
Description	This functions displays the restrictions to the motion of one Train Unit (i.e. allowed distance to run and allowed speed profile) on the DMI for the Train Driver by rendering the system internal state into a human readable format.
Rationale	It has been defined that the DMI between the system and the driver shall be realised according to the ERA_ERTMS_015560, hence all internal states must be displayed according to this subset. This includes the door operation state of the train unit. Furthermore, the improvement of the integration of the DMI into the system is part of the development task. Therefore this function needs to be inside the development scope and inside the system boundary.

Figure 47: Context of Display the restrictions to the motion of one train unit

Input	Rationale	From
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	To be able to display the restrictions of motion to the driver (i.e. how far and fast the train is allowed to move), this internal state is needed.	Control the motion of one train unit

Output	To
Human perceptible state of restrictions on the movement of one train unit **Exchange Items:** • movement_authority_indication	Command the requested state of all doors of one train unit

Output	To
Human perceptible state of restrictions on the movement of one train unit **Exchange Items:** • movement_authority_indication	Decide about intervention into train unit movement

6.4.16 Duplicated instance of function 'Control the motion of one train unit'

Attribute	Content
Name	Duplicated instance of function 'Control the motion of one train unit'
Description	This function represents all other instances of the function "Control the motion of one train unit".
Rationale	To fulfil the non-functional requirements (especially safety, reliability, availability and performance) of controlling the motion states of train units, a technical solution to this functionality is inevitably required. Furthermore ,high grades of automation also require a technical realisation of this functionality. Also, this functionality is an fundamental principle of fully automatic railway operation. Therefore, this function needs to be inside the development scope and inside the system boundary. To be able to protect train unit movements from each other, each instance of the function "Control the motion of one train unit" needs to know the granted movements for all other Train Units. This is represented by this function and the connections of functional exchanges.

Figure 48: Context of Duplicated instance of function 'Control the motion of one train unit'

Input	Rationale	From
Abstract required state of motion restriction of one train unit (reflexive) **Exchange Items:** • motion_restriction_requirement	To be able to check for conflicts between granted movements, the output of all instances of the function "Control the motion state of one Train Unit" must be fed as input to all other instances.	Control the motion of one train unit

Output	To
Abstract required state of motion restriction of one train unit (reflexive) **Exchange Items:** • motion_restriction_requirement	Control the motion of one train unit

6.4.17 Maintain current date and time

Attribute	Content
Name	Maintain current date and time
Description	This function maintains the current data and time as the single reference.
Rationale	Using different sources of date and time for different functions inside the system can lead to problems, especially for time critical functions and for correlation of events across the system. Hence all functions needing date and time information should be fed from one source. As a connection to external date and time references is not always feasible, an internal maintain function is needed. Therefore this function needs to be inside the development scope and inside the system boundary. Note: this function is dependent on an external definition of date and time.
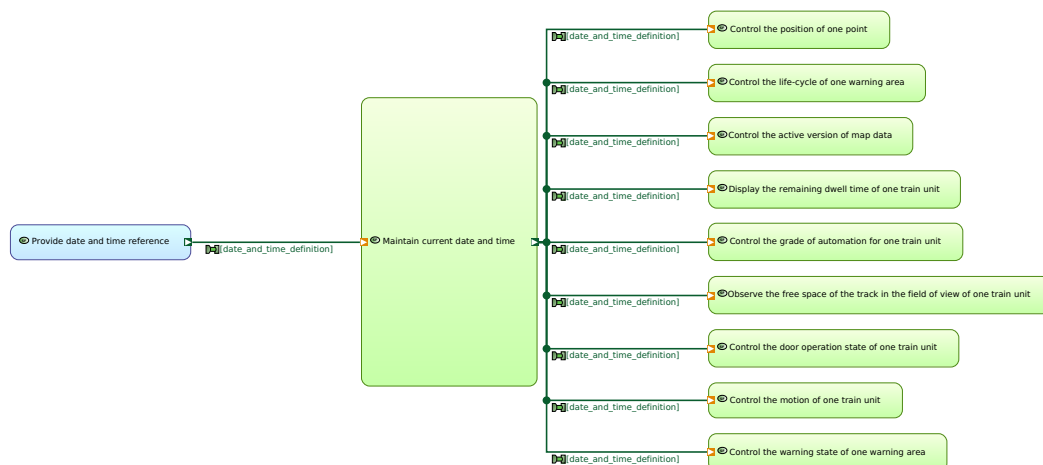
Figure 49: Context of Maintain current date and time

Input	Rationale	From
Provided date and time **Exchange Items:** • date_and_time_definition	To be able to provide the current time to all other functions, this functions needs an input from an external time source.	Provide date and time reference

Output	To
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Control the motion of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Control the warning state of one warning area
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Control the position of one point
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Control the active version of map data
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Observe the free space of the track in the field of view of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Control the door operation state of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Control the grade of automation for one train unit

Output	To
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Control the life-cycle of one warning area
Estimated internal state of time **Exchange Items:** • date_and_time_definition	Display the remaining dwell time of one train unit

6.4.18 Maintain map data

Attribute	Content
Name	Maintain map data
Description	This function acts as a reference of Map Data for all other relevant functions inside the system boundary. It can maintain multiple versions of Map Data, but only provides one active version of Map Data to other functions at any given point in time. Switching between versions is controlled by the function Control the life-cycle of map data.
Rationale	Nearly all functionality of the system is dependent on map data. Hence all relevant functions of the system must be provided with consistent map data, as otherwise severe PRAMS implications are to be expected. It must also be possible to change map data, e.g. as consequence of changes to the track layout, with only minimal interruptions of operations. A consistent distribution of map data is therefore a key functionality of the system. Therefore this function needs to be inside the development scope and inside the system boundary.
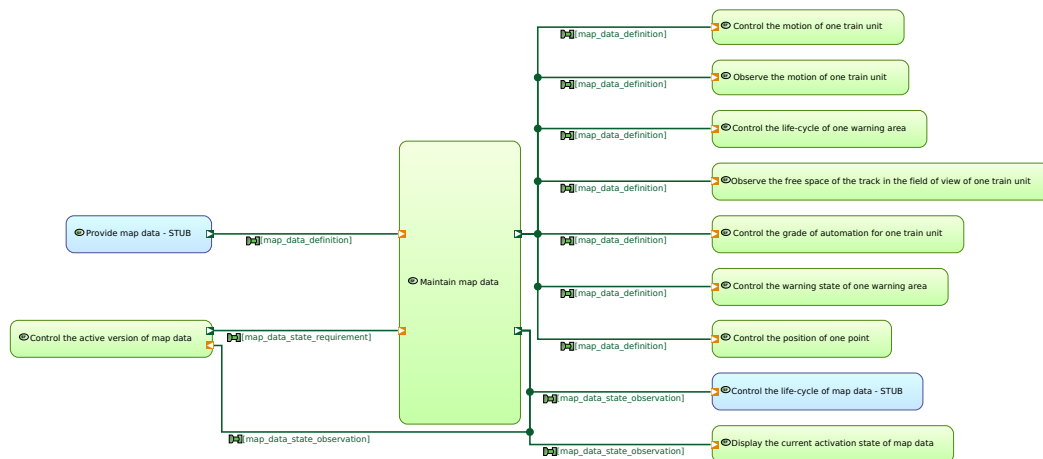
Figure 50: Context of Maintain map data

Input	Rationale	From
Abstract required state of map data **Exchange Items:** • map_data_state_requirement	To be able to maintain the correct version of map data at any point in time, this functions needs the control input that defines, which version of map data shall be distributed to consuming functions.	Control the active version of map data
Provided map data **Exchange Items:** • map_data_definition	To be able to maintain the map data to all consuming functions, this functions needs an external input of the map data from an actor.	Provide map data - STUB
Output	**To**	
Reported state of map data **Exchange Items:** • map_data_state_observation	Display the current activation state of map data	
Reported state of map data **Exchange Items:** • map_data_state_observation	Control the life-cycle of map data - STUB	
Reported state of map data **Exchange Items:** • map_data_state_observation	Control the active version of map data	

Output	To
Defined active map data **Exchange Items:** • map_data_definition	Control the position of one point
Defined active map data **Exchange Items:** • map_data_definition	Control the grade of automation for one train unit
Defined active map data **Exchange Items:** • map_data_definition	Observe the free space of the track in the field of view of one train unit
Defined active map data **Exchange Items:** • map_data_definition	Observe the motion of one train unit
Defined active map data **Exchange Items:** • map_data_definition	Control the motion of one train unit
Defined active map data **Exchange Items:** • map_data_definition	Control the life-cycle of one warning area
Defined active map data **Exchange Items:** • map_data_definition	Control the warning state of one warning area

6.4.19 Maintain train unit configuration data

Attribute	Content
Name	Maintain train unit configuration data
Description	This function acts as a reference of train unit configuration data for all other relevant functions inside the system boundary.

Attribute	Content
Rationale	Nearly all train unit related functionality of the system is dependent on train unit configuration data. Hence all relevant functions of the system must be provided with consistent train unit configuration data, as otherwise severe PRAMS implications are to be expected. A consistent distribution of train unit configuration data is therefore a key functionality of the system. Therefore this function needs to be inside the development scope and inside the system boundary.
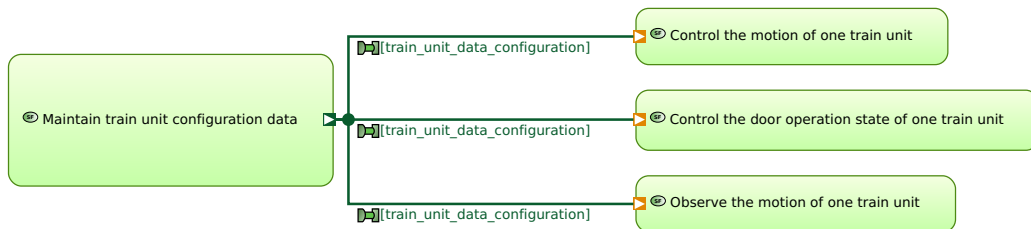
Figure 51: Context of Maintain train unit configuration data

Input	Rationale	From
No inputs defined		

Output	To
Defined train unit configuration data **Exchange Items:** • train_unit_data_configuration	Control the door operation state of one train unit
Defined train unit configuration data **Exchange Items:** • train_unit_data_configuration	Observe the motion of one train unit
Defined train unit configuration data of one train unit **Exchange Items:** • train_unit_data_configuration	Control the motion of one train unit

6.4.20 Observe the free space of the track in the field of view of one train unit

Attribute	Content
Name	Observe the free space of the track in the field of view of one train unit

Attribute	Content
Description	This function observes the free space of the track in the field of view in front of one train unit. Based on the sensor inputs, the function analyses and evaluates, if or if not and if, what objects are inside in the free space in front of the train unit.
Rationale	To be able to protect train unit from collision with obstacles, observing the free space state is a key functionality for fully automatic railway operation which is not available off the shelf yet but needs to be performed by the system. Therefore, this function needs to be inside the development scope and inside the system boundary.
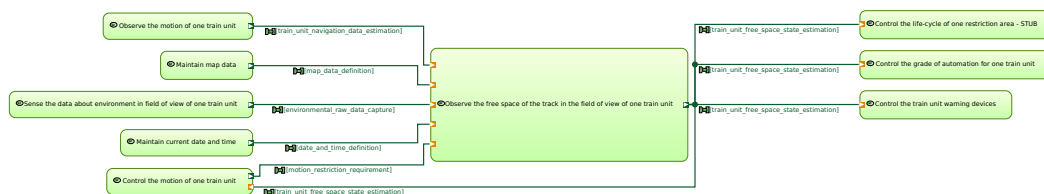
**Figure 52: Context of Observe the free space of the track in the field of view of one train unit**

Input	Rationale	From
Sensed output state of environmental raw data **Exchange Items:** • environmental_raw_data_capture	To be able to observe the free space state in front of the train unit, this functions needs the data from the sensors perceiving the field of vision.	Sense the data about environment in field of view of one train unit
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	To be able to correlate the position of obstacles to the navigation data of the train unit, this function needs the estimated motion state of the train unit.	Observe the motion of one train unit
Estimated internal state of time **Exchange Items:** • date_and_time_definition	To be able to assess the motion path of obstacles, this function needs the current time, e.g. for time stamping of obstacle positions.	Maintain current date and time

Input	Rationale	From
Defined active map data **Exchange Items:** • map_data_definition	To be able to asses the criticality of obstacles, this functions needs to know the map data, e.g. defined risk zones and track topography.	Maintain map data
Abstract required state of motion restriction of one train unit **Exchange Items:** • motion_restriction_requirement	To be abale to ensure that the free space state is observed for the correct track, the allowed/required speed over distance is needed.	Control the motion of one train unit

Output	To
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation	Control the motion of one train unit
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation	Control the train unit warning devices
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation	Control the life-cycle of one restriction area - STUB
Estimated internal free space state field of view of one train unit **Exchange Items:** • train_unit_free_space_state_estimation	Control the grade of automation for one train unit

6.4.21 Observe the motion of one train unit

Attribute	Content
Name	Observe the motion of one train unit

Attribute	Content
Description	This function combines multiple sensory inputs to derive an observation of the estimated motion of the train unit. This includes the occupation of topology by the train unit and all of its relevant navigation parameters.
Rationale	To ensure the safe train operation the navigation data of train units is needed for nearly all operational functionality of the system. Knowing the position, speed and acceleration of train units is required to close the control loops, while heading information is required for obstacle detection. The PRAMSS requirements enforce a technical solution for this function, also this function will be realised by a complex combination of different interacting technologies. Therefore this function needs to be inside the development scope and inside the system boundary.
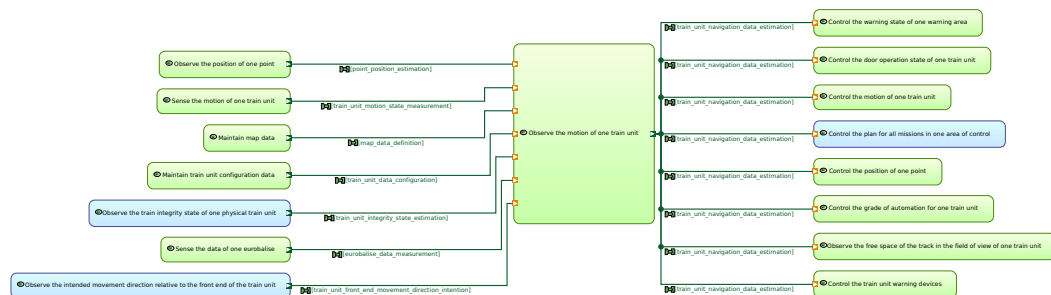
Figure 53: Context of Observe the motion of one train unit

Input	Rationale	From
Sensed output state of train units motion **Exchange Items:** • train_unit_motion_state_measurement	To be able to have observable physical data available for the observation (e.g. speed, distance,...).	Sense the motion of one train unit
Defined active map data **Exchange Items:** • map_data_definition	To be able to determine the navigation data into relation with the topology.	Maintain map data
Defined train unit configuration data **Exchange Items:** • train_unit_data_configuration	To be able to estimate the safe train length / Safe Train Unit Rear End.	Maintain train unit configuration data

Input	Rationale	From
Estimated internal state of train integrity **Exchange Items:** • train_unit_integrity_state_estimation	To be able to estimate the safe train length / Safe Train Unit Rear End.	Observe the train integrity state of one physical train unit
Sensed output state of eurobalise data **Exchange Items:** • eurobalise_data_measurement	To be able to estimate the train unit navigation data in relation to a referenceon point.	Sense the data of one eurobalise
Estimated internal state of movement direction of one train unit front end **Exchange Items:** • train_unit_front_end_movement_direction_intention	To be able to determine which end of a train unit is considered the Front End, i.e. the end, the train unit intends to move towards.	Observe the intended movement direction relative to the front end of the train unit
Estimated internal position state of one point **Exchange Items:** • point_position_estimation	To be able to locate the positions of both ends of a train unit track-selectively on the topology, if the train unit on the track edge has not yet been updated by passing a reference point.	Observe the position of one point

Output	To
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Observe the free space of the track in the field of view of one train unit
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Control the train unit warning devices
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Control the warning state of one warning area
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Control the motion of one train unit
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Control the position of one point
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Control the grade of automation for one train unit
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Control the plan for all missions in one area of control

Output	To
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Control the door operation state of one train unit

6.4.22 Observe the position of one point

Attribute	Content
Name	Observe the position of one point
Description	This function uses observations from one or more Point Machines to derive an observation of the estimated position of one point.
Rationale	To ensure the safe train operation, the position state of points is needed for the guideway control functionality of the system. The PRAMSS requirements enforce a technical solution for this function. Therefore this function needs to be inside the development scope and inside the system boundary.
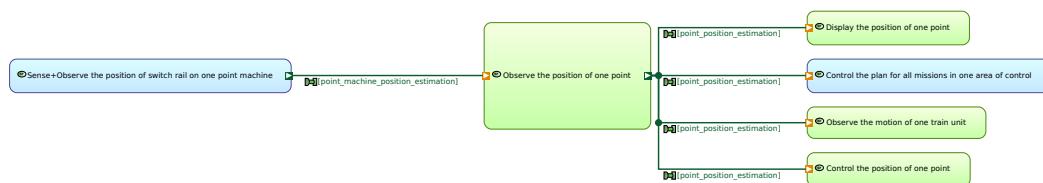
Figure 54: Context of Observe the position of one point

Input	Rationale	From
Estimated internal state of point machine position **Exchange Items:** • point_machine_position_estimation	To be able to observe the position state of one point, this function needs information about the position of the switch rail on one point machine for all point machines of the point.	Sense+Observe the position of switch rail on one point machine

Output	To
Estimated internal position state of one point **Exchange Items:** • point_position_estimation	Observe the motion of one train unit

Output	To
Estimated internal state of point position **Exchange Items:** • point_position_estimation	Control the position of one point
Estimated internal state of point position **Exchange Items:** • point_position_estimation	Display the position of one point
Estimated internal position state of point **Exchange Items:** • point_position_estimation	Control the plan for all missions in one area of control

6.4.23 Register the automatic driving engagement input event

Attribute	Content
Name	Register the automatic driving engagement input event
Description	This function registers the DMI input for engaging the automatic driving of a train unit from the driver and transforms it into a continuous input state requirement for the automatic driving engagement state inside the system.
Rationale	Optimising the DMI is part of the development task, hence the DMI needs to be part of the system. Therefore, this function needs to be inside the development scope and inside the system boundary.
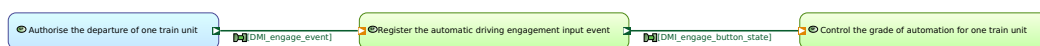
Figure 55: Context of Register the automatic driving engagement input event

Input	Rationale	From
Abstract required state of departure authorisation **Exchange Items:** • DMI_engage_event	To be able to derive the required state of the departure observation, this function needs to register the input event triggered by a human actor on an HMI.	Authorise the departure of one train unit

Output	To
Abstract required state of departure authorisation **Exchange Items:** • DMI_engage_button_state	Control the grade of automation for one train unit

6.4.24 Register the map data version authorisation input event

Attribute	Content
Name	Register the map data version authorisation input event
Description	This function registers the HMI input for authorising a map data version change from the Infrastructure Manager (IM) and transforms it into a continuous input state requirement for the map data version authrisation state inside the system.
Rationale	*None*
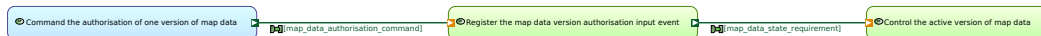
Figure 56: Context of Register the map data version authorisation input event

Input	Rationale	From
Permission of activation of one map data version **Exchange Items:** • map_data_authorisation_command	To be able to determine the internal state of the permission to activate a specific version of the map data, this function needs to register the input event triggered by a human actor on an HMI.	Command the authorisation of one version of map data

Output	To
Permission of activation of one map data version **Exchange Items:** • map_data_state_requirement	Control the active version of map data

6.4.25 Sense the data about environment in field of view of one train unit

Attribute	Content
Name	Sense the data about environment in field of view of one train unit
Description	This function captures abstract information on the spatial properties of the Environment in the field of view of one Train Unit.

Attribute	Content
Rationale	To react to obstacles on or near the line in fully automated driving, spatial awareness of the environment in front of a train unit is needed. Capturing the necessary data is a key functionality which is not available off the shelf in the railway domain yet. Therefore this function needs to be inside the development scope and inside the system boundary.
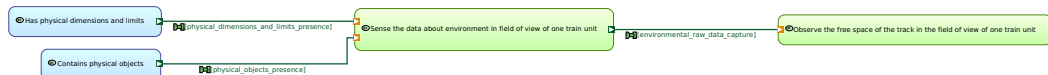
Figure 57: Context of Sense the data about environment in field of view of one train unit

Input	Rationale	From
Present actual output of objects in field of view of one train unit **Exchange Items:** • physical_objects_presence	To be able to sense the data about the environment, this function needs to be able to get input about structural features of the environment.	Contains physical objects
Present actual output of dimensions and limits in field of view of one train unit **Exchange Items:** • physical_dimensions_and_limits_presence	*None*	Has physical dimensions and limits

Output		To
Sensed output state of environmental raw data **Exchange Items:** • environmental_raw_data_capture		Observe the free space of the track in the field of view of one train unit

6.4.26 Sense the data of one eurobalise

Attribute	Content
Name	Sense the data of one eurobalise
Description	Depending on the proximity of the Physical Train Unit (PTU) to a particular Eurobalise (EUB), this function senses the data transmitted from one Eurobalise (EUB) while passing.

Attribute	Content
Rationale	This function is needed to update the reference coordinate system for position observation of the train unit front end. As this cannot feasibly be done manually, a technical solution is necessary. Therefore, this function needs to be inside the development scope and inside the system boundary.

Figure 58: Context of Sense the data of one eurobalise

Input	Rationale	From
Transmitted balise data **Exchange Items:** • eurobalise_telegram	To be able to sense the data content of one Eurobalise, this functions needs an input from the actual Eurobalise actor. This input represents the airgap Eurobalise-interface towards the system.	Transmit eurobalise static information

Output		To
Sensed output state of eurobalise data **Exchange Items:** • eurobalise_data_measurement		Observe the motion of one train unit

6.4.27 Sense the motion of one train unit

Attribute	Content
Name	Sense the motion of one train unit
Description	This function exploits different physical principles to sense the actual motion of one Train Unit.
Rationale	To observe the position of a train unit, the system requires sensor input. Existing sensor functionality, however, does not meet the requirements for the intended allocation of functionality to track side or onboard side. Also the required range of functionality, e.g. precise absolute positioning, is not readily available. Therefore this function needs to be inside the development scope and inside the system boundary.
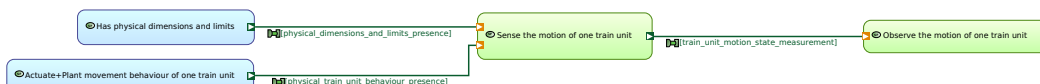
Figure 59: Context of Sense the motion of one train unit

Input		Rationale	From
Plant actual output state of train unit motion **Exchange Items:** • physical_train_unit_behaviour_presence		To be able to sense the motion properties of one train unit, this functions needs input about the actual plant behaviour of the train unit.	Actuate+Plant movement behaviour of one train unit
Present actual output of dimensions and limits in field of view of one train unit **Exchange Items:** • physical_dimensions_and_limits_presence		To be able to sense motion parameters of the Train Unit, some of them in relation to the environment.	Has physical dimensions and limits
Output		**To**	
Sensed output state of train units motion **Exchange Items:** • train_unit_motion_state_measurement		Observe the motion of one train unit	

6.5 Actor functions

In this chapter, all actor functions defined and described by the following aspects:

- List of the attributes of the actor function.
- A functions context diagram, showing the relationship between the actor function under consideration and other functions, including the functional exchanges.

6.5.1 Actuate+Plant behaviour of all doors of one train unit

Attribute	Content
Name	Actuate+Plant behaviour of all doors of one train unit
Description	This function represents the functionality that actually actuates the doors of one train unit and also the mechanical behaviour of the moveable parts of the train unit doors.
Rationale	The actuation and also the mechanical behaviour of the doors of one train unit are long-established aspects inside the railway domain and are not going to be significantly changed due to the automation of railway operation. Therefore, they do need to be part of the development scope and can allocated to actors Physical Train Unit (PTU) outside of the system boundary. Aso, the plant behaviour cannot be part of the system itself.
Actor	Physical Train Unit (PTU)

Figure 60: Context of Actuate+Plant behaviour of all doors of one train unit

Input	From
Plant external required input state of one train units doors **Exchange Items:** *None*	Control the required state of all doors of one train unit
Output	**To**
Plant actual output state of all doors of one train unit **Exchange Items:** *None*	Sense+Observe the state of all doors of one train unit

6.5.2 Actuate+Plant movement behaviour of one train unit

Attribute	Content
Name	Actuate+Plant movement behaviour of one train unit
Description	This function represents the functionality of a train unit to actuate traction and brake efforts as well as the resulting plant behaviour.
Rationale	The actuation of traction and brake effort to achieve the train unit motion are long-established technologies and are not going to be significantly changed due to the automation of railway operation. Therefore, they do not need to be part of the development scope and can be allocated to actor Physical Train Unit (PTU) outside of the system boundary. Also, the plant behaviour cannot be part of the system itself.
Actor	Physical Train Unit (PTU)

Figure 61: Context of Actuate+Plant movement behaviour of one train unit

Input	From
Plant external required input state of movement **Exchange Items:** *None*	Control the traction and brake effort of one train unit
Output	**To**
Plant actual output state of train unit motion **Exchange Items:** • physical_train_unit_behaviour_presence	Sense the motion of one train unit

6.5.3 Authorise the departure of one train unit

Attribute	Content
Name	Authorise the departure of one train unit
Description	This function represents the responsability to validate, if all conditions are fulfilled to engage the departure of the train unit according to the rules of GoA2 operation.
Rationale	In GoA2 operation the Train Driver is responsible for assuring that a train unit movement can be safely engaged. Hence, this responsibility becomes a function of the actor and cannot be inside the system boundary.
Actor	Train Driver
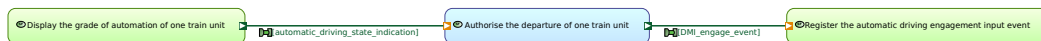
Figure 62: Context of Authorise the departure of one train unit

Input	From
Human perceptible state of automatic driving **Exchange Items:** • automatic_driving_state_indication	Display the grade of automation of one train unit
Output	**To**
Abstract required state of departure authorisation **Exchange Items:** • DMI_engage_event	Register the automatic driving engagement input event

6.5.4 Command the authorisation of one version of map data

Attribute	Content
Name	Command the authorisation of one version of map data
Description	This function represents the responsibility of the Infrastructure Manager to command the authorisation of one version of the map data, according to the rules for infrastructure changes and construction works.

Attribute	Content
Rationale	The Infrastructure Manager is responsible for ensuring that the changes to the actual railway infrastructure has been built as per plan and is ready to be operated. Hence, this responsibility becomes a function of the actor and cannot be inside the system boundary.
Actor	Infrastructure Manager (IM)
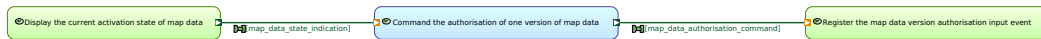
Figure 63: Context of Command the authorisation of one version of map data

Input	From
Human perceptible state of map data **Exchange Items:** • map_data_state_indication	Display the current activation state of map data

Output	To
Permission of activation of one map data version **Exchange Items:** • map_data_authorisation_command	Register the map data version authorisation input event

6.5.5 Command the requested state of all doors of one train unit

Attribute	Content
Name	Command the requested state of all doors of one train unit
Description	This function represents the responsibility of the Train Driver to command the required door state of the Physical Train Unit (PTU), according to the operational situation and the operational rules and inputs from the DMI.
Rationale	In GoA2 operation with manual door operation by the driver, the Train Driver is responsible for assuring that the correct door status is commanded. Hence this responsibility becomes a function of the actor and cannot be inside the system boundary.
Actor	Train Driver
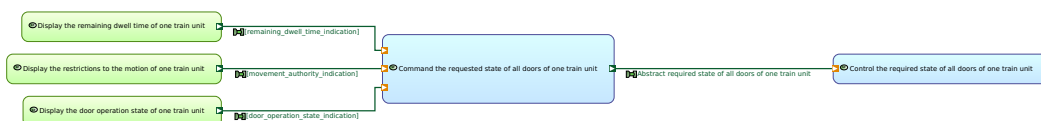
**Figure 64: Context of Command the requested state of all doors of one train unit**

Input	From
Human perceptible state of all doors of one train unit **Exchange Items:** • door_operation_state_indication	Display the door operation state of one train unit
Human perceptible state of restrictions on the movement of one train unit **Exchange Items:** • movement_authority_indication	Display the restrictions to the motion of one train unit
Human perceptible state of remaining dwell time of one train unit **Exchange Items:** • remaining_dwell_time_indication	Display the remaining dwell time of one train unit

Output	To
Abstract required state of all doors of one train unit **Exchange Items:** *None*	Control the required state of all doors of one train unit

6.5.6 Contains physical objects

Attribute	Content
Name	Contains physical objects
Description	This function represents the presence of physical objects in the Environment.
Rationale	External objects affecting the railway operation cannot be inside the system boundary. Hence, the function representing the presence of objects needs to be allocated to the actor Environment.
Actor	Environment

Figure 65: Context of Contains physical objects

Input	From
No inputs defined	

Output	To
Present actual output of objects in field of view of one train unit **Exchange Items:** • physical_objects_presence	Sense the data about environment in field of view of one train unit

6.5.7 Control the life-cycle of map data - STUB

Attribute	Content
Name	Control the life-cycle of map data - STUB
Description	This function controls the life-cycle of Map Data within the Planning System.
Rationale	It is assumed that the actor Planning System also has an internal management of map data. It is crucial, that the map data usage inside of RCA and the map data used in the Planning System are of the same version. Hence, the planning systems needs a function controlling the life-cycle of its own map data, represented by this function. As it is allocated to the actor Planning System it is outside the system boundary.
Actor	Planning System

Figure 66: Context of Control the life-cycle of map data - STUB

Input	From
Reported state of map data **Exchange Items:** • map_data_state_observation	Maintain map data

Output	To
No outputs defined	

6.5.8 Control the plan for all missions in one area of control

Attribute	Content
Name	Control the plan for all missions in one area of control

Attribute	Content
Description	This function determines conflict-free missions for of all train units in one defined area of control for the time horizon of one schedule segment. It permanently optimises the output according to the optimisation goal and the observed behaviour of all train units in the area of control. This function also determines the required grade auf automation for move segments of the missions and also the required door operations for passenger exchanges in stop segments of the missions.
Rationale	The required state of all missions shall be conflict free and well optimised. This serves as a reference input for train operation control inside the system RCA. This functionality is explicitly not considered part of the development scope of RCA, but of a dedicated, external planning system. Hence, this function is allocated to the actor Planning System and not inside the system boundary.
Actor	Planning System
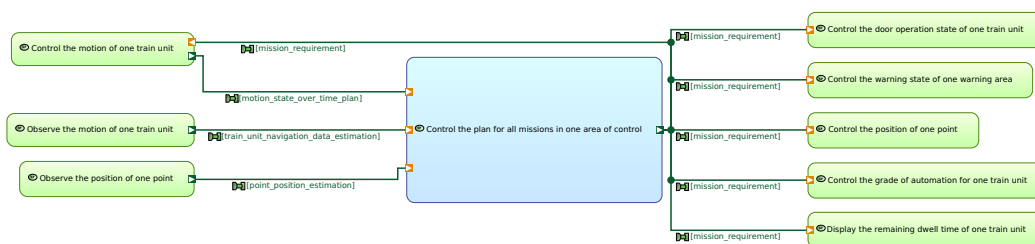
Figure 67: Context of Control the plan for all missions in one area of control

Input	From
Estimated internal position state of point **Exchange Items:** • point_position_estimation	Observe the position of one point
Estimated internal motion state of one train unit **Exchange Items:** • train_unit_navigation_data_estimation	Observe the motion of one train unit
Defined actual motion state plan over time **Exchange Items:** • motion_state_over_time_plan	Control the motion of one train unit

Output	To
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	Control the warning state of one warning area
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	Control the motion of one train unit
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	Control the position of one point
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	Display the remaining dwell time of one train unit
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	Control the grade of automation for one train unit
Abstract required state of missions in one area of control **Exchange Items:** • mission_requirement	Control the door operation state of one train unit

6.5.9 Control the plan for restriction areas over time for all tracks in one area of control

Attribute	Content
Name	Control the plan for restriction areas over time for all tracks in one area of control
Description	This function represents the responsibility of the Planning System to provide the required restriction areas and the required time constraints of their life-cycle.
Rationale	*None*
Actor	Planning System

Figure 68: Context of Control the plan for restriction areas over time for all tracks in one area of control

Input	From
Defined actual state of restriction area - STUB **Exchange Items:** • restriction_area_actual_definition_STUB	Control the life-cycle of one restriction area - STUB

Output	To
Abstract required state of restriction areas in one area of control - STUB **Exchange Items:** • restriction_area_requirement_STUB	Control the life-cycle of one restriction area - STUB

6.5.10 Control the plan for warning areas over time for all tracks in one area of control

Attribute	Content
Name	Control the plan for warning areas over time for all tracks in one area of control
Description	This function represents the responsibility of the Planning System to provide the required warning areas and the required time constraints of their life-cycle.
Rationale	The current state of understanding is, that planning of warning areas is not in the development scope and can be allocated to the actor Planning System outside of the system boundary.
Actor	Planning System

Figure 69: Context of Control the plan for warning areas over time for all tracks in one area of control

Input	From
Defined actual state of one warning area **Exchange Items:** • warning_area_actual_definition	Control the life-cycle of one warning area

Output	To
Abstract required state of warning areas in one area of control **Exchange Items:** • warning_area_requirement	Control the life-cycle of one warning area

6.5.11 Control the required state of all doors of one train unit

Attribute	Content
Name	Control the required state of all doors of one train unit
Description	This function controls the doors of one Physical Train Unit (PTU) by issuing commands to the door actuators.
Rationale	Controlling the doors of a train unit is a core functionality of the Physical Train Unit Operations System (PTU-OS) and a long established technology in the railway domain which will not be significantly changed. Hence this function is outside the system boundary.
Actor	Physical Train Unit Operation Systems (PTU-OS)

Figure 70: Context of Control the required state of all doors of one train unit

Input	From
Abstract required state of all doors of one train unit **Exchange Items:** *None*	Command the requested state of all doors of one train unit
Abstract required state of door operation of one train unit **Exchange Items:** • door_operation_state_requirement	Control the door operation state of one train unit

Output	To
Plant external required input state of one train units doors **Exchange Items:** *None*	Actuate+Plant behaviour of all doors of one train unit

6.5.12 Control the sounding state of horn

Attribute	Content
Name	Control the sounding state of horn

Attribute	Content
Description	This function commands the activation of the Physical Train Unit horn.
Rationale	Controlling the horn of a Physical Train Unit is a core functionality of the Physical Train Unit Operations System (PTU-OS) and a long established technology in the railway domain which will not be significantly changed. Hence this function is outside the system boundary.
Actor	Physical Train Unit Operation Systems (PTU-OS)

Figure 71: Context of Control the sounding state of horn

Input	From
Abstract required state of one train unit warning device **Exchange Items:** • audible_warning_device_requirement	Control the train unit warning devices

Output	To
No outputs defined	

6.5.13 Control the traction and brake effort of one train unit

Attribute	Content
Name	Control the traction and brake effort of one train unit
Description	This function controls the effective traction and brake efforts of one Physical Train Unit, depending on the technical properties of this Train Unit.
Rationale	Controlling the appropriate amount of traction and breaking force depending on the actual technical characteristics of a Physical Train Unit is part of the functionality of the actor Physical Train Unit Operation Systems (PTU-OS). Hence this functions is outside of the system boundary.
Actor	Physical Train Unit Operation Systems (PTU-OS)

Figure 72: Context of Control the traction and brake effort of one train unit

Input	From
Abstract required state of emergency brake intervention **Exchange Items:** • emergency_brake_requirement	Control the motion of one train unit
Abstract required state of traction-level and brake effort of one train unit **Exchange Items:** • relative_traction_braking_effort_level_requirement	Control the motion of one train unit

Output		To
Plant external required input state of movement **Exchange Items:** *None*		Actuate+Plant movement behaviour of one train unit

6.5.14 Control+Execute the warning state for all warning devices within one warning area

Attribute	Content
Name	Control+Execute the warning state for all warning devices within one warning area
Description	This function controls and executes the warning state based on the required state by System RCA.
Rationale	Collective Warning Systems are widely established in the railway domain and the actual design and functionality of the warning devices of the Collective Warning Systems will not change with RCA. Only the control of the activation and warning state will be optimised within RCA. Currently, it is assumed that the actual execution of a warning is a functionality of the actor Collective Warning Systems. Hence, this function is not inside the system boundary.
Actor	Collective Warning System

Figure 73: Context of Control+Execute the warning state for all warning devices within one warning area

Input	From
Abstract required state of warning for one warning area **Exchange Items:** • warning_area_warning_requirement	Control the warning state of one warning area

Output	To
No outputs defined	

6.5.15 Decide about intervention into train unit movement

| Attribute	Content
Name	Decide about intervention into train unit movement
Description	This function represents the responsibility of the Train Driver to intervene into Physical Train Unit movement in GoA2, if any unexpected environment condition occurs.
Rationale	In GoA2 operation the Train Driver is responsible for observing the environment while driving and the safe movement of the Physical Train Unit . Hence, this is a function of the actor Train Driver and cannot be inside the system boundary.
Actor	Train Driver
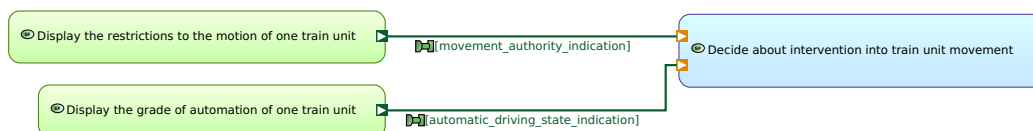
Figure 74: Context of Decide about intervention into train unit movement

Input	From
Human perceptible state of automatic driving **Exchange Items:** • automatic_driving_state_indication	Display the grade of automation of one train unit
Human perceptible state of restrictions on the movement of one train unit **Exchange Items:** • movement_authority_indication	Display the restrictions to the motion of one train unit

Output	To
No outputs defined	

6.5.16 Exert force on one switch rail actuation mount point

Attribute	Content
Name	Exert force on one switch rail actuation mount point
Description	This function represents the functionality to exert force on on switch rail actuation mount point to change the position state of one point.

Attribute	Content
Rationale	The bare moving of points is already provided by long-established technologies and is not going to be significantly changed due to the automation of the railway operation. Therefore, this function is not part of the development scope and can be allocated to actor Point Machine outside of the system boundary.
Actor	Point Machine

Figure 75: Context of Exert force on one switch rail actuation mount point

Input	From
Plant external required input state of point machine position **Exchange Items:** • point_machine_actuation_requirement	Control the position of one point

Output	To
No outputs defined	

6.5.17 Has physical dimensions and limits

| Attribute	Content
Name	Has physical dimensions and limits
Description	This function represents the spatial characteristics of the objects in the Environment.
Rationale	To react on obstacles on or near the line in fully automated driving, spatial awareness of the environment in front of a train unit is needed. Therefore, the environment needs to provide those spatial dimensions and is outside the system boundary.
Actor	Environment
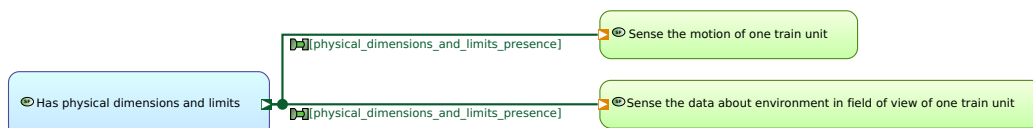
Figure 76: Context of Has physical dimensions and limits

Input	From
No inputs defined	

Output	To
Present actual output of dimensions and limits in field of view of one train unit **Exchange Items:** • physical_dimensions_and_limits_presence	Sense the motion of one train unit
Present actual output of dimensions and limits in field of view of one train unit **Exchange Items:** • physical_dimensions_and_limits_presence	Sense the data about environment in field of view of one train unit

6.5.18 Observe the intended movement direction relative to the front end of the train unit

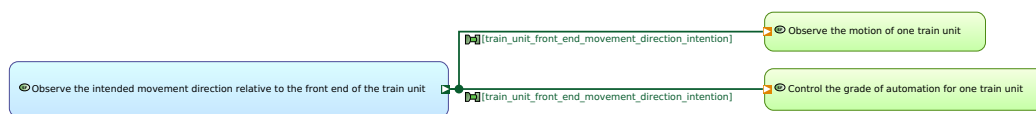| Attribute	Content
Name	Observe the intended movement direction relative to the front end of the train unit
Description	This function represents the observation of the intended movement direction of the train unit with respect to the defined front end of the train unit by the Physical Train Unit Operation Systems (PTU-OS). Therefore, it observes the direction controller of the Train Driver.
Rationale	Observing the position of the direction controller is not going to be significantly changed due to the automation of railway operation. Therefore, it does not need to be part of the development scope and can be allocated to the actor Physical Train Unit Operation Systems (PTU-OS).
Actor	Physical Train Unit Operation Systems (PTU-OS)

Figure 77: Context of Observe the intended movement direction relative to the front end of the train unit

Input	From
No inputs defined	

Output	To
Estimated internal state of movement direction of one train unit front end **Exchange Items:** • train_unit_front_end_movement_direction_intention	Observe the motion of one train unit

Output	To
Estimated internal state of movement direction of one train unit front end **Exchange Items:** • train_unit_front_end_movement_direction_intention	Control the grade of automation for one train unit

6.5.19 Observe the state of the railway - STUB

Attribute	Content
Name	Observe the state of the railway - STUB
Description	This function represents the responsibility of the Operations Manager to observe the state of the railway.
Rationale	The Operations Manager is a human actor with a role to observe and monitor the operation of an Area of Control. Hence, this is a function of the actor Operations Manager and cannot be inside the system boundary
Actor	Operations Manager

Figure 78: Context of Observe the state of the railway - STUB

Input	From
Human perceptable state of point position **Exchange Items:** • point_position_indication	Display the position of one point

Output	To
No outputs defined	

6.5.20 Observe the train integrity state of one physical train unit

Attribute	Content
Name	Observe the train integrity state of one physical train unit
Description	This function estimates the integrity state of a physical train unit based on inputs from multiple sensors on the train.

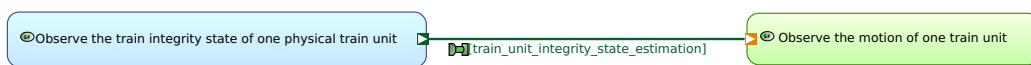| Attribute	Content
Rationale	Train Integrity Monitoring System currently considered to be part of the Physical Train Unit Operation Systems (PTU-OS) Function and therefore, it is also considered to be outside the scope of the system. This reasoning is based on the assumption that train integrity detection can be done by various physical principles and by different technologies. These differences are very specific to a vehicle class and should be abstracted away by Physical Train Unit Operation Systems (PTU-OS). Hence, this is a function of the actor Physical Train Unit Operation Systems (PTU-OS) and cannot be inside the system boundary.
Actor	Physical Train Unit Operation Systems (PTU-OS)

Figure 79: Context of Observe the train integrity state of one physical train unit

Input	From
No inputs defined	
Output	**To**
Estimated internal state of train integrity **Exchange Items:** • train_unit_integrity_state_estimation	Observe the motion of one train unit

6.5.21 Provide date and time reference

| Attribute	Content
Name	Provide date and time reference
Description	This function represents the responsibility to provide an actual date and time from a single, official reference.
Rationale	By definition, the date and time must be provided by an official source like a metrology institute. Hence, this function cannot be inside the system boundary.
Actor	Date Time Reference
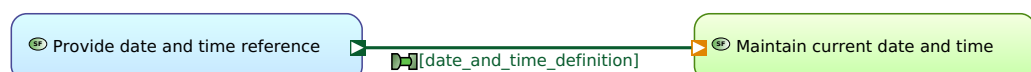
Figure 80: Context of Provide date and time reference

Input	From
No inputs defined	

Output	To
Provided date and time **Exchange Items:** • date_and_time_definition	Maintain current date and time

6.5.22 Provide map data - STUB

Attribute	Content
Name	Provide map data - STUB
Description	This function represents the responsibility of the Infrastructure Manager (IM) to provide Map Data to the system.
Rationale	Map data can be gathered from many external data sources and will require control and configuration outside of the system. Also, this process is different from IM to IM according to the individual context and needs. Hence, the actual provision of map data cannot be part of the system.
Actor	Infrastructure Manager (IM)

Figure 81: Context of Provide map data - STUB

Input	From
No inputs defined	

Output	To
Provided map data **Exchange Items:** • map_data_definition	Maintain map data

6.5.23 Sense+Observe the position of switch rail on one point machine

Attribute	Content
Name	Sense+Observe the position of switch rail on one point machine
Description	This function determines the estimated state of one point by sensing and observing the relative position of switch blades using different sensing technologies of one connected Point Machine.

| Attribute	Content
Rationale	Point Machines are widely established in the railway domain and their actual design and functionality will likely not change with RCA. Most Point Machine designs come with internal switch rail position sensing capabilities and/or can connect to external sensors.Therefore the Point Machine will be an actor to the System RCA and this function will be outside of the system boundary.
Actor	Point Machine
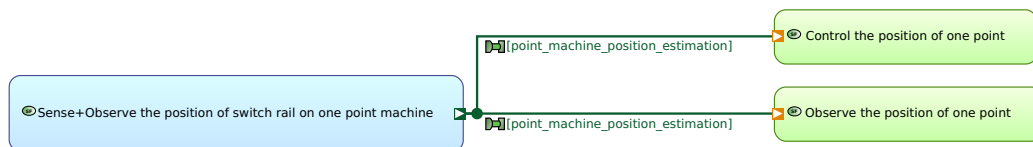
Figure 82: Context of Sense+Observe the position of switch rail on one point machine

Input	From
No inputs defined	

Output	To
Estimated internal state of point machine position **Exchange Items:** • point_machine_position_estimation	Control the position of one point
Estimated internal state of point machine position **Exchange Items:** • point_machine_position_estimation	Observe the position of one point

6.5.24 Sense+Observe the state of all doors of one train unit

| Attribute	Content
Name	Sense+Observe the state of all doors of one train unit
Description	This function determines the estimated state of all doors for one train unit by sensing and observing the relative position of all doors using one or multiple connected door actuators and different sensors.
Rationale	Sensing and observing the state of train doors are long-established aspects inside the railway domain. Furthermore, this function is highly dependent on the actual door systems in use on a given train unit. RCA should not deal with these technological differences and variability and only focus in controlling the doors. Hence, this function is allocated to the actor Physical Train Unit Operation Systems (PTU-OS) and is outside the system boundary.
Actor	Physical Train Unit Operation Systems (PTU-OS)
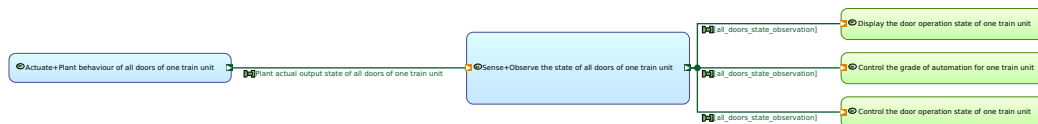
Figure 83: Context of Sense+Observe the state of all doors of one train unit

Input	From
Plant actual output state of all doors of one train unit **Exchange Items:** *None*	Actuate+Plant behaviour of all doors of one train unit
Output	**To**
Estimated internal state of all doors of one train unit **Exchange Items:** • all_doors_state_observation	Control the grade of automation for one train unit
Estimated internal state of all doors of one train unit **Exchange Items:** • all_doors_state_observation	Control the door operation state of one train unit
Estimated internal state of all doors of one train unit **Exchange Items:** • all_doors_state_observation	Display the door operation state of one train unit

6.5.25 Transmit eurobalise static information

Attribute	Content
Name	Transmit eurobalise static information
Description	This function represents the data transmission from a Eurobalise (EUB) to a Train Unit.
Rationale	The current assumption is, that the Eurobalise (EUB) will be primarily used for location references also in RCA and will be conceptually unchanged. Hence, also this function needs to be outside the system border.
Actor	Eurobalise (EUB)

Figure 84: Context of Transmit eurobalise static information

Input	From
No inputs defined	

Output	To
Transmitted balise data **Exchange Items:** • eurobalise_telegram	Sense the data of one eurobalise

7 Scope of operational requirements

Content for this chapter will be added later.

7.1 Review of past experience data for similar systems

Content for this chapter will be added later.

7.2 Constraints imposed by existing infrastructure

Content for this chapter will be added later.

7.3 Operational conditions

Content for this chapter will be added later.

7.4 Maintenance conditions

Content for this chapter will be added later.

7.5 Logistic conditions

Content for this chapter will be added later.

7.6 Operating procedures

Content for this chapter will be added later.

7.7 Mode of operation

Content for this chapter will be added later.

8 System reference version

Content for this chapter will be added later.

9 Assumptions

Content for this chapter will be added later.