

RCA



Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

Functional decomposition

Table of contents

1 Preamble	5
1.1 Release Information	5
1.2 Imprint	5
1.3 Disclaimer	5
1.4 Purpose	5
2 Version history	6
3 References	7
4 Instructions for reading	8
5 Logical decomposition of system needs	9
5.1 Logical capability realisations	9
5.1.1 01: Set point to position required by mission	9
5.1.2 02: Authorise train unit movement	10
5.1.3 09: Move one train unit	11
5.1.4 11: Prepare departure of train unit	13
5.1.5 15: Respond autonomously to object on or near the line	14
5.1.6 85: Provide navigation data of train unit	17
5.1.7 87: Activate map data	19
5.2 Decomposed system functions	20
5.2.1 Authorise the activation of map data	20
5.2.2 Calculate the forecasted arrival time of current timing point	21
5.2.3 Calculate the observed free space state of the track in field of view of one train unit	22
5.2.4 Calculate the observed state of one trackbound moveable object	24
5.2.5 Calculate the remaining dwell time of one train unit	26
5.2.6 Calculate the required safety-critical speed profile for one train unit	27
5.2.7 Calculate the required speed profile for one train unit	29
5.2.8 Capture the data about environment in field of view of one train unit	30
5.2.9 Control the activation of map data	31
5.2.10 Control the door automation state of one train unit	33
5.2.11 Control the driving automation state of one train unit	34
5.2.12 Control the execution of one mission segment for one train unit	36
5.2.13 Control the life-cycle of one restriction area - STUB	38
5.2.14 Convert global map data into local coordinates perspective for one train unit front end	39
5.2.15 Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end	40
5.2.16 Detect the track geometry in field of view of one train unit	41
5.2.17 Determine the current timing point state of one train unit	42
5.2.18 Determine the required door operation state of one train unit for next timing point	44
5.2.19 Determine the required driveability state of DPSes in one DPS group	45
5.2.20 Determine the required level of traction and brake effort for one train unit	47

5.2.21 Determine the required movement permission for one move segment	48
5.2.22 Determine the required position of one obstacle end of authority	50
5.2.23 Determine the required position of one point	52
5.2.24 Determine the required position state of one point machine	53
5.2.25 Determine the required state of train unit warning device	54
5.2.26 Display the current activation state of map data	54
5.2.27 Display the door operation state of one train unit	55
5.2.28 Display the grade of automation of one train unit	56
5.2.29 Display the position of one point	57
5.2.30 Display the remaining dwell time of one train unit	58
5.2.31 Display the restrictions to the motion of one train unit	58
5.2.32 Duplicated instance of function 'Determine the required movement permission for one move segment'	59
5.2.33 Estimate the acceleration of one train unit	60
5.2.34 Estimate the ego route 3D space ahead of one train unit	61
5.2.35 Estimate the extent of dynamic zones of one train unit	62
5.2.36 Estimate the front end position of one train unit	63
5.2.37 Estimate the global 3D position and heading of one train unit front end - STUB	66
5.2.38 Estimate the passing direction of one train unit in relation to infrastructure reference point	67
5.2.39 Estimate the physical orientation of one train unit in relation to infrastructure reference point	68
5.2.40 Estimate the rear end position of one train unit	69
5.2.41 Estimate the reference point position of one train unit in relation to infrastructure reference point	70
5.2.42 Estimate the running direction of one train unit	72
5.2.43 Estimate the velocity of one train unit	73
5.2.44 Maintain current date and time	75
5.2.45 Maintain map data	77
5.2.46 Maintain train unit configuration data	81
5.2.47 Measure the acceleration along track of one train unit	83
5.2.48 Measure the angular velocity of one wheelset	84
5.2.49 Measure the velocity of one train unit	85
5.2.50 Observe the driveability state of DPSes of one DPS group	87
5.2.51 Observe the position of one point	87
5.2.52 Recognise the 3D objects in field of view of one train unit	88
5.2.53 Register the automatic driving engagement input event	89
5.2.54 Register the map data version authorisation input event	90
5.2.55 Sense the data of one eurobalise	91
5.2.56 Supervise the compliance state of the safety-critical speed profile for one train unit	92
5.3 Logical actor functions	93
5.3.1 Actuate+Plant behaviour of all doors of one train unit	94
5.3.2 Actuate+Plant movement behaviour of one train unit	94
5.3.3 Authorise the departure of one train unit	95

5.3.4 Command the authorisation of one version of map data	95
5.3.5 Command the requested state of all doors of one train unit	96
5.3.6 Contains physical objects	97
5.3.7 Control the life-cycle of map data - STUB	98
5.3.8 Control the plan for all missions in one area of control	98
5.3.9 Control the plan for restriction areas over time for all tracks in one area of control	99
5.3.10 Control the required state of all doors of one train unit	100
5.3.11 Control the sounding state of horn	101
5.3.12 Control the traction and brake effort of one train unit	101
5.3.13 Decide about intervention into train unit movement	102
5.3.14 Exert force on one switch rail actuation mount point	103
5.3.15 Has physical dimensions and limits	103
5.3.16 Observe the intended movement direction relative to the front end of the train unit	104
5.3.17 Observe the state of the railway - STUB	105
5.3.18 Observe the train integrity state of one physical train unit	105
5.3.19 Provide date and time reference	106
5.3.20 Provide map data - STUB	106
5.3.21 Sense+Observe the position of switch rail on one point machine	107
5.3.22 Sense+Observe the state of all doors of one train unit	108
5.3.23 Transmit eurobalise static information	108

1 Preamble

1.1 Release Information

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Support and Feedback:

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1.3 Disclaimer

No disclaimer defined.

1.4 Purpose

The purpose of this document is the decomposition of the system functionality of System RCA from the system needs analysis (RCA.Doc.82) into logical functions. Logical functions do not yet define a solution towards a specific architecture, but instead subdivide a system function into smaller processing steps, which together are able to generate the output of a system function from the available inputs.

The system functional decomposition for RCA includes the following aspects:

- Decomposition of system functions into logical functions for selected system capabilities (see release notes in RCA.Doc.5)
- Descriptions of logical functions

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.

Also, the logical functions as derived in this document cannot directly be allocated to subsystems. This will require further engineering, especially conducting trade-of studies of possible detailed architecture and possible refinement of logical functions.

2 Version history

Version	Date	Author	Description
0.1	2022-09-30	Dr. Oliver Lemke	First release.
0.2	2022-10-19	Dr. Oliver Lemke	Minor formal changes.

3 References

Reference ID	Name	Document ID	Version
1	Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Generic RAMS Process	EN 50126-1	2017
2	European Union Agency for Railways - European Rail Traffic Management System-Driver Machine Interface	ERA_ERTMS_015560	3.6.0
3	RCA Terms and Abstract Concepts	RCA.Doc.14	1.0

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 herein in a later version of this document.

5 Logical decomposition of system needs

5.1 Logical capability realisations

In this chapter, all logical capability realisations provided by the system are described by the following aspects:

- List of the attributes of the capability realisation.
- Logical functional chain diagram, showing how the capability will be realised by the functions.

5.1.1 01: Set point to position required by mission

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.
Post-condition	(All Point Machines 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

Attribute	Content
Involved functions	<p><u>allocated to system:</u></p> <p>Display the position of one point</p> <p>Maintain current date and time</p> <p>Determine the required position of one point</p> <p>Determine the required position state of one point machine</p> <p>Determine the required driveability state of DPSes in one DPS group</p> <p>Observe the position of one point</p> <p>Observe the driveability state of DPSes of one DPS group</p> <p>Maintain map data</p> <p>Calculate the observed state of one trackbound moveable object</p> <p>Control the execution of one mission segment for one train unit</p> <p><u>allocated to actor:</u></p> <p>Control the plan for all missions in one area of control</p> <p>Exert force on one switch rail actuation mount point</p> <p>Sense+Observe the position of switch rail on one point machine</p> <p>Observe the state of the railway - STUB</p>
Realized capabilities	01: Set point to position required by mission

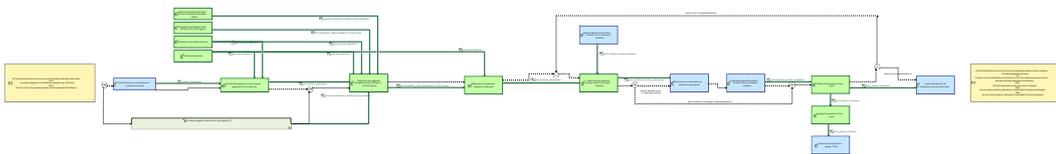


Figure 1: [LFCD][AMOD-082] Set point to position required by operation plan [Logical functional chain definition]

5.1.2 02: Authorise train unit movement

Attribute	Content
Name	02: Authorise train unit movement
Description	The Planning System requires the system to move one Train Unit across the next Move Segment. To do so the system needs to authorise the movement.
Pre-condition	Physical Train Unit Operation Systems (PTU-OS) is technically able to execute required movement AND There are neither technical nor operational restrictions in System RCA conflicting with the required train movement
Post-condition	Planning System is informed about the Movement Permission for one Train Unit

Attribute	Content
Involved actors and external systems	Train Driver Planning System Physical Train Unit Operation Systems (PTU-OS) Physical Train Unit (PTU)
Involved functions	<p><u>allocated to system:</u></p> <p>Maintain map data</p> <p>Maintain train unit configuration data</p> <p>Maintain current date and time</p> <p>Display the restrictions to the motion of one train unit</p> <p>Determine the required movement permission for one move segment</p> <p>Calculate the required safety-critical speed profile for one train unit</p> <p>Calculate the observed state of one trackbound moveable object</p> <p>Control the execution of one mission segment for one train unit</p> <p><u>allocated to actor:</u></p> <p>Control the plan for all missions in one area of control</p> <p>Decide about intervention into train unit movement</p> <p>Command the requested state of all doors of one train unit</p>
Realized capabilities	09: Move one train unit

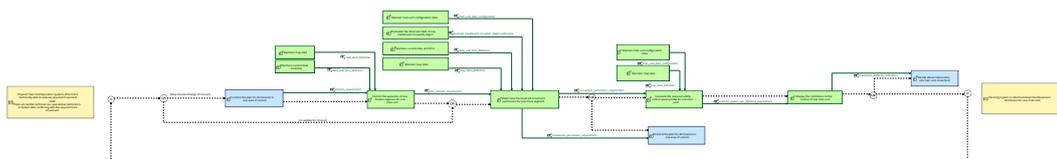


Figure 2: [LFCD][AMOD-082] Authorise train unit movement [Logical functional chain definition]

5.1.3 09: Move one train unit

Attribute	Content
Name	09: Move one train unit
Description	The Planning System requires the system to move one Physical Train Unit (PTU) 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 is in state Engaged

Attribute	Content
Post-condition	Physical Train Unit (PTU) has stopped at the next required stopping location AND Planning System is informed about the authorised and the current motion state 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)
Involved functions	<p><u>allocated to system:</u></p> <p>Determine the required level of traction and brake effort for one train unit</p> <p>Maintain current date and time</p> <p>Control the driving automation state of one train unit</p> <p>Maintain map data</p> <p>Maintain train unit configuration data</p> <p>Supervise the compliance state of the safety-critical speed profile for one train unit</p> <p>Calculate the required safety-critical speed profile for one train unit</p> <p>Calculate the required speed profile for one train unit</p> <p>Control the execution of one mission segment for one train unit</p> <p>Estimate the velocity of one train unit</p> <p>Estimate the front end position of one train unit</p> <p>Determine the current timing point state of one train unit</p> <p>Calculate the forecasted arrival time of current timing point</p> <p>Display the restrictions to the motion of one train unit</p> <p>Display the grade of automation of one train unit</p> <p><u>allocated to actor:</u></p> <p>Control the traction and brake effort of one train unit</p> <p>Control the plan for all missions in one area of control</p> <p>Decide about intervention into train unit movement</p>
Realized capabilities	09: Move one train unit

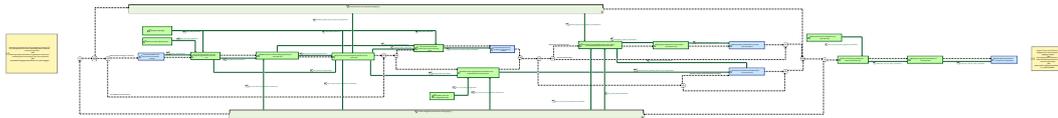


Figure 3: [LFCD][AMOD-082] Move Train Unit (GoA2)

5.1.4 11: Prepare departure of train unit

Attribute	Content
Name	11: Prepare departure of train unit
Description	The Planning System requires the system 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 Unit 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 in state 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	<p><u>allocated to system:</u></p> <ul style="list-style-type: none"> Register the automatic driving engagement input event Display the grade of automation of one train unit Control the driving automation state of one train unit Display the door operation state of one train unit Maintain current date and time Determine the required door operation state of one train unit for next timing point Calculate the remaining dwell time of one train unit Control the execution of one mission segment for one train unit Maintain map data Determine the current timing point state of one train unit Estimate the front end position of one train unit Calculate the required safety-critical speed profile for one train unit Control the door automation state of one train unit <p><u>allocated to actor:</u></p> <ul style="list-style-type: none"> 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 Decide about intervention into train unit movement
	Realized capabilities

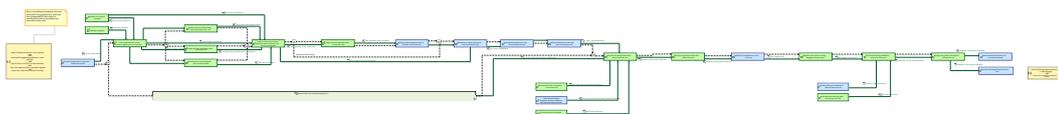


Figure 4: [LFCD][AMOD-082] Prepare departure of train unit (GoA2)[Logical functional chain definition]

5.1.5 15: Respond autonomously to object on or near the line

Attribute	Content
Name	15: Respond autonomously to object on or near the line

Attribute	Content
Description	The Infrastructure Manager (IM) and Railway Undertaking (RU) require 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 occurred with lower severity (impact). OR The collision with an obstacle occurred with full impact without mitigation.
Involved actors and external systems	Physical Train Unit Operation Systems (PTU-OS) Environment

Attribute	Content
Involved functions	<p><u>allocated to system:</u></p> <p>Capture the data about environment in field of view of one train unit</p> <p>Control the life-cycle of one restriction area - STUB</p> <p>Calculate the observed free space state of the track in field of view of one train unit</p> <p>Recognise the 3D objects in field of view of one train unit</p> <p>Detect the track geometry in field of view of one train unit</p> <p>Determine the required position of one obstacle end of authority</p> <p>Calculate the required safety-critical speed profile for one train unit</p> <p>Supervise the compliance state of the safety-critical speed profile for one train unit</p> <p>Determine the required level of traction and brake effort for one train unit</p> <p>Determine the required state of train unit warning device</p> <p>Estimate the ego route 3D space ahead of one train unit</p> <p>Maintain current date and time</p> <p>Calculate the required speed profile for one train unit</p> <p>Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end</p> <p>Convert global map data into local coordinates perspective for one train unit front end</p> <p>Estimate the extent of dynamic zones of one train unit</p> <p>Determine the required movement permission for one move segment</p> <p>Estimate the velocity of one train unit</p> <p>Estimate the front end position of one train unit</p> <p><u>allocated to actor:</u></p> <p>Contains physical objects</p> <p>Has physical dimensions and limits</p> <p>Control the traction and brake effort of one train unit</p> <p>Control the sounding state of horn</p> <p>Actuate+Plant movement behaviour of one train unit</p>
Realized capabilities	15: Respond autonomously to object on or near the line

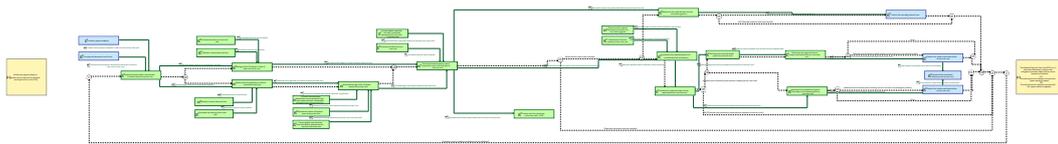


Figure 5: [LFCD][AMOD-082] Respond autonomously to object on or near the line [Logical functional chain definition]

5.1.6 85: Provide navigation data of train unit

Attribute	Content
Name	85: Provide navigation data of train unit
Description	The Infrastructure Manager (IM) requires the system to provide navigation data of the Physical Train Unit (PTU).
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	<p><u>allocated to system:</u></p> <p>Maintain map data</p> <p>Maintain train unit configuration data</p> <p>Measure the angular velocity of one wheelset</p> <p>Measure the velocity of one train unit</p> <p>Measure the acceleration along track of one train unit</p> <p>Estimate the acceleration of one train unit</p> <p>Estimate the velocity of one train unit</p> <p>Estimate the front end position of one train unit</p> <p>Estimate the passing direction of one train unit in relation to infrastructure reference point</p> <p>Calculate the observed state of one trackbound moveable object</p> <p>Sense the data of one eurobalise</p> <p>Estimate the physical orientation of one train unit in relation to infrastructure reference point</p> <p>Estimate the rear end position of one train unit</p> <p>Estimate the reference point position of one train unit in relation to infrastructure reference point</p> <p>Observe the position of one point</p> <p>Estimate the running direction of one train unit</p> <p><u>allocated to actor:</u></p> <p>Observe the train integrity state of one physical train unit</p> <p>Has physical dimensions and limits</p> <p>Actuate+Plant movement behaviour of one train unit</p> <p>Transmit eurobalise static information</p> <p>Observe the intended movement direction relative to the front end of the train unit</p> <p>Control the plan for all missions in one area of control</p>
Realized capabilities	85: Provide navigation data of train unit

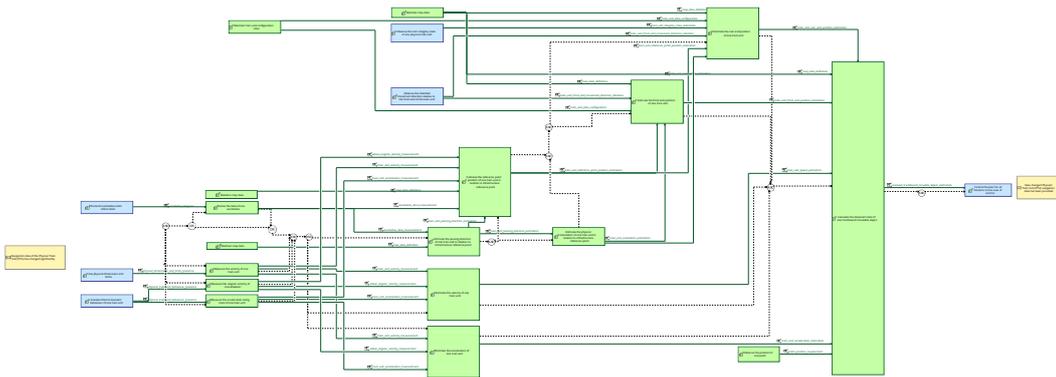


Figure 6: [LFCD][AMOD-082] Provide navigation data of train unit [Logical functional chain definition]

5.1.7 87: Activate map data

Attribute	Content
Name	87: Activate map data
Description	The Infrastructure Manager (IM) requires the system to activate Map Data so that the system is able to operate on the currently correct version of Map Data.
Pre-condition	The new version of Map Data 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	<p><u>allocated to system:</u></p> <ul style="list-style-type: none"> Control the activation of map data Authorise the activation of map data Maintain map data Display the current activation state of map data Control the life-cycle of one restriction area - STUB Register the map data version authorisation input event Maintain current date and time <p><u>allocated to actor:</u></p> <ul style="list-style-type: none"> 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
Realized capabilities	87: Activate map data

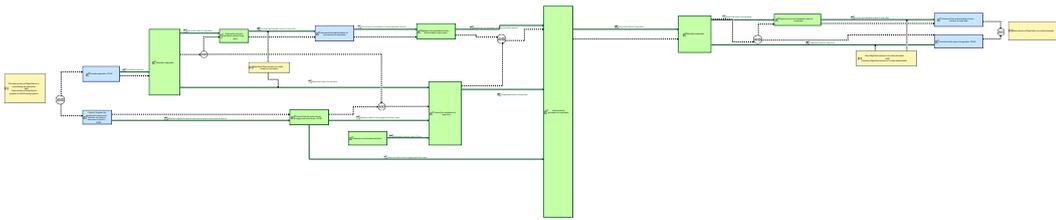


Figure 7: [LFCD][AMOD-082] Activate map data [Logical functional chain definition]

5.2 Decomposed system functions

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

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

5.2.1 Authorise the activation of map data

Attribute	Content
Name	Authorise the activation of map data
Description	This function authorises a required version change of map data against necessary criteria. By this, it controls which version of Map Data is to be provided by the function "Maintain map data" at a given point in time. In addition, this function also controls the transitions between different versions of Map Data.
Rationale	To ensure the safe activation of the Map Data e.g. check that no Train Units are moving in the area affected by Map Data update.
Realized system functions	Control the active version of map data

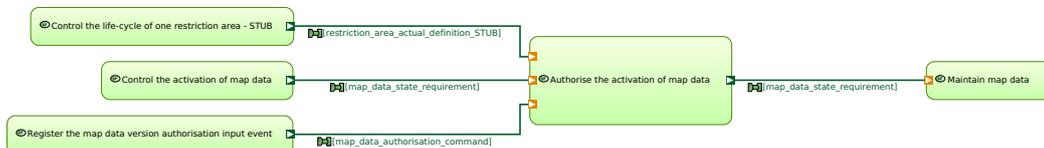


Figure 8: Context of Authorise the activation of map data

Input	From
Permission of activation of one map data version	
Exchange Items:	Register the map data version authorisation input event
• map_data_authorisation_command	

Input	From
Abstract required state of map data Exchange Items: <ul style="list-style-type: none"> map_data_state_requirement 	Control the activation of map data
Abstract state of one restriction area Exchange Items: <ul style="list-style-type: none"> restriction_area_actual_definition_STUB 	Control the life-cycle of one restriction area - STUB
Output	To
Abstract required state of map data Exchange Items: <ul style="list-style-type: none"> map_data_state_requirement 	Maintain map data

5.2.2 Calculate the forecasted arrival time of current timing point

Attribute	Content
Name	Calculate the forecasted arrival time of current timing point
Description	This function calculates the estimated arrival time of the Train Unit to the current timing point. The forecasted arrival time is only calculated when the current timing point is in state Targeted.
Rationale	To close the feedback loop to the planning systems and for usage by other potential logical functions.
Realized system functions	<i>None</i>

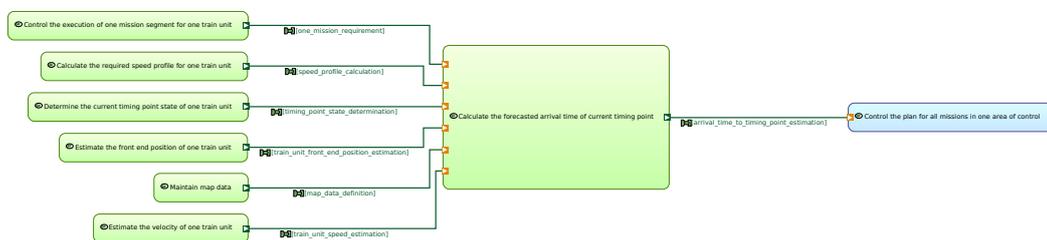


Figure 9: Context of Calculate the forecasted arrival time of current timing point

Input	From
Abstract required speed over distance of one speed profile Exchange Items: <ul style="list-style-type: none"> • speed_profile_calculation 	Calculate the required speed profile for one train unit
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> • timing_point_state_determination 	Determine the current timing point state of one train unit
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	Estimate the front end position of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Estimated velocity of one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Estimate the velocity of one train unit
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Control the execution of one mission segment for one train unit
Output	To
Estimated arrival time of the targeted timing point Exchange Items: <ul style="list-style-type: none"> • arrival_time_to_timing_point_estimation 	Control the plan for all missions in one area of control

5.2.3 Calculate the observed free space state of the track in field of view of one train unit

Attribute	Content
Name	Calculate the observed free space state of the track in field of view of one train unit

Attribute	Content
Description	This function analyses the scene within the field of view of one Train Unit and understands the current and potential behaviour of different entities/objects (e.g. human, tunnel, wall). It calculates the state of the observed free space by assessing the recognised objects whether the objects are an obstacle for the Train Unit.
Rationale	To ensure the assessment of the recognised objects and tracks and understand the scene.
Realized system functions	Observe the free space of the track in the field of view of one train unit

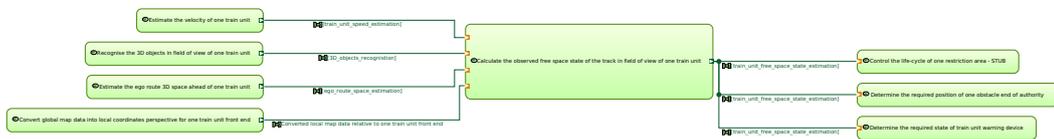


Figure 10: Context of Calculate the observed free space state of the track in field of view of one train unit

Input	From
Recognised 3D objects in field of view of one train unit Exchange Items: • 3D_objects_recognition	Recognise the 3D objects in field of view of one train unit
Estimated ego route space ahead of one train unit Exchange Items: • ego_route_space_estimation	Estimate the ego route 3D space ahead of one train unit
Converted local map data relative to one train unit front end Exchange Items: <i>None</i>	Convert global map data into local coordinates perspective for one train unit front end
Estimated internal state of speed Exchange Items: • train_unit_speed_estimation	Estimate the velocity of one train unit

Output	To
Observed internal free space state field of view of one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_free_space_state_estimation 	Determine the required position of one obstacle end of authority
Observed internal free space state field of view of one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_free_space_state_estimation 	Determine the required state of train unit warning device
Observed internal free space state field of view of one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_free_space_state_estimation 	Control the life-cycle of one restriction area - STUB

5.2.4 Calculate the observed state of one trackbound moveable object

Attribute	Content
Name	Calculate the observed state of one trackbound moveable object
Description	This function calculates which extent of the topology is occupied by one Train Unit and generates the Moveable Object representing it. It evaluates the train unit front end position of the Train Unit, the rear end position of the Train Unit as well as the point positions to allow a track edge selective representation of the Moveable Object.
Rationale	To authoritatively define which parts of the topology are occupied by moveable objects.
Realized system functions	Observe the motion of one train unit

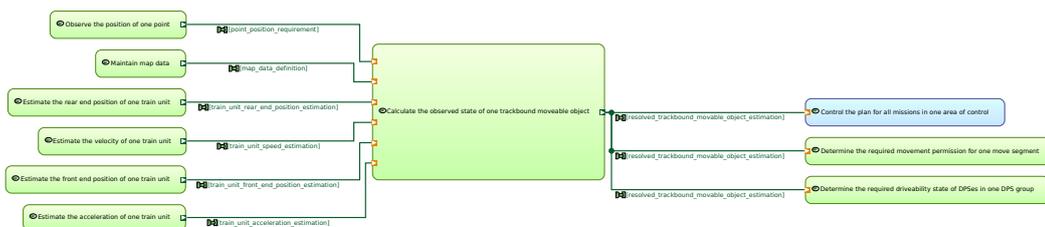


Figure 11: Context of Calculate the observed state of one trackbound moveable object

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Estimated internal state of rear end position for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_rear_end_position_estimation 	Estimate the rear end position of one train unit
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Estimate the velocity of one train unit
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	Estimate the front end position of one train unit
Estimated internal state of acceleration Exchange Items: <ul style="list-style-type: none"> • train_unit_acceleration_estimation 	Estimate the acceleration of one train unit
Estimated internal position state of one point Exchange Items: <ul style="list-style-type: none"> • point_position_requirement 	Observe the position of one point
Output	To
Estimated internal state of moveable object Exchange Items: <ul style="list-style-type: none"> • resolved_trackbound_movable_object_estimation 	Determine the required movement permission for one move segment
Estimated internal state of moveable object Exchange Items: <ul style="list-style-type: none"> • resolved_trackbound_movable_object_estimation 	Determine the required driveability state of DPSes in one DPS group

Output	To
Estimated internal state of moveable object Exchange Items: <ul style="list-style-type: none"> resolved_trackbound_movable_object_estimation 	Control the plan for all missions in one area of control

5.2.5 Calculate the remaining dwell time of one train unit

Attribute	Content
Name	Calculate the remaining dwell time of one train unit
Description	This function calculates the remaining time until the Train Unit needs to depart according to either the scheduled departure time or the minimum dwell time.
Rationale	To be able to inform actors and other logical functions about the remaining dwell time for preparing an on-time departure of the train unit.
Realized system functions	Control the grade of automation for one train unit Control the door operation state of one train unit Display the remaining dwell time of one train unit

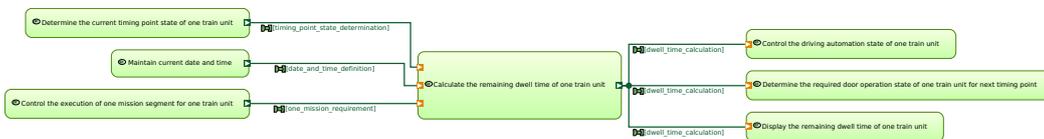


Figure 12: Context of Calculate the remaining dwell time of one train unit

Input	From
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> one_mission_requirement 	Control the execution of one mission segment for one train unit
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> date_and_time_definition 	Maintain current date and time
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> timing_point_state_determination 	Determine the current timing point state of one train unit

Output	To
Abstract required remaining dwell time of one train unit Exchange Items: <ul style="list-style-type: none"> • dwell_time_calculation 	Determine the required door operation state of one train unit for next timing point
Abstract required remaining dwell time of one train unit Exchange Items: <ul style="list-style-type: none"> • dwell_time_calculation 	Display the remaining dwell time of one train unit
Abstract required remaining dwell time of one train unit Exchange Items: <ul style="list-style-type: none"> • dwell_time_calculation 	Control the driving automation state of one train unit

5.2.6 Calculate the required safety-critical speed profile for one train unit

Attribute	Content
Name	Calculate the required safety-critical speed profile for one train unit
Description	This function authoritatively calculates the safety relevant breaking curves for one Train Unit based upon the Movement Permission of the Train Unit, the Train Unit Configuration Data and, in fully automatic driving, the positions of detected obstacles on or near the line.
Rationale	To authoritatively define the maximum safe speed profile for a Train Unit so that all functions driving and supervising the Train Unit motion are working with the same safe ceiling speed.
Realized system functions	Control the motion of one train unit



Figure 13: Context of Calculate the required safety-critical speed profile for one train unit

Input	From
Abstract required state of obstacle end of authority Exchange Items: <ul style="list-style-type: none"> • obstacle_end_of_authority_state_requirement 	Determine the required position of one obstacle end of authority
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Determine the required movement permission for one move segment
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Output	To
Abstract required maximum speed over distance of one train unit Exchange Items: <ul style="list-style-type: none"> • maximal_speed_over_distance_requirement 	Calculate the required speed profile for one train unit
Abstract required maximum speed over distance of one train unit Exchange Items: <ul style="list-style-type: none"> • maximal_speed_over_distance_requirement 	Supervise the compliance state of the safety-critical speed profile for one train unit
Abstract required maximum speed over distance of one train unit Exchange Items: <ul style="list-style-type: none"> • maximal_speed_over_distance_requirement 	Display the restrictions to the motion of one train unit
Abstract required safety-critical speed profile of one train unit Exchange Items: <ul style="list-style-type: none"> • maximal_speed_over_distance_requirement 	Control the driving automation state of one train unit

5.2.7 Calculate the required speed profile for one train unit

Attribute	Content
Name	Calculate the required speed profile for one train unit
Description	This function calculates the optimised Speed Profile for one Train Unit. This Speed Profile takes into consideration the safety critical speed profile, the arrival time at the timing points including tolerances, and other factors like energy consumption and passenger comfort. The Speed Profile must not violate the restrictions of the Safety-critical speed profile.
Rationale	To define the operational speed profile a Train Unit should run to in a move segment for logical functions controlling the actual required motion of the Train Unit.
Realized system functions	Control the motion of one train unit

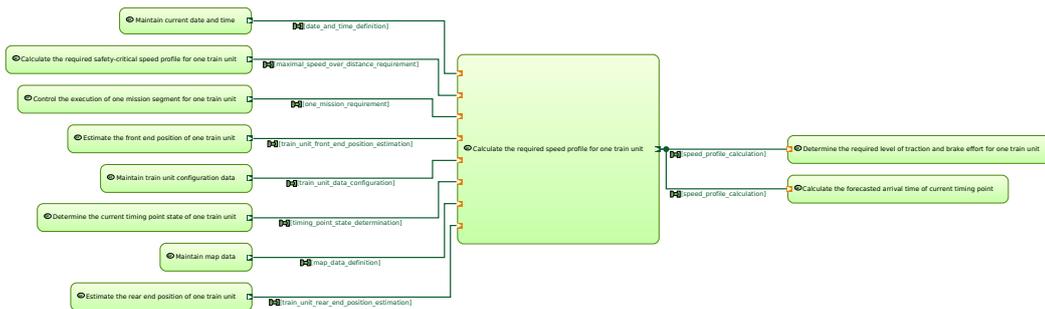


Figure 14: Context of Calculate the required speed profile for one train unit

Input	From
Abstract required maximum speed over distance of one train unit Exchange Items: <ul style="list-style-type: none"> maximal_speed_over_distance_requirement 	Calculate the required safety-critical speed profile for one train unit
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> one_mission_requirement 	Control the execution of one mission segment for one train unit
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> train_unit_front_end_position_estimation 	Estimate the front end position of one train unit

Input	From
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> • timing_point_state_determination 	Determine the current timing point state of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Estimated internal state of rear end position for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_rear_end_position_estimation 	Estimate the rear end position of one train unit
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Maintain current date and time
Output	To
Abstract required speed over distance of one speed profile Exchange Items: <ul style="list-style-type: none"> • speed_profile_calculation 	Determine the required level of traction and brake effort for one train unit
Abstract required speed over distance of one speed profile Exchange Items: <ul style="list-style-type: none"> • speed_profile_calculation 	Calculate the forecasted arrival time of current timing point

5.2.8 Capture the data about environment in field of view of one train unit

Attribute	Content
Name	Capture 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 ensure that the system can fulfil the drivers task of observing the track, the environment must be technology independent captured by sensors through this function.
Realized system functions	Sense the data about environment in field of view of one train unit



Figure 15: Context of Capture the data about environment in field of view of one train unit

Input	From
Present actual output of objects in field of view of one train unit Exchange Items: • physical_objects_presence	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	Has physical dimensions and limits
Output	To
Sensed output state of environmental raw data Exchange Items: • environmental_raw_data_capture	Recognise the 3D objects in field of view of one train unit
Sensed output state of environmental raw data Exchange Items: • environmental_raw_data_capture	Detect the track geometry in field of view of one train unit

5.2.9 Control the activation of map data

Attribute	Content
Name	Control the activation of map data

Attribute	Content
Description	This function determines the right point in time according to the planning of the usage restriction in place for the map data and forwards an activation request to the function "Authorise activation of map data".
Rationale	To be able to control, which version of the Map Data is available to all other logical functions at any point in time.
Realized system functions	Control the active version of map data

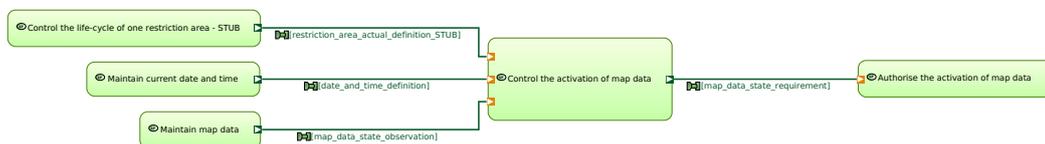


Figure 16: Context of Control the activation of map data

Input	From
Reported state of map data Exchange Items: • map_data_state_observation	Maintain map data
Estimated internal state of time Exchange Items: • date_and_time_definition	Maintain current date and time
Abstract state of one restriction area Exchange Items: • restriction_area_actual_definition_STUB	Control the life-cycle of one restriction area - STUB
Output	To
Abstract required state of map data Exchange Items: • map_data_state_requirement	Authorise the activation of map data

5.2.10 Control the door automation state of one train unit

Attribute	Content
Name	Control the door automation state of one train unit
Description	This function authoritatively controls the door operation automation state of one Train Unit by evaluating the required door automation state defined in the Mission, the driving automation state and other parameters.
Rationale	To have a central function that defines the current automation state for door operation of a Train Unit for other logical functions.
Realized system functions	Control the grade of automation for one train unit



Figure 17: Context of Control the door automation state of one train unit

Input	From
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Control the execution of one mission segment for one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Abstract required automatic driving state of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_calculation 	Control the driving automation state of one train unit
Output	To
Abstract required automatic door operation configuration of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_door_operation_level_requirement 	Determine the required door operation state of one train unit for next timing point

Output	To
Abstract required automatic door operation configuration of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_door_operation_level_requirement 	Display the door operation state of one train unit

5.2.11 Control the driving automation state of one train unit

Attribute	Content
Name	Control the driving automation state of one train unit
Description	This function authoritatively controls the driving automation state of one Train Unit by evaluating the required driving automation state defined in the Mission and other parameters.
Rationale	To have a central function that defines the current automation state for driving the Train Unit for other logical functions.
Realized system functions	Control the grade of automation for one train unit

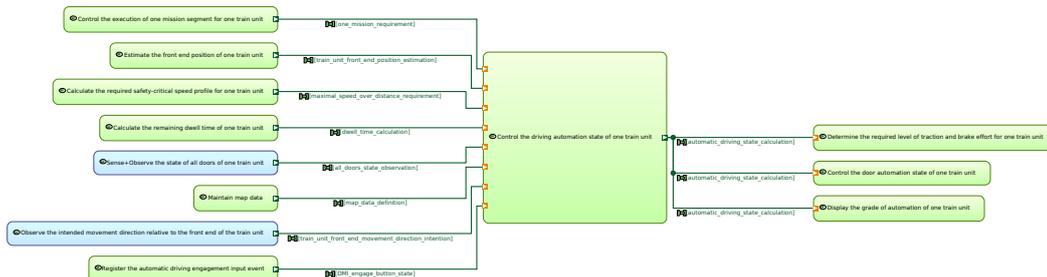


Figure 18: Context of Control the driving automation state of one train unit

Input	From
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	Estimate the front end position of one train unit
Abstract required safety-critical speed profile of one train unit Exchange Items: <ul style="list-style-type: none"> • maximal_speed_over_distance_requirement 	Calculate the required safety-critical speed profile for one train unit

Input	From
Abstract required remaining dwell time of one train unit Exchange Items: <ul style="list-style-type: none"> • dwell_time_calculation 	Calculate the remaining dwell time of one train unit
Estimated internal state of all doors of one train unit Exchange Items: <ul style="list-style-type: none"> • all_doors_state_observation 	Sense+Observe the state of all doors of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Estimated internal state of movement direction of one train unit front end Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_movement_direction_intention 	Observe the intended movement direction relative to the front end of the train unit
Abstract required state of departure authorisation Exchange Items: <ul style="list-style-type: none"> • DMI_engage_button_state 	Register the automatic driving engagement input event
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Control the execution of one mission segment for one train unit
Output	To
Abstract required automatic driving state of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_calculation 	Control the door automation state of one train unit
Abstract required automatic driving state of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_calculation 	Display the grade of automation of one train unit

Output	To
Abstract required automatic driving state of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_calculation 	Determine the required level of traction and brake effort for one train unit

5.2.12 Control the execution of one mission segment for one train unit

Attribute	Content
Name	Control the execution of one mission segment for one train unit
Description	This function controls the execution of Mission Segment contained in a Mission. It filters the next mission segment for one Train Unit and provides it to all downstream functions.
Rationale	<p>To have a central function filtering one mission segment for one Train Unit from all missions and all mission segments and providing that to all other logical functions.</p> <p>To be able to provide information about the train unit front end position to subsequent function. The information are needed to perform a safe and optimised train unit mission movement.</p>
Realized system functions	Control the motion of one train unit Control the door operation state of one train unit Control the position of one point Control the grade of automation for one train unit

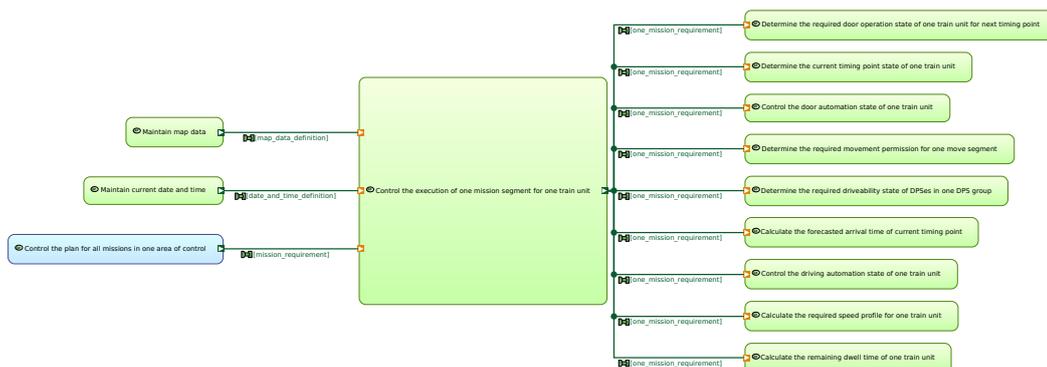


Figure 19: Context of Control the execution of one mission segment for one train unit

Input	From
Abstract required state of missions in one area of control Exchange Items: <ul style="list-style-type: none"> • mission_requirement 	Control the plan for all missions in one area of control

Input	From
<p>Estimated internal state of time</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • date_and_time_definition 	<p>Maintain current date and time</p>
<p>Defined active map data</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • map_data_definition 	<p>Maintain map data</p>
Output	To
<p>Abstract required state of the mission of one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • one_mission_requirement 	<p>Calculate the required speed profile for one train unit</p>
<p>Abstract required state of the mission of one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • one_mission_requirement 	<p>Calculate the remaining dwell time of one train unit</p>
<p>Abstract required state of the mission of one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • one_mission_requirement 	<p>Determine the required door operation state of one train unit for next timing point</p>
<p>Abstract required state of the mission of one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • one_mission_requirement 	<p>Control the door automation state of one train unit</p>
<p>Abstract required state of the mission of one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • one_mission_requirement 	<p>Calculate the forecasted arrival time of current timing point</p>

Output	To
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Control the driving automation state of one train unit
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Determine the required driveability state of DPSes in one DPS group
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Determine the current timing point state of one train unit
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Determine the required movement permission for one move segment

5.2.13 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 life-cycle state of one usage restriction area. This function is currently an unfinished stub.
Rationale	<i>None</i>
Realized system functions	Control the life-cycle of one restriction area - STUB

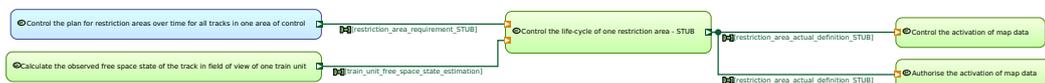


Figure 20: Context of Control the life-cycle of one restriction area - STUB

Input	From
Observed internal free space state field of view of one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_free_space_state_estimation 	Calculate the observed free space state of the track in field of view of one train unit

Input	From
Abstract required state of restriction areas in one area of control Exchange Items: <ul style="list-style-type: none"> • restriction_area_requirement_STUB 	Control the plan for restriction areas over time for all tracks in one area of control
Output	To
Abstract state of one restriction area Exchange Items: <ul style="list-style-type: none"> • restriction_area_actual_definition_STUB 	Control the activation of map data
Abstract state of one restriction area Exchange Items: <ul style="list-style-type: none"> • restriction_area_actual_definition_STUB 	Authorise the activation of map data

5.2.14 Convert global map data into local coordinates perspective for one train unit front end

Attribute	Content
Name	Convert global map data into local coordinates perspective for one train unit front end
Description	This function converts Map Data in global coordinates to Map Data in local coordinates normalised to a reference point on the train unit front end. Result is Map Data that is described relative to the current position and pose of the reference point of the train unit front end.
Rationale	To have one central function converting Map Data in global coordinates to local coordinates relative to the front end position of the Train Unit, as this conversion is complex and multiple instances doing this in parallel can come to different results.
Realized system functions	Maintain map data



Figure 21: Context of Convert global map data into local coordinates perspective for one train unit front end

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Maintain map data
Estimated absolute 3D position and heading of one train unit Exchange Items: <i>None</i>	Estimate the global 3D position and heading of one train unit front end - STUB
Output	To
Converted local map data relative to one train unit front end Exchange Items: <i>None</i>	Estimate the extent of dynamic zones of one train unit
Converted local map data relative to one train unit front end Exchange Items: <i>None</i>	Calculate the observed free space state of the track in field of view of one train unit
Converted local map data relative to one train unit front end Exchange Items: <i>None</i>	Estimate the ego route 3D space ahead of one train unit

5.2.15 Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end

Attribute	Content
Name	Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end
Description	This function determines the ego route for one Train Unit by mapping the topography, topology and the Movement Permission together.
Rationale	To be able to assess detected objects in relation to the topographical view of the movement permission and to decide, if movement permission and obstacles intersect.
Realized system functions	Control the motion of one train unit



Figure 22: Context of Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end

Input	From
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Determine the required movement permission for one move segment
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Estimated absolute 3D position and heading of one train unit Exchange Items: <i>None</i>	Estimate the global 3D position and heading of one train unit front end - STUB
Output	To
Converted intended driving path into local coordinates Exchange Items: <i>None</i>	Estimate the ego route 3D space ahead of one train unit
Converted intended driving path into local coordinates Exchange Items: <i>None</i>	Estimate the extent of dynamic zones of one train unit

5.2.16 Detect the track geometry in field of view of one train unit

Attribute	Content
Name	Detect the track geometry in field of view of one train unit
Description	This function detects the geometrical features of the track within field of view of one train unit out of the captured, abstract representation of environmental features. This function does not yet distinguish between the track on which the train unit is moving and parallel tracks.
Rationale	To additionally validate the intended driving path of a Train Unit in relation to detected obstacles.
Realized system functions	Observe the free space of the track in the field of view of one train unit

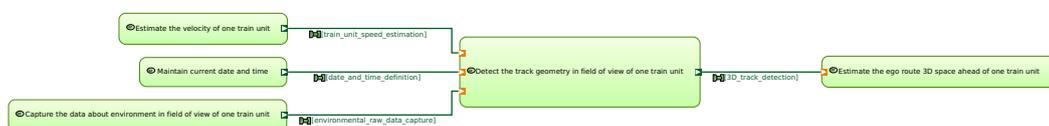


Figure 23: Context of Detect the track geometry in field of view of one train unit

Input	From
<p>Sensed output state of environmental raw data</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • environmental_raw_data_capture 	<p>Capture the data about environment in field of view of one train unit</p>
<p>Estimated internal state of time</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • date_and_time_definition 	<p>Maintain current date and time</p>
<p>Estimated internal state of speed</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_speed_estimation 	<p>Estimate the velocity of one train unit</p>
Output	To
<p>Detected track geometry in field of view of one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • 3D_track_detection 	<p>Estimate the ego route 3D space ahead of one train unit</p>

5.2.17 Determine the current timing point state of one train unit

Attribute	Content
Name	Determine the current timing point state of one train unit
Description	This function determines the state of the current relevant timing point according to the Mission and the current front end position of the Train Unit, and determines its state.
Rationale	<p>To be able to provide information about the train unit front end position to subsequent function. The information are needed to perform a safe and optimised train unit mission movement.</p> <p>To centrally decide which timing point is the next relevant timing point in the mission segment.</p>
Realized system functions	<p>Control the motion of one train unit</p> <p>Control the door operation state of one train unit</p>

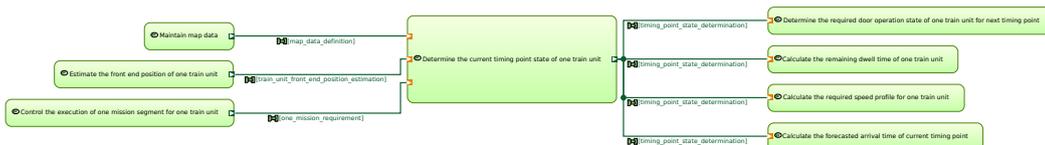


Figure 24: Context of Determine the current timing point state of one train unit

Input	From
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Control the execution of one mission segment for one train unit
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	Estimate the front end position of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Output	To
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> • timing_point_state_determination 	Calculate the required speed profile for one train unit
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> • timing_point_state_determination 	Calculate the forecasted arrival time of current timing point
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> • timing_point_state_determination 	Determine the required door operation state of one train unit for next timing point
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> • timing_point_state_determination 	Calculate the remaining dwell time of one train unit

5.2.18 Determine the required door operation state of one train unit for next timing point

Attribute	Content
Name	Determine the required door operation state of one train unit for next timing point
Description	This functions controls the current required door operation state of one Train Unit based on the general door automation state, the dwell time, and other parameters. The functions forwards this required state to an indicate function for lower grade of automation and to the actor PTU-OS for higher grade of automation.
Rationale	To determine, how Train Unit doors shall be operated at the next stop segment.
Realized system functions	Control the door operation state of one train unit

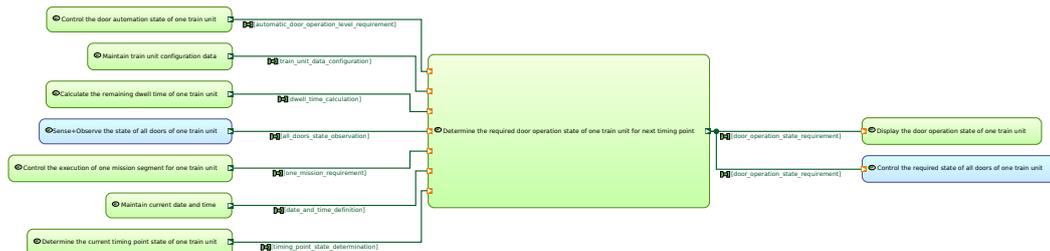


Figure 25: Context of Determine the required door operation state of one train unit for next timing point

Input	From
Defined train unit configuration data Exchange Items: • train_unit_data_configuration	Maintain train unit configuration data
Abstract required remaining dwell time of one train unit Exchange Items: • dwell_time_calculation	Calculate the remaining dwell time of one train unit
Estimated internal state of all doors of one train unit Exchange Items: • all_doors_state_observation	Sense+Observe the state of all doors of one train unit

Input		From
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 		Control the execution of one mission segment for one train unit
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 		Maintain current date and time
Abstract state of actual timing point Exchange Items: <ul style="list-style-type: none"> • timing_point_state_determination 		Determine the current timing point state of one train unit
Abstract required automatic door operation configuration of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_door_operation_level_requirement 		Control the door automation state of one train unit
Output		To
Abstract required state of door operation of one train unit Exchange Items: <ul style="list-style-type: none"> • door_operation_state_requirement 		Display the door operation state of one train unit
Abstract required state of door operation of one train unit Exchange Items: <ul style="list-style-type: none"> • door_operation_state_requirement 		Control the required state of all doors of one train unit

5.2.19 Determine the required driveability state of DPSes in one DPS group

Attribute	Content
Name	Determine the required driveability state of DPSes in one DPS group
Description	This function determines the required state of Drive Protection Sections of one Drive Protection Section Group for performing a Move Segment of one Mission of one Train Unit. It takes the Mission definition, the current time, the estimated position of Train Units and other parameters into account. If necessary conditions are not met the required state is not changed.

Attribute	Content
Rationale	To be able to set a correct train path in time for a move segment in a mission for a Train Unit.
Realized system functions	Control the position of one point

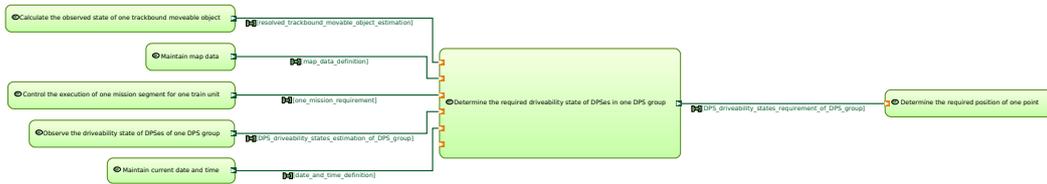


Figure 26: Context of Determine the required driveability state of DPSes in one DPS group

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Maintain map data
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> one_mission_requirement 	Control the execution of one mission segment for one train unit
Estimated internal driveability state of one DPS Exchange Items: <ul style="list-style-type: none"> DPS_driveability_states_estimation_of_DPS_group 	Observe the driveability state of DPSes of one DPS group
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> date_and_time_definition 	Maintain current date and time
Estimated internal state of moveable object Exchange Items: <ul style="list-style-type: none"> resolved_trackbound_movable_object_estimation 	Calculate the observed state of one trackbound moveable object

Output	To
Abstract required driveability state of DPSes of one DPS group Exchange Items: <ul style="list-style-type: none"> DPS_driveability_states_requirement_of_DPS_group 	Determine the required position of one point

5.2.20 Determine the required level of traction and brake effort for one train unit

Attribute	Content
Name	Determine the required level of traction and brake effort for one train unit
Description	This function determines the instantaneous required level of traction and brake effort to accomplish the given Speed Profile based on the estimated position and speed of the Train Unit.
Rationale	<p>The physical train unit is technical state of the art that means we have to split between safety and non safety critical traction and brake effort functions.</p> <p>To be able to provide a required traction and brake effort to the On-Board systems of the Physical Train Unit, so that the Train Unit will move according to the operational speed profile.</p>
Realized system functions	Control the motion of one train unit

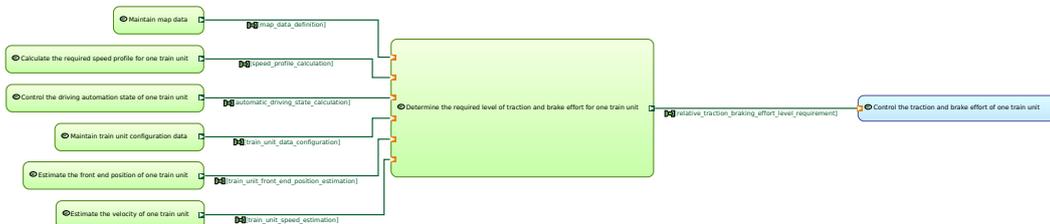


Figure 27: Context of Determine the required level of traction and brake effort for one train unit

Input	From
Abstract required speed over distance of one speed profile Exchange Items: <ul style="list-style-type: none"> speed_profile_calculation 	Calculate the required speed profile for one train unit

Input	From
Abstract required automatic driving state of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_calculation 	Control the driving automation state of one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	Estimate the front end position of one train unit
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Estimate the velocity of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Output	To
Abstract required state of traction-level and brake effort of one train unit Exchange Items: <ul style="list-style-type: none"> • relative_traction_braking_effort_level_requirement 	Control the traction and brake effort of one train unit

5.2.21 Determine the required movement permission for one move segment

Attribute	Content
Name	Determine the required movement permission for one move segment
Description	This function determines authoritatively the required Movement Permission for performing a Move Segment of one Mission of one Train Unit. It takes the Mission definition, the estimated position of Train Units, the state of Drive Protection Sections and other parameters into account. If necessary conditions are not met, the required movement permission state change is not forwarded downstream. The Movement Permission is safely allocating an extend of the infrastructure to the movement of one Train Unit.

Attribute	Content
Rationale	To centrally decide, which elements of the topology are occupied by movement permissions for Train Units and to safely allow the movement of Train Units inside these reservations.
Realized system functions	Control the motion of one train unit

Failure while rendering diagram 'Context of Determine the required movement permission for one move segment': JSONDecodeError: Expecting value: line 1 column 1 (char 0)

Figure 28: Context of Determine the required movement permission for one move segment

Input	From
Abstract required state of the mission of one train unit Exchange Items: <ul style="list-style-type: none"> • one_mission_requirement 	Control the execution of one mission segment for one train unit
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Maintain current date and time
Estimated internal state of moveable object Exchange Items: <ul style="list-style-type: none"> • resolved_trackbound_movable_object_estimation 	Calculate the observed state of one trackbound moveable object
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Duplicated instance of function 'Determine the required movement permission for one move segment'
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Determine the required movement permission for one move segment

Input	From
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Output	To
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Calculate the required safety-critical speed profile for one train unit
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Control the plan for all missions in one area of control
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Determine the required movement permission for one move segment
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Duplicated instance of function 'Determine the required movement permission for one move segment'
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Determine the required position of one obstacle end of authority

5.2.22 Determine the required position of one obstacle end of authority

Attribute	Content
Name	Determine the required position of one obstacle end of authority

Attribute	Content
Description	This function determines whether it is necessary to stop the train unit because of an obstacle (by defining an obstacle end of authority point in relation to an existing Movement Permission) or not (required state: Continue planned mission movement). The obstacle end of authority, if present, will limit the existing Movement Permission by generating a stopping point before the actual end of the Movement Permission. If the obstacle is within the ego route space of the train unit, an obstacle end of authority position is defined. In case that the obstacle is moving the position of the obstacle end of authority is changed accordingly. If the obstacle is leaving the ego route space, the obstacle end of authority position is removed allowing the train unit to continue its mission.
Rationale	To be able to define a point along the movement permission where a Train Unit needs to stop to avoid a collision with an obstacle.
Realized system functions	Control the motion of one train unit

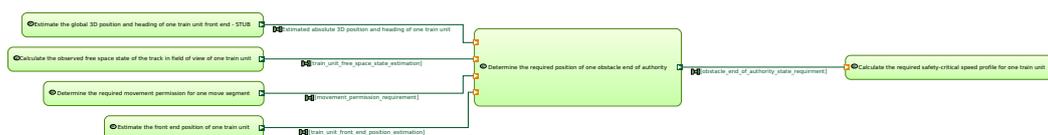


Figure 29: Context of Determine the required position of one obstacle end of authority

Input	From
Observed internal free space state field of view of one train unit Exchange Items: • train_unit_free_space_state_estimation	Calculate the observed free space state of the track in field of view of one train unit
Abstract required state of one movement permission Exchange Items: • movement_permission_requirement	Determine the required movement permission for one move segment
Estimated internal state of front end position Exchange Items: • train_unit_front_end_position_estimation	Estimate the front end position of one train unit

Input	From
Estimated absolute 3D position and heading of one train unit Exchange Items: <i>None</i>	Estimate the global 3D position and heading of one train unit front end - STUB
Output	To
Abstract required state of obstacle end of authority Exchange Items: <ul style="list-style-type: none"> • obstacle_end_of_authority_state_requirement 	Calculate the required safety-critical speed profile for one train unit

5.2.23 Determine the required position of one point

Attribute	Content
Name	Determine the required position of one point
Description	This function determines which Point Machines relate to the Drive Protection Section Group and requests their state according to the state change of the Drive Protection Section Group of the Drive Protection Section Group.
Rationale	To be able to control point machines from the abstract Drive Protection Section Group definition, in a first step a Drive Protection Section Group definition has to be mapped to one specific point.
Realized system functions	Control the position of one point



Figure 30: Context of Determine the required position of one point

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data
Abstract required driveability state of DPSes of one DPS group Exchange Items: <ul style="list-style-type: none"> • DPS_driveability_states_requirement_of_DPS_group 	Determine the required driveability state of DPSes in one DPS group

Output	To
Abstract required position state of one point Exchange Items: <ul style="list-style-type: none"> • point_position_requirement 	Determine the required position state of one point machine

5.2.24 Determine the required position state of one point machine

Attribute	Content
Name	Determine the required position state of one point machine
Description	This function determines the control outputs for one Point Machine allocated to one Point according to the required position of that point and the estimated position of the switch rail of that point.
Rationale	To be able to control individual point machines of one point, control commands for each point machine needs to be derived from the required point position.
Realized system functions	Control the position of one point



Figure 31: Context of Determine the required position state of one point machine

Input	From
Abstract required position state of one point Exchange Items: <ul style="list-style-type: none"> • point_position_requirement 	Determine the required position of one point
Estimated internal state of point machine position Exchange Items: <ul style="list-style-type: none"> • point_machine_position_estimation 	Sense+Observe the position of switch rail on one point machine
Output	To
Plant external required input state of point machine position Exchange Items: <ul style="list-style-type: none"> • point_machine_actuation_requirement 	Exert force on one switch rail actuation mount point

5.2.25 Determine the required state of train unit warning device

Attribute	Content
Name	Determine the required state of train unit warning device
Description	This function determines based on the assessment of the free space state of a train unit, if the warning device needs to be activated to warn an obstacle (e.g. person) on or near the line. Operational rules are taken into account.
Rationale	To be able to warn obstacles on or near the line, the system must be able to control the warning devices of the Physical Train Unit.
Realized system functions	Control the train unit warning devices



Figure 32: Context of Determine the required state of train unit warning device

Input	From
Observed internal free space state field of view of one train unit Exchange Items: • train_unit_free_space_state_estimation	Calculate the observed free space state of the track in field of view 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

5.2.26 Display the current activation state of map data

Attribute	Content
Name	Display the current activation state of map data
Description	This indicate function converts the internal activation state of the Map Data into a human readable by indicating which version of the Map Data is active.
Rationale	To be able to indicate an internal state of the system into a human readable display.

Attribute	Content
Realized system functions	Display the current activation state of map data



Figure 33: Context of Display the current activation state of map data

Input	From
Reported state of map data Exchange Items: • map_data_state_observation	Maintain map data
Output	To
Human perceptible state of map data Exchange Items: • map_data_state_indication	Command the authorisation of one version of map data

5.2.27 Display the door operation state of one train unit

Attribute	Content
Name	Display the door operation state of one train unit
Description	This function converts the required door automation state of one Train Unit, the estimated state of all doors of one Train Unit and the required door operation state of one train Unit for the next timing point into a human readable display of the door state according to subset 125.
Rationale	To be able to indicate an internal state of the system into a human readable display.
Realized system functions	Display the door operation state of one train unit

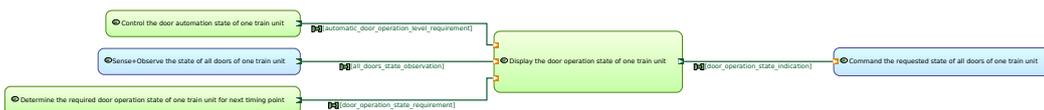


Figure 34: Context of Display the door operation state of one train unit

Input	From
Abstract required state of door operation of one train unit Exchange Items: <ul style="list-style-type: none"> • door_operation_state_requirement 	Determine the required door operation state of one train unit for next timing point
Estimated internal state of all doors of one train unit Exchange Items: <ul style="list-style-type: none"> • all_doors_state_observation 	Sense+Observe the state of all doors of one train unit
Abstract required automatic door operation configuration of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_door_operation_level_requirement 	Control the door automation state of one train unit
Output	To
Human perceptible state of door operation of one train unit Exchange Items: <ul style="list-style-type: none"> • door_operation_state_indication 	Command the requested state of all doors of one train unit

5.2.28 Display the grade of automation of one train unit

Attribute	Content
Name	Display the grade of automation of one train unit
Description	This function converts the required driving automation state of one Train Unit into a human readable display of the Grade of Automation (GoA).
Rationale	To be able to indicate an internal state of the system into a human readable display.
Realized system functions	Display the grade of automation of one train unit

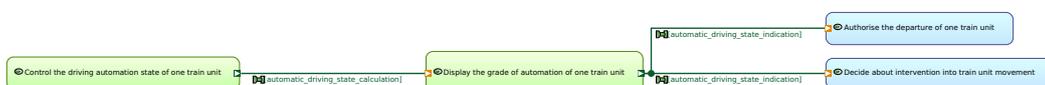


Figure 35: Context of Display the grade of automation of one train unit

Input	From
Abstract required automatic driving state of one train unit Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_calculation 	Control the driving automation state of one train unit
Output	To
Human perceptible state of automatic driving Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_indication 	Authorise the departure of one train unit
Human perceptible state of automatic driving Exchange Items: <ul style="list-style-type: none"> • automatic_driving_state_indication 	Decide about intervention into train unit movement

5.2.29 Display the position of one point

Attribute	Content
Name	Display the position of one point
Description	This function converts the estimated state of one Point into a human readable display of the point position.
Rationale	To be able to indicate an internal state of the system into a human readable display.
Realized system functions	Display the position of one point



Figure 36: Context of Display the position of one point

Input	From
Estimated internal state of point position Exchange Items: <ul style="list-style-type: none"> • point_position_estimation 	Observe the position of one point

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Maintain map data
Output	To
Human perceptible state of point position Exchange Items: <ul style="list-style-type: none"> point_position_indication 	Observe the state of the railway - STUB

5.2.30 Display the remaining dwell time of one train unit

Attribute	Content
Name	Display the remaining dwell time of one train unit
Description	This function converts the required remaining dwell time of one Train Unit into a human readable display of the remaining dwell time.
Rationale	To be able to indicate an internal state of the system into a human readable display.
Realized system functions	Display the remaining dwell time of one train unit



Figure 37: Context of Display the remaining dwell time of one train unit

Input	From
Abstract required remaining dwell time of one train unit Exchange Items: <ul style="list-style-type: none"> dwell_time_calculation 	Calculate the remaining dwell time of one train unit
Output	To
Human perceptible state of remaining dwell time of one train unit Exchange Items: <ul style="list-style-type: none"> remaining_dwell_time_indication 	Command the requested state of all doors of one train unit

5.2.31 Display the restrictions to the motion of one train unit

Attribute	Content
Name	Display the restrictions to the motion of one train unit

Attribute	Content
Description	This function converts the required safety critical speed-profile and the supervision state of that speed profile into a human readable display according to ERA_ERTMS_015560.
Rationale	To be able to indicate an internal state of the system into a human readable display.
Realized system functions	Display the restrictions to the motion of one train unit



Figure 38: Context of Display the restrictions to the motion of one train unit

Input	From
Abstract required maximum speed over distance of one train unit Exchange Items: <ul style="list-style-type: none"> maximal_speed_over_distance_requirement 	Calculate the required safety-critical speed profile for one train unit
Abstract required restrictions on the motion state of one train unit Exchange Items: <ul style="list-style-type: none"> emergency_brake_requirement 	Supervise the compliance state of the safety-critical speed profile for one train unit
Output	To
Human perceptible state of restrictions on the movement of one train unit Exchange Items: <ul style="list-style-type: none"> movement_authority_indication 	Command the requested state of all doors of one train unit
Human perceptible state of restrictions on the movement of one train unit Exchange Items: <ul style="list-style-type: none"> movement_authority_indication 	Decide about intervention into train unit movement

5.2.32 Duplicated instance of function 'Determine the required movement permission for one move segment'

Attribute	Content
Name	Duplicated instance of function 'Determine the required movement permission for one move segment'

Attribute	Content
Description	This function represents other instance of the function "Determine the required infrastructure reservation for one move segment". The latter function requires the current state of all movement permissions for all Train Units to decide, if a infrastructure reservation can be granted.
Rationale	<i>None</i>
Realized system functions	Duplicated instance of function 'Control the motion of one train unit'



Figure 39: Context of Duplicated instance of function 'Determine the required movement permission for one move segment'

Input	From
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Determine the required movement permission for one move segment
Output	To
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> • movement_permission_requirement 	Determine the required movement permission for one move segment

5.2.33 Estimate the acceleration of one train unit

Attribute	Content
Name	Estimate the acceleration of one train unit
Description	This function estimates the acceleration of one Train Unit by evaluating sensor inputs. It authoritatively generates the linear acceleration value for the Train Unit.
Rationale	To be able to fulfil the need of other logical functions needing the estimated acceleration, this function provides the acceleration centrally and authoritatively.
Realized system functions	Observe the motion of one train unit

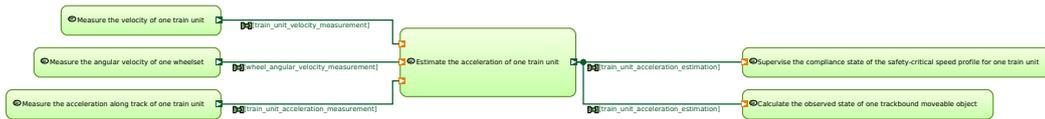


Figure 40: Context of Estimate the acceleration of one train unit

Input	From
Measured output state of acceleration for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_acceleration_measurement 	Measure the acceleration along track of one train unit
Measured output state of angular velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • wheel_angular_velocity_measurement 	Measure the angular velocity of one wheelset
Measured output state velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_velocity_measurement 	Measure the velocity of one train unit
Output	To
Estimated internal state of acceleration Exchange Items: <ul style="list-style-type: none"> • train_unit_acceleration_estimation 	Supervise the compliance state of the safety-critical speed profile for one train unit
Estimated internal state of acceleration Exchange Items: <ul style="list-style-type: none"> • train_unit_acceleration_estimation 	Calculate the observed state of one trackbound moveable object

5.2.34 Estimate the ego route 3D space ahead of one train unit

Attribute	Content
Name	Estimate the ego route 3D space ahead of one train unit
Description	This function estimates the ego route space ahead of one train unit by combining the detected track geometry, the ego route and Map Data converted into local coordinates. The ego route space describes the 3D space of the ego route set in the actual Movement Permission for the respective Train Unit and consists of the risk assesment zones.
Rationale	<i>None</i>

Attribute	Content
Realized system functions	Observe the free space of the track in the field of view of one train unit

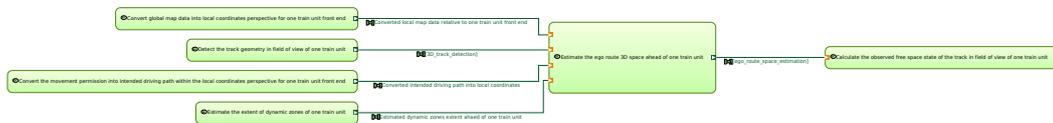


Figure 41: Context of Estimate the ego route 3D space ahead of one train unit

Input	From
Detected track geometry in field of view of one train unit Exchange Items: <ul style="list-style-type: none"> • 3D_track_detection 	Detect the track geometry in field of view of one train unit
Converted intended driving path into local coordinates Exchange Items: <i>None</i>	Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end
Estimated dynamic zones extent ahead of one train unit Exchange Items: <i>None</i>	Estimate the extent of dynamic zones of one train unit
Converted local map data relative to one train unit front end Exchange Items: <i>None</i>	Convert global map data into local coordinates perspective for one train unit front end
Output	To
Estimated ego route space ahead of one train unit Exchange Items: <ul style="list-style-type: none"> • ego_route_space_estimation 	Calculate the observed free space state of the track in field of view of one train unit

5.2.35 Estimate the extent of dynamic zones of one train unit

Attribute	Content
Name	Estimate the extent of dynamic zones of one train unit
Description	This functions determines the extend of near-track zones based on the current velocity of oneTrain Unit and the Map Data converted to local coordinates.

Attribute	Content
Rationale	To be able to assess, if an obstacle is possible colliding with the driving path of the Train Unit, this function dynamically defines the near track zones and provides this information to other logical functions.
Realized system functions	<i>None</i>



Figure 42: Context of Estimate the extent of dynamic zones of one train unit

Input	From
Converted local map data relative to one train unit front end Exchange Items: <i>None</i>	Convert global map data into local coordinates perspective for one train unit front end
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> train_unit_speed_estimation 	Estimate the velocity of one train unit
Converted intended driving path into local coordinates Exchange Items: <i>None</i>	Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end
Output	To
Estimated dynamic zones extent ahead of one train unit Exchange Items: <i>None</i>	Estimate the ego route 3D space ahead of one train unit

5.2.36 Estimate the front end position of one train unit

Attribute	Content
Name	Estimate the front end position of one train unit
Description	This function estimates the train unit front end position by evaluating the position of the reference point on the Train Unit in relation to the infrastructure, the train unit physical orientation, train unit configuration data and Map Data. It outputs one or more track edge points defining the front end position.

Attribute	Content
Rationale	<p>To be able to provide information about the train unit front end position to subsequent function. The information are needed to perform a safe and optimised train unit mission movement.</p> <p>To be able to fulfil the need of other logical functions needing the estimated front end position of a Train Unit, this function provides the front end position centrally and authoritatively.</p>
Realized system functions	Observe the motion of one train unit

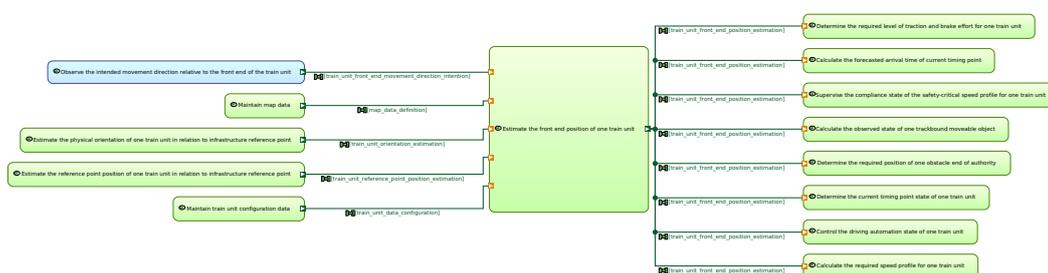


Figure 43: Context of Estimate the front end position of one train unit

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Maintain map data
Estimated internal state of orientation for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_orientation_estimation 	Estimate the physical orientation of one train unit in relation to infrastructure reference point
Estimated internal state of referece point position for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_reference_point_position_estimation 	Estimate the reference point position of one train unit in relation to infrastructure reference point
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> train_unit_data_configuration 	Maintain train unit configuration data

Input	From
<p>Estimated internal state of movement direction of one train unit front end</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_movement_direction_intention 	<p>Observe the intended movement direction relative to the front end of the train unit</p>
Output	To
<p>Estimated internal state of front end position</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	<p>Control the driving automation state of one train unit</p>
<p>Estimated internal state of front end position</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	<p>Calculate the required speed profile for one train unit</p>
<p>Estimated internal state of front end position</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	<p>Determine the required level of traction and brake effort for one train unit</p>
<p>Estimated internal state of front end position</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	<p>Supervise the compliance state of the safety-critical speed profile for one train unit</p>
<p>Estimated internal state of front end position</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	<p>Determine the required position of one obstacle end of authority</p>
<p>Estimated internal state of front end position</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	<p>Determine the current timing point state of one train unit</p>
<p>Estimated internal state of front end position</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	<p>Calculate the observed state of one trackbound moveable object</p>

Output	To
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	Calculate the forecasted arrival time of current timing point

5.2.37 Estimate the global 3D position and heading of one train unit front end - STUB

Attribute	Content
Name	Estimate the global 3D position and heading of one train unit front end - STUB
Description	This function estimates the 3D position and the heading of the Train Unit Front End in relation to a global coordinate system.
Rationale	<i>None</i>
Realized system functions	Observe the motion of one train unit



Figure 44: Context of Estimate the global 3D position and heading of one train unit front end - STUB

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data

Output	To
Estimated absolute 3D position and heading of one train unit Exchange Items: <i>None</i>	Convert global map data into local coordinates perspective for one train unit front end
Estimated absolute 3D position and heading of one train unit Exchange Items: <i>None</i>	Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end
Estimated absolute 3D position and heading of one train unit Exchange Items: <i>None</i>	Determine the required position of one obstacle end of authority

5.2.38 Estimate the passing direction of one train unit in relation to infrastructure reference point

Attribute	Content
Name	Estimate the passing direction of one train unit in relation to infrastructure reference point
Description	<p>This function estimates the movement direction of the Train Unit in relation to the orientation of one infrastructure reference point. It outputs, if the Train Unit is moving in the same direction or in the opposite direction of the infrastructure reference point.</p> <p>Note:</p> <p>E.g. in ETCS, the direction of an infrastructure reference point is equivalent to the direction of the balise group.</p>
Rationale	<p>To be able to detect, in which direction in relation to the infrastructure a Train Unit is moving.</p> <p>To be able to detect, in which direction in relation to the infrastructure a Train Unit is moving.</p>
Realized system functions	Observe the motion of one train unit



Figure 45: Context of Estimate the passing direction of one train unit in relation to infrastructure reference point

Input	From
Sensed output state of eurobalise data Exchange Items: <ul style="list-style-type: none"> eurobalise_data_measurement 	Sense the data of one eurobalise
Defined active map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Maintain map data
Output	To
Estimated internal state of passing direction for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_passing_direction_estimation 	Estimate the physical orientation of one train unit in relation to infrastructure reference point

Output	To
<p>Estimated internal state of passing direction for one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_passing_direction_estimation 	<p>Estimate the reference point position of one train unit in relation to infrastructure reference point</p>

5.2.39 Estimate the physical orientation of one train unit in relation to infrastructure reference point

Attribute	Content
Name	Estimate the physical orientation of one train unit in relation to infrastructure reference point
Description	This function estimates the physical orientation of the Train Unit in relation to the infrastructure reference point by evaluating the running direction of the train unit (towards A-end or B-end) and the passing direction of the infrastructure reference point. It outputs, how the ends of the train units (A-end and B-end) are oriented in relation to the orientation of the reference point (e.g "A-end facing in direction of the reference point").
Rationale	To be able to detect, in which orientation a Train Unit is placed on the track infrastructure.
Realized system functions	Observe the motion of one train unit



Figure 46: Context of Estimate the physical orientation of one train unit in relation to infrastructure reference point

Input	From
<p>Estimated internal state of passing direction for one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_passing_direction_estimation 	<p>Estimate the passing direction of one train unit in relation to infrastructure reference point</p>
<p>Estimated running direction of one train unit</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • train_unit_running_direction_estimation 	<p>Estimate the running direction of one train unit</p>

Output	To
Estimated internal state of orientation for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_orientation_estimation 	Estimate the front end position of one train unit
Estimated internal state of orientation for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_orientation_estimation 	Estimate the rear end position of one train unit

5.2.40 Estimate the rear end position of one train unit

Attribute	Content
Name	Estimate the rear end position of one train unit
Description	This function estimates the train unit rear position end by evaluating the position of the reference point on the Train Unit in relation to the infrastructure, the train unit physical orientation, train unit configuration data and Map Data. It outputs one or more Track Edge Points defining the rear end position.
Rationale	To be able to fulfil the need of other logical functions needing the estimated rear end position of a Train Unit, this function provides the rear end position centrally and authoritatively.
Realized system functions	Observe the motion of one train unit

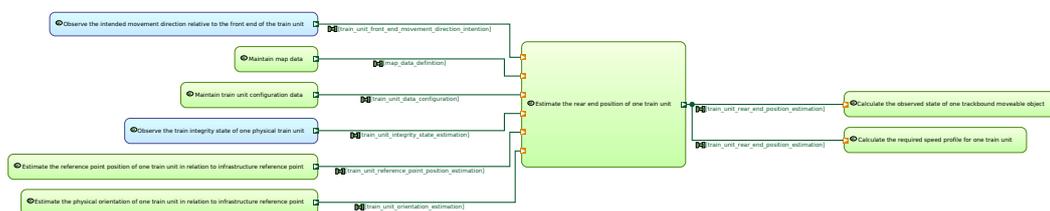


Figure 47: Context of Estimate the rear end position of one train unit

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Maintain map data

Input	From
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Estimated internal state of train integrity Exchange Items: <ul style="list-style-type: none"> • train_unit_integrity_state_estimation 	Observe the train integrity state of one physical train unit
Estimated internal state of reference point position for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_reference_point_position_estimation 	Estimate the reference point position of one train unit in relation to infrastructure reference point
Estimated internal state of orientation for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_orientation_estimation 	Estimate the physical orientation of one train unit in relation to infrastructure reference point
Estimated internal state of movement direction of one train unit front end Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_movement_direction_intention 	Observe the intended movement direction relative to the front end of the train unit
Output	To
Estimated internal state of rear end position for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_rear_end_position_estimation 	Calculate the observed state of one trackbound moveable object
Estimated internal state of rear end position for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_rear_end_position_estimation 	Calculate the required speed profile for one train unit

5.2.41 Estimate the reference point position of one train unit in relation to infrastructure reference point

Attribute	Content
Name	Estimate the reference point position of one train unit in relation to infrastructure reference point

Attribute	Content
Description	This function estimates the position of the train unit reference point by evaluating the passing of infrastructure reference points, multiple sensor inputs regarding velocity and acceleration and Map Data. it outputs one or more Track Edge Points representing possible positions of the train unit reference point on the infrastructure.
Rationale	To be able to determine the front end and rear end positions of a Train Unit, the position of the reference point of a Train Unit in relation to a reference point on the infrastructure is needed.
Realized system functions	Observe the motion of one train unit

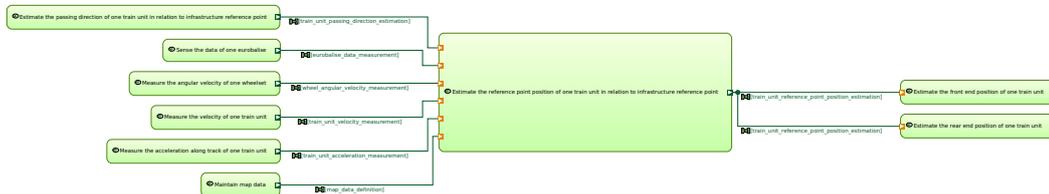


Figure 48: Context of Estimate the reference point position of one train unit in relation to infrastructure reference point

Input	From
Sensed output state of eurobalise data Exchange Items: • eurobalise_data_measurement	Sense the data of one eurobalise
Measured output state of angular velocity for one train unit Exchange Items: • wheel_angular_velocity_measurement	Measure the angular velocity of one wheelset
Measured output state velocity for one train unit Exchange Items: • train_unit_velocity_measurement	Measure the velocity of one train unit
Measured output state of acceleration for one train unit Exchange Items: • train_unit_acceleration_measurement	Measure the acceleration along track of one train unit

Input	From
Defined active map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Maintain map data
Estimated internal state of passing direction for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_passing_direction_estimation 	Estimate the passing direction of one train unit in relation to infrastructure reference point
Output	To
Estimated internal state of referece point position for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_reference_point_position_estimation 	Estimate the front end position of one train unit
Estimated internal state of referece point position for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_reference_point_position_estimation 	Estimate the rear end position of one train unit

5.2.42 Estimate the running direction of one train unit

Attribute	Content
Name	Estimate the running direction of one train unit
Description	This function estimates the train unit running direction (if a Train Unit is moving towards its A-end or B-end) by evaluating multiple sensor inputs regarding velocity and acceleration.
Rationale	To be able to decide about the physical orientation of the train unit, the system needs to estimate towards which end the Train Unit is currently moving.
Realized system functions	<i>None</i>

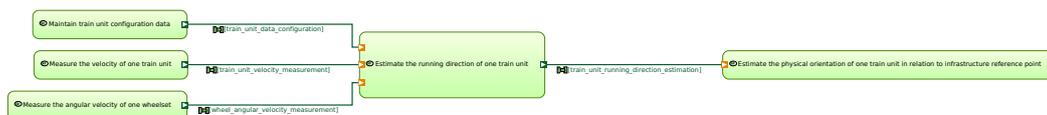


Figure 49: Context of Estimate the running direction of one train unit

Input	From
Measured output state of angular velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • wheel_angular_velocity_measurement 	Measure the angular velocity of one wheelset
Measured output state velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_velocity_measurement 	Measure the velocity of one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Output	To
Estimated running direction of one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_running_direction_estimation 	Estimate the physical orientation of one train unit in relation to infrastructure reference point

5.2.43 Estimate the velocity of one train unit

Attribute	Content
Name	Estimate the velocity of one train unit
Description	This function estimates the velocity of one Train Unit by evaluating sensor information regarding the angular wheel speed, linear speed and acceleration of the Train Unit.
Rationale	To be able to fulfil the need of other logical functions needing the estimated velocity, this function provides the velocity centrally and authoritatively.
Realized system functions	Observe the motion of one train unit

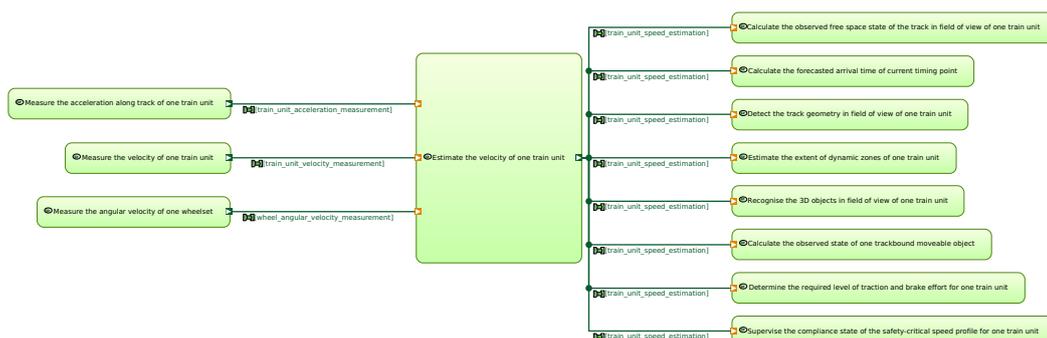


Figure 50: Context of Estimate the velocity of one train unit

Input		From
Measured output state of angular velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • wheel_angular_velocity_measurement 		Measure the angular velocity of one wheelset
Measured output state velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_velocity_measurement 		Measure the velocity of one train unit
Measured output state of acceleration for one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_acceleration_measurement 		Measure the acceleration along track of one train unit
Output	To	
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Determine the required level of traction and brake effort for one train unit	
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Supervise the compliance state of the safety-critical speed profile for one train unit	
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Calculate the observed free space state of the track in field of view of one train unit	
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Detect the track geometry in field of view of one train unit	
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Recognise the 3D objects in field of view of one train unit	

Output	To
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Calculate the observed state of one trackbound moveable object
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Estimate the extent of dynamic zones of one train unit
Estimated velocity of one train unit Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Calculate the forecasted arrival time of current timing point

5.2.44 Maintain current date and time

Attribute	Content
Name	Maintain current date and time
Description	This function maintains the current DateTime as the single reference.
Rationale	To be able to make timing critical decision, a lot of functions need the current time as input. As different time sources lead to problems, this functions provides the current time centrally and authoritatively.
Realized system functions	Maintain current date and time

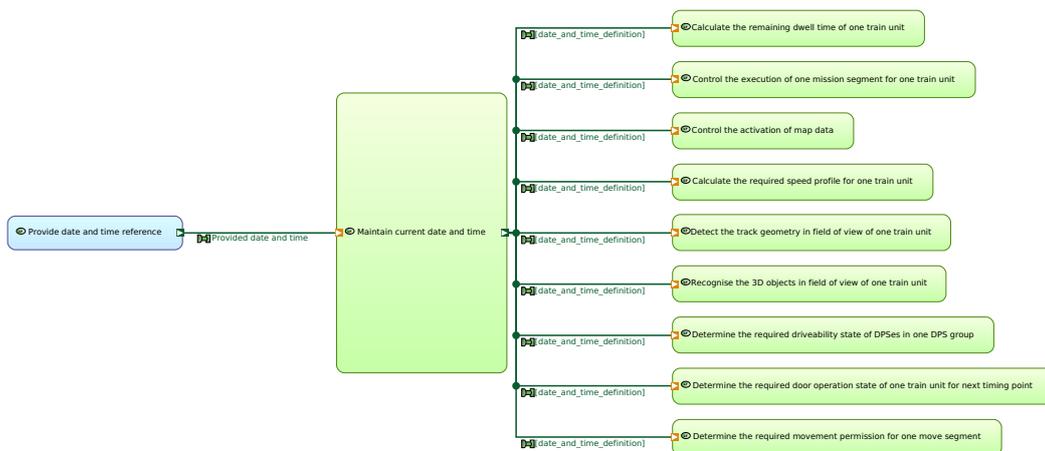


Figure 51: Context of Maintain current date and time

Input	From
Provided date and time Exchange Items: <i>None</i>	Provide date and time reference
Output	To
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Determine the required door operation state of one train unit for next timing point
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Determine the required movement permission for one move segment
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Calculate the remaining dwell time of one train unit
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Control the activation of map data
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Recognise the 3D objects in field of view of one train unit
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Determine the required driveability state of DPSes in one DPS group
Estimated internal state of time Exchange Items: <ul style="list-style-type: none"> • date_and_time_definition 	Detect the track geometry in field of view of one train unit

Output	To
<p>Estimated internal state of time</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • date_and_time_definition 	Control the execution of one mission segment for one train unit
<p>Estimated internal state of time</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> • date_and_time_definition 	Calculate the required speed profile for one train unit

5.2.45 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.
Rationale	To be able to make decision with regard to the topology, a lot of functions need the Map Data as input. As different definitions of Map Data lead to problems, this functions provides the Map Data centrally and authoritatively.
Realized system functions	Maintain map data

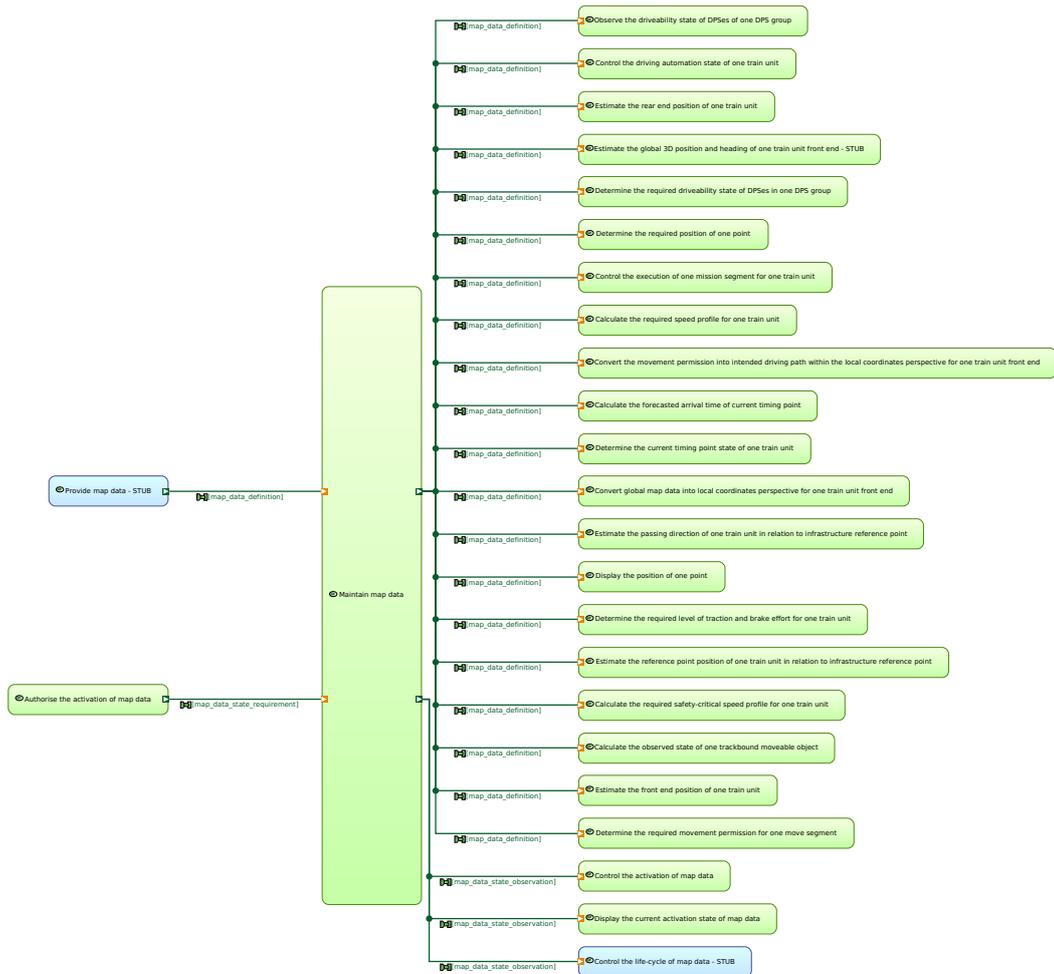


Figure 52: Context of Maintain map data

Input	From
Abstract required state of map data Exchange Items: <ul style="list-style-type: none"> map_data_state_requirement 	Authorise the activation of map data
Provided map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Provide map data - STUB
Output	To
Defined active map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Control the driving automation state of one train unit

Output	To
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Calculate the required speed profile for one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Determine the required level of traction and brake effort for one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Determine the current timing point state of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Determine the required driveability state of DPSes in one DPS group
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Calculate the observed state of one trackbound moveable object
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Convert the movement permission into intended driving path within the local coordinates perspective for one train unit front end
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Convert global map data into local coordinates perspective for one train unit front end
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Determine the required position of one point
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Observe the driveability state of DPSes of one DPS group

Output	To
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Display the position of one point
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Determine the required movement permission for one move segment
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Control the execution of one mission segment for one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Estimate the rear end position of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Estimate the front end position of one train unit
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Estimate the global 3D position and heading of one train unit front end - STUB
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Calculate the forecasted arrival time of current timing point
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Estimate the reference point position of one train unit in relation to infrastructure reference point
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Calculate the required safety-critical speed profile for one train unit

Output	To
Defined active map data Exchange Items: <ul style="list-style-type: none"> • map_data_definition 	Estimate the passing direction of one train unit in relation to infrastructure reference point
Reported state of map data Exchange Items: <ul style="list-style-type: none"> • map_data_state_observation 	Control the activation of map data
Reported state of map data Exchange Items: <ul style="list-style-type: none"> • map_data_state_observation 	Control the life-cycle of map data - STUB
Reported state of map data Exchange Items: <ul style="list-style-type: none"> • map_data_state_observation 	Display the current activation state of map data

5.2.46 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.
Rationale	To be able to make decisions with regard to configuration parameters of the Train Unit, a lot of functions need the Train Unit Configuration Data as input. As different sources of these parameters lead to problems, this functions provides the Train Unit Configuration Data centrally and authoritatively.
Realized system functions	Maintain train unit configuration data

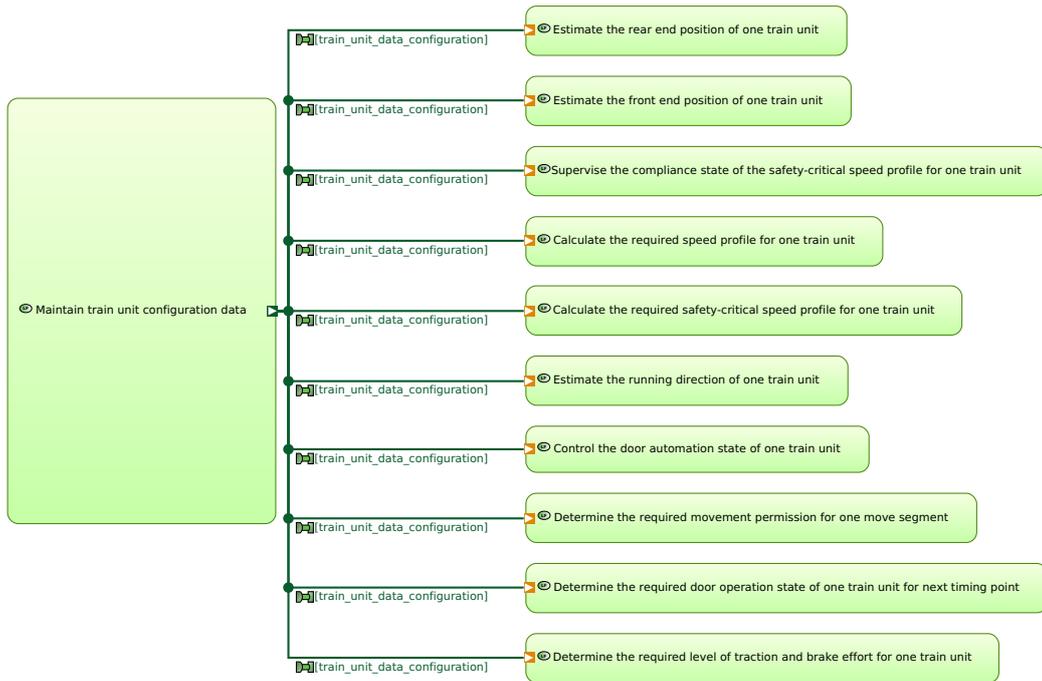


Figure 53: Context of Maintain train unit configuration data

Input	From
<i>No inputs defined</i>	
Output	To
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Determine the required door operation state of one train unit for next timing point
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Determine the required level of traction and brake effort for one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Estimate the rear end position of one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Calculate the required speed profile for one train unit

Output	To
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Control the door automation state of one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Determine the required movement permission for one move segment
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Estimate the running direction of one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Estimate the front end position of one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Calculate the required safety-critical speed profile for one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Supervise the compliance state of the safety-critical speed profile for one train unit

5.2.47 Measure the acceleration along track of one train unit

Attribute	Content
Name	Measure the acceleration along track of one train unit
Description	This function measures the linear acceleration (m/s ² or g) at a point in the train unit.
Rationale	To be able to estimate various physical parameters regarding the motion state of a Train Unit, the acceleration along the track axis needs to be measured.

Attribute	Content
Realized system functions	Sense the motion of one train unit

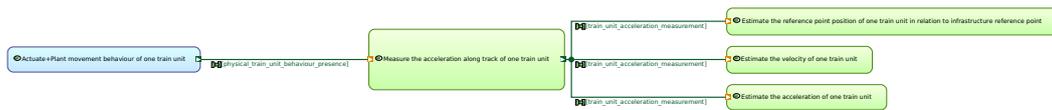


Figure 54: Context of Measure the acceleration along track of one train unit

Input	From
Plant actual output state of train unit motion Exchange Items: • physical_train_unit_behaviour_presence	Actuate+Plant movement behaviour of one train unit
Output	To
Measured output state of acceleration for one train unit Exchange Items: • train_unit_acceleration_measurement	Estimate the velocity of one train unit
Measured output state of acceleration for one train unit Exchange Items: • train_unit_acceleration_measurement	Estimate the acceleration of one train unit
Measured output state of acceleration for one train unit Exchange Items: • train_unit_acceleration_measurement	Estimate the reference point position of one train unit in relation to infrastructure reference point

5.2.48 Measure the angular velocity of one wheelset

Attribute	Content
Name	Measure the angular velocity of one wheelset
Description	This function measures the angular velocity of one wheelset (equivalent to rotations per minute).
Rationale	To be able to estimate various physical parameters regarding the motion state of a Train Unit, the angular velocity of one wheel set needs to be measured.
Realized system functions	Sense the motion of one train unit

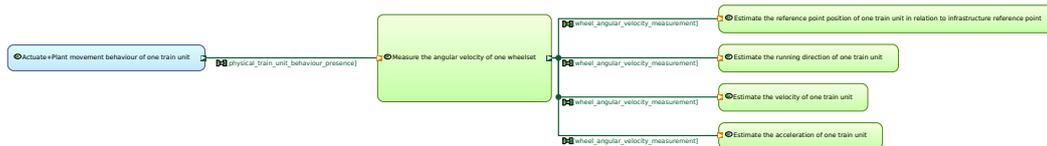


Figure 55: Context of Measure the angular velocity of one wheelset

Input	From
Plant actual output state of train unit motion Exchange Items: <ul style="list-style-type: none"> • physical_train_unit_behaviour_presence 	Actuate+Plant movement behaviour of one train unit
Output	To
Measured output state of angular velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • wheel_angular_velocity_measurement 	Estimate the velocity of one train unit
Measured output state of angular velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • wheel_angular_velocity_measurement 	Estimate the acceleration of one train unit
Measured output state of angular velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • wheel_angular_velocity_measurement 	Estimate the reference point position of one train unit in relation to infrastructure reference point
Measured output state of angular velocity for one train unit Exchange Items: <ul style="list-style-type: none"> • wheel_angular_velocity_measurement 	Estimate the running direction of one train unit

5.2.49 Measure the velocity of one train unit

Attribute	Content
Name	Measure the velocity of one train unit
Description	This function measures the velocity of the train unit.

Attribute	Content
Rationale	To be able to estimate various physical parameters regarding the motion state of a Train Unit, the velocity of one Train Unit needs to be measured.
Realized system functions	Sense the motion of one train unit

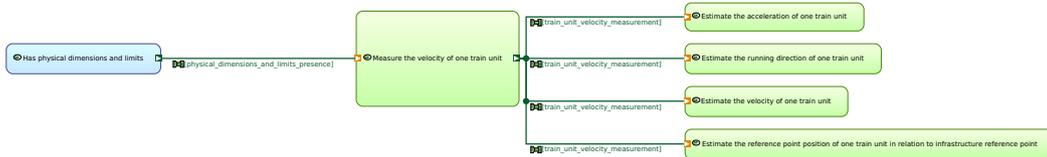


Figure 56: Context of Measure the velocity of one train unit

Input	From
Present actual output of dimensions and limits in field of view of one train unit Exchange Items: <ul style="list-style-type: none"> physical_dimensions_and_limits_presence 	Has physical dimensions and limits
Output	To
Measured output state velocity for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_velocity_measurement 	Estimate the velocity of one train unit
Measured output state velocity for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_velocity_measurement 	Estimate the reference point position of one train unit in relation to infrastructure reference point
Measured output state velocity for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_velocity_measurement 	Estimate the acceleration of one train unit
Measured output state velocity for one train unit Exchange Items: <ul style="list-style-type: none"> train_unit_velocity_measurement 	Estimate the running direction of one train unit

5.2.50 Observe the driveability state of DPSes of one DPS group

Attribute	Content
Name	Observe the driveability state of DPSes of one DPS group
Description	This function maps the position of the Point to drivability states of the Drive Protection Sections in one Drive Protection Section Group.
Rationale	To be able to control the motion of Train units an the position state of infrastructure assets, the system needs to observe the driveability state of Drive Protection Sections from the observation of point positions.
Realized system functions	Observe the position of one point

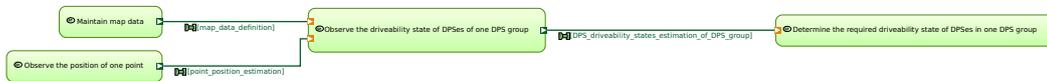


Figure 57: Context of Observe the driveability state of DPSes of one DPS group

Input	From
Estimated internal position state of one point Exchange Items: • point_position_estimation	Observe the position of one point
Defined active map data Exchange Items: • map_data_definition	Maintain map data
Output	To
Estimated internal driveability state of one DPS Exchange Items: • DPS_driveability_states_estimation_of_DPS_group	Determine the required driveability state of DPSes in one DPS group

5.2.51 Observe the position of one point

Attribute	Content
Name	Observe the position of one point
Description	This function observes the position state of one Point from the observation of the switch rail position on one or more Point Machines.
Rationale	To be able to observe Drive Protection Section driveability states, first the position state of one point needs to be observed from the position state of the switch rail on one or more point machines.

Attribute	Content
Realized system functions	Observe the position of one point

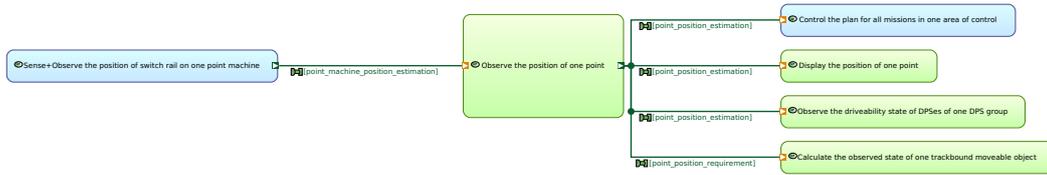


Figure 58: Context of Observe the position of one point

Input	From
Estimated internal state of point machine position Exchange Items: <ul style="list-style-type: none"> point_machine_position_estimation 	Sense+Observe the position of switch rail on one point machine
Output	To
Estimated internal position state of one point Exchange Items: <ul style="list-style-type: none"> point_position_estimation 	Observe the driveability state of DPSes of one DPS group
Estimated internal position state of one point Exchange Items: <ul style="list-style-type: none"> point_position_requirement 	Calculate the observed state of one trackbound moveable object
Estimated internal state of point position Exchange Items: <ul style="list-style-type: none"> point_position_estimation 	Control the plan for all missions in one area of control
Estimated internal state of point position Exchange Items: <ul style="list-style-type: none"> point_position_estimation 	Display the position of one point

5.2.52 Recognise the 3D objects in field of view of one train unit

Attribute	Content
Name	Recognise the 3D objects in field of view of one train unit

Attribute	Content
Description	This function detects individual objects out of the captured, abstract representation of environmental features. Specific object attributes are provided as output.
Rationale	To be able to assess the risk of obstacles on or near the line, these obstacles and their properties need to be detected out of the perception sensor inputs.
Realized system functions	Observe the free space of the track in the field of view of one train unit

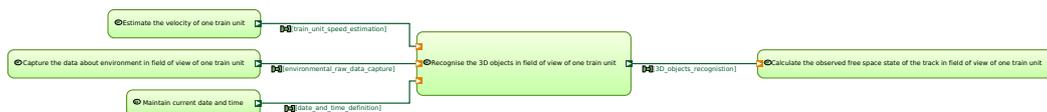


Figure 59: Context of Recognise the 3D objects in field of view of one train unit

Input	From
Estimated internal state of time Exchange Items: • date_and_time_definition	Maintain current date and time
Sensed output state of environmental raw data Exchange Items: • environmental_raw_data_capture	Capture the data about environment in field of view of one train unit
Estimated internal state of speed Exchange Items: • train_unit_speed_estimation	Estimate the velocity of one train unit
Output	To
Recognised 3D objects in field of view of one train unit Exchange Items: • 3D_objects_recognition	Calculate the observed free space state of the track in field of view of one train unit

5.2.53 Register the automatic driving engagement input event

Attribute	Content
Name	Register the automatic driving engagement input event

Attribute	Content
Description	This function registers the input event from the Train Driver operating the Driver Machine Interface (DMI) into a continuous input state requirement for the automatic driving engagement state.
Rationale	To be able to detect a human interaction with the system.
Realized system functions	Register the automatic driving engagement input event



Figure 60: Context of Register the automatic driving engagement input event

Input	From
Abstract required state of departure authorisation Exchange Items: <ul style="list-style-type: none"> • DMI_engage_event 	Authorise the departure of one train unit
Output	To
Abstract required state of departure authorisation Exchange Items: <ul style="list-style-type: none"> • DMI_engage_button_state 	Control the driving automation state of one train unit

5.2.54 Register the map data version authorisation input event

Attribute	Content
Name	Register the map data version authorisation input event
Description	This function registers the input event from the Infrastructure Manager (IM) operating the HMI into a continuous input state requirement for the map data version authorisation state.
Rationale	To be able to detect a human interaction with the system.
Realized system functions	Register the map data version authorisation input event



Figure 61: Context of Register the map data version authorisation input event

Input	From
Permission of activation of one map data version Exchange Items: <ul style="list-style-type: none"> • map_data_authorisation_command 	Command the authorisation of one version of map data
Output	To
Permission of activation of one map data version Exchange Items: <ul style="list-style-type: none"> • map_data_authorisation_command 	Authorise the activation of map data

5.2.55 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.
Rationale	To be able to detect the passing of an infrastructure reference point, under the current technological limitations, the passing of one Eurobalise needs to be detected.
Realized system functions	Sense the data of one eurobalise

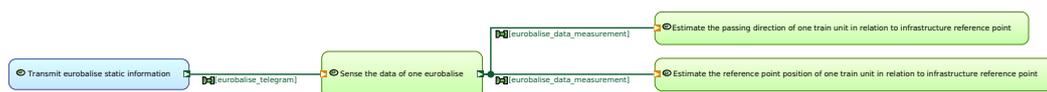


Figure 62: Context of Sense the data of one eurobalise

Input	From
Balise data Exchange Items: <ul style="list-style-type: none"> • eurobalise_telegram 	Transmit eurobalise static information
Output	To
Sensed output state of eurobalise data Exchange Items: <ul style="list-style-type: none"> • eurobalise_data_measurement 	Estimate the passing direction of one train unit in relation to infrastructure reference point

Output	To
<p>Sensed output state of eurobalise data</p> <p>Exchange Items:</p> <ul style="list-style-type: none"> eurobalise_data_measurement 	<p>Estimate the reference point position of one train unit in relation to infrastructure reference point</p>

5.2.56 Supervise the compliance state of the safety-critical speed profile for one train unit

Attribute	Content
Name	Supervise the compliance state of the safety-critical speed profile for one train unit
Description	This function supervises the compliance of the Train Unit estimated motion state with the safety-critical speed profile of that Train Unit by taking the estimated front-end position, velocity and acceleration of the Train Unit into account. If the speed-profile is about to be violated or is actually violated, an emergency brake reaction is required.
Rationale	<p>The physical train unit is technical state of the art that means we have to split between safety and non safety critical traction and brake effort functions.</p> <p>To be able to protect the Train Unit motion from exceeding safe limits, the system needs to supervise the estimated motion state against the safety-critical speed profile.</p>
Realized system functions	Control the motion of one train unit



Figure 63: Context of Supervise the compliance state of the safety-critical speed profile for one train unit

Input	From
Abstract required maximum speed over distance of one train unit Exchange Items: <ul style="list-style-type: none"> • maximal_speed_over_distance_requirement 	Calculate the required safety-critical speed profile for one train unit
Estimated internal state of speed Exchange Items: <ul style="list-style-type: none"> • train_unit_speed_estimation 	Estimate the velocity of one train unit
Estimated internal state of front end position Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_position_estimation 	Estimate the front end position of one train unit
Estimated internal state of acceleration Exchange Items: <ul style="list-style-type: none"> • train_unit_acceleration_estimation 	Estimate the acceleration of one train unit
Defined train unit configuration data Exchange Items: <ul style="list-style-type: none"> • train_unit_data_configuration 	Maintain train unit configuration data
Output	To
Abstract required restrictions on the motion state of one train unit Exchange Items: <ul style="list-style-type: none"> • emergency_brake_requirement 	Display the restrictions to the motion of one train unit
Abstract required restrictions on the motion state of one train unit Exchange Items: <ul style="list-style-type: none"> • emergency_brake_requirement 	Control the traction and brake effort of one train unit

5.3 Logical 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.

5.3.1 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	<i>None</i>
Realized actor functions	Actuate+Plant behaviour of all doors of one train unit



Figure 64: 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: • door_state_requirement	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: <i>None</i>	Sense+Observe the state of all doors of one train unit

5.3.2 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	<i>None</i>
Realized actor functions	Actuate+Plant movement behaviour of one train unit



Figure 65: Context of Actuate+Plant movement behaviour of one train unit

Input	From
Plant external required input state of movement Exchange Items: <i>None</i>	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	Measure the angular velocity of one wheelset
Plant actual output state of train unit motion Exchange Items: • physical_train_unit_behaviour_presence	Measure the acceleration along track of one train unit

5.3.3 Authorise the departure of one train unit

Attribute	Content
Name	Authorise the departure of one train unit
Description	This function represents the responsibility to validate, if all conditions are fulfilled to engage the departure of the train unit according to the rules of GoA2 operation.
Rationale	<i>None</i>
Realized actor functions	Authorise the departure of one train unit



Figure 66: 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

5.3.4 Command the authorisation of one version of map data

Attribute	Content
Name	Command the authorisation of one version of map data

Attribute	Content
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.
Rationale	<i>None</i>
Realized actor functions	Command the authorisation of one version of map data



Figure 67: 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

5.3.5 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	<i>None</i>
Realized actor functions	Command the requested state of all doors of one train unit



Figure 68: Context of Command the requested state of all doors of one train unit

Input		From
Human perceptible state of door operation 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: <i>None</i>	Control the required state of all doors of one train unit	

5.3.6 Contains physical objects

Attribute	Content
Name	Contains physical objects
Description	This function represents the presence of physical objects in the Environment.
Rationale	<i>None</i>
Realized actor functions	Contains physical objects



Figure 69: Context of Contains physical objects

Input	From
<i>No inputs defined</i>	

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

5.3.7 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	<i>None</i>
Realized actor functions	Control the life-cycle of map data - STUB



Figure 70: 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
<i>No outputs defined</i>	

5.3.8 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
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 of Automation (GoA) for Move Segments of the missions and also the required door operations for passenger exchanges in Stop Segments of the missions.
Rationale	<i>None</i>
Realized actor functions	Control the plan for all missions in one area of control



Figure 71: Context of Control the plan for all missions in one area of control

Input	From
Estimated internal state of point position Exchange Items: <ul style="list-style-type: none"> point_position_estimation 	Observe the position of one point
Estimated arrival time of the targeted timing point Exchange Items: <ul style="list-style-type: none"> arrival_time_to_timing_point_estimation 	Calculate the forecasted arrival time of current timing point
Abstract required state of one movement permission Exchange Items: <ul style="list-style-type: none"> movement_permission_requirement 	Determine the required movement permission for one move segment
Estimated internal state of moveable object Exchange Items: <ul style="list-style-type: none"> resolved_trackbound_movable_object_estimation 	Calculate the observed state of one trackbound moveable object
Output	To
Abstract required state of missions in one area of control Exchange Items: <ul style="list-style-type: none"> mission_requirement 	Control the execution of one mission segment for one train unit

5.3.9 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	<i>None</i>
Realized actor functions	Control the plan for restriction areas over time for all tracks in one area of control



Figure 72: Context of Control the plan for restriction areas over time for all tracks in one area of control

Input	From
<i>No inputs defined</i>	
Output	To
Abstract required state of restriction areas in one area of control Exchange Items: <ul style="list-style-type: none"> • restriction_area_requirement_STUB 	Control the life-cycle of one restriction area - STUB

5.3.10 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 is a Physical Train Unit Operation Systems (PTU-OS) function controlling all doors.
Rationale	<i>None</i>
Realized actor functions	Control the required state of all doors of one train unit



Figure 73: 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: <i>None</i>	Command the requested state of all doors of one train unit
Abstract required state of door operation of one train unit Exchange Items: <ul style="list-style-type: none"> • door_operation_state_requirement 	Determine the required door operation state of one train unit for next timing point
Output	To
Plant external required input state of one train units doors Exchange Items: <ul style="list-style-type: none"> • door_state_requirement 	Actuate+Plant behaviour of all doors of one train unit

5.3.11 Control the sounding state of horn

Attribute	Content
Name	Control the sounding state of horn
Description	This function commands the activation of the Physical Train Unit horn.
Rationale	<i>None</i>
Realized actor functions	Control the sounding state of horn



Figure 74: Context of Control the sounding state of horn

Input	From
Abstract required state of one train unit warning device Exchange Items: <ul style="list-style-type: none"> audible_warning_device_requirement 	Determine the required state of train unit warning device

Output	To
<i>No outputs defined</i>	

5.3.12 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 (PTU), depending on the technical properties of this Train Unit.
Rationale	<i>None</i>
Realized actor functions	Control the traction and brake effort of one train unit

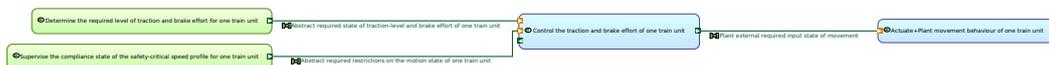


Figure 75: Context of Control the traction and brake effort of one train unit

Input	From
Abstract required restrictions on the motion state of one train unit Exchange Items: <ul style="list-style-type: none"> emergency_brake_requirement 	Supervise the compliance state of the safety-critical speed profile for one train unit

Input	From
Abstract required state of traction-level and brake effort of one train unit Exchange Items: <ul style="list-style-type: none"> • relative_traction_braking_effort_level_requirement 	Determine the required level of traction and brake effort for one train unit
Output	To
Plant external required input state of movement Exchange Items: <i>None</i>	Actuate+Plant movement behaviour of one train unit

5.3.13 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	<i>None</i>
Realized actor functions	Decide about intervention into train unit movement

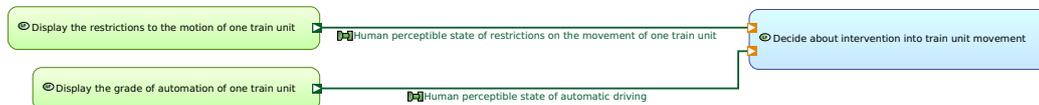


Figure 76: Context of Decide about intervention into train unit movement

Input	From
Human perceptible state of automatic driving Exchange Items: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • movement_authority_indication 	Display the restrictions to the motion of one train unit
Output	To
<i>No outputs defined</i>	

5.3.14 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.
Rationale	<i>None</i>
Realized actor functions	Exert force on one switch rail actuation mount point



Figure 77: Context of Exert force on one switch rail actuation mount point

Input	From
Plant external required input state of point machine position	Determine the required position state of one point machine
Exchange Items: <ul style="list-style-type: none"> point_machine_actuation_requirement 	

Output	To
<i>No outputs defined</i>	

5.3.15 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	<i>None</i>
Realized actor functions	Has physical dimensions and limits

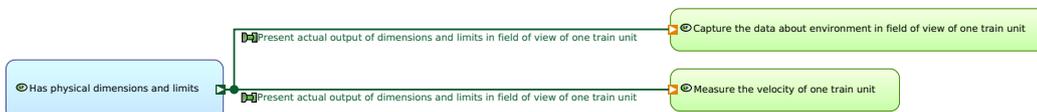


Figure 78: Context of Has physical dimensions and limits

Input	From
<i>No inputs defined</i>	

Output	To
Present actual output of dimensions and limits in field of view of one train unit Exchange Items: <ul style="list-style-type: none"> • physical_dimensions_and_limits_presence 	Capture the data about environment in field of view of one train unit
Present actual output of dimensions and limits in field of view of one train unit Exchange Items: <ul style="list-style-type: none"> • physical_dimensions_and_limits_presence 	Measure the velocity of one train unit

5.3.16 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	<i>None</i>
Realized actor functions	Observe the intended movement direction relative to the front end of the train unit

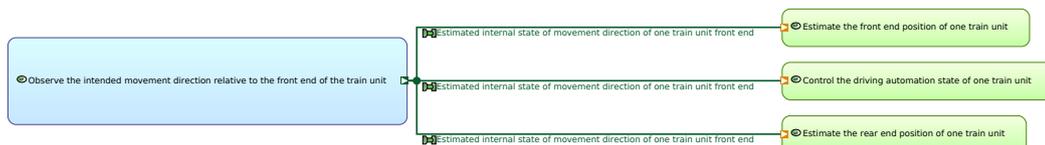


Figure 79: Context of Observe the intended movement direction relative to the front end of the train unit

Input	From
<i>No inputs defined</i>	
Output	To
Estimated internal state of movement direction of one train unit front end Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_movement_direction_intention 	Control the driving automation state of one train unit

Output	To
Estimated internal state of movement direction of one train unit front end Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_movement_direction_intention 	Estimate the rear end position of one train unit
Estimated internal state of movement direction of one train unit front end Exchange Items: <ul style="list-style-type: none"> • train_unit_front_end_movement_direction_intention 	Estimate the front end position of one train unit

5.3.17 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	<i>None</i>
Realized actor functions	Observe the state of the railway - STUB



Figure 80: Context of Observe the state of the railway - STUB

Input	From
Human perceptible state of point position Exchange Items: <ul style="list-style-type: none"> • point_position_indication 	Display the position of one point

Output	To
<i>No outputs defined</i>	

5.3.18 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.
Rationale	<i>None</i>
Realized actor functions	Observe the train integrity state of one physical train unit



Figure 81: Context of Observe the train integrity state of one physical train unit

Input	From
<i>No inputs defined</i>	
Output	To
Estimated internal state of train integrity Exchange Items: <ul style="list-style-type: none"> • train_unit_integrity_state_estimation 	Estimate the rear end position of one train unit

5.3.19 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	<i>None</i>
Realized actor functions	Provide date and time reference



Figure 82: Context of Provide date and time reference

Input	From
<i>No inputs defined</i>	
Output	To
Provided date and time Exchange Items: <i>None</i>	Maintain current date and time

5.3.20 Provide map data - STUB

Attribute	Content
Name	Provide map data - STUB
Description	This function enables to provide Map Data with predefined version. Multiple versions of Map Data can also be provided.
Rationale	<i>None</i>
Realized actor functions	Provide map data - STUB



Figure 83: Context of Provide map data - STUB

Input	From
No inputs defined	
Output	To
Provided map data Exchange Items: <ul style="list-style-type: none"> map_data_definition 	Maintain map data

5.3.21 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.
Rationale	None
Realized actor functions	Sense+Observe the position of switch rail on one point machine

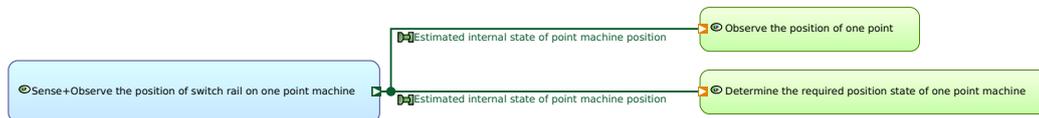


Figure 84: Context of Sense+Observe the position of switch rail on one point machine

Input	From
No inputs defined	
Output	To
Estimated internal state of point machine position Exchange Items: <ul style="list-style-type: none"> point_machine_position_estimation 	Observe the position of one point
Estimated internal state of point machine position Exchange Items: <ul style="list-style-type: none"> point_machine_position_estimation 	Determine the required position state of one point machine

5.3.22 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	<i>None</i>
Realized actor functions	Sense+Observe the state of all doors of one train unit

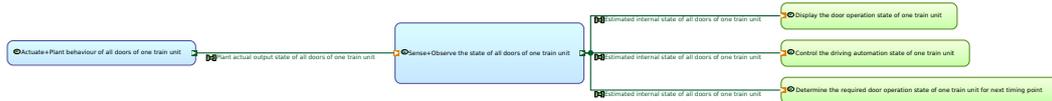


Figure 85: Context of Sense+Observe the state of all doors of one train unit

Input	From
Plant actual output state of all doors of one train unit Exchange Items: <i>None</i>	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 driving automation state of one train unit
Estimated internal state of all doors of one train unit Exchange Items: • all_doors_state_observation	Determine the required door operation state of one train unit for next timing point
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

5.3.23 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.

Attribute	Content
Rationale	None
Realized actor functions	Transmit eurobalise static information



Figure 86: Context of Transmit eurobalise static information

Input	From
<i>No inputs defined</i>	
Output	To
Balise data Exchange Items: <ul style="list-style-type: none"> eurobalise_telegram 	Sense the data of one eurobalise