ERJU SYSTEM PILLAR

System Concept_CCS - Main

CCS System Concept

)

Author(s) Davinder Bhatia

Abstract Logical architecture (on System Level 3) of the CCS Reference: Coherent overview on the CCS reference architecture identifying the TSI relevant parts. Specify the common CCS architecture including all interface relevant for: · Interoperability · basic functional allocation · to facilitate integration · overview on Level 3 interface standards and external interfaces · clarification of the scope and the system boundaries of the CCS system · High level control loops including high level hazards and allocation of risk acceptance for the logical components on System Level 3. Support of vertical PRAMS and Security design work.

Config Item	System Concept
Document ID	SC2_4/D03 System Level 3 Architecture#714331 System Concept_CCS - Main
Classification	Public
Status	In Progress (first discussion in domain started)
Version	0.1
Revision	714330
Last Change Date	24.09.2025
Copyright	Brussels: Europe's Rail Joint Undertaking, 2025

This work is currently a work in progress. The content presented is subject to change as it undergoes further review, refinement, and development. Please do not consider this version as final or authoritative.

INFO: History table is not displayed, because this document is in status **doc_inprogress**.
RULE: History table is not displayed, in statuses: { draft doc_open doc_inprogress doc_contentApproval doc_contentDecision }
CONTACT: For more information contact Administrator

Approval by reviewers (captured at end of 'In Review by System Pillar')

Approval by approvers (captured at end of 'In Approval by System Pillar')

Table of Contents

1 Preamble

Single European Railway Area (SERA) - European Green Deal Single European Railway Area is a system of harmonised and connected rail networks across the European Union (EU). Aiming to create a more efficient, sustainable, and competitive railway system. System Pillar role, to fulfil these objectives, is to standardise the CCS system enabling the same system to be deployed across Europe.

A harmonised CCS system is only achievable by defining and agreeing a harmonised system[1] describing how the CCS operates, focusing on the functions and tasks needed to perform harmonised operational processes. It outlines the components or modules of the CCS system, how they interact, and how they collectively contribute to achieving the overall objectives of the CCS system.

1.1 Purpose

This document summarises the System Pillar harmonised CCS architecture based upon the operational needs CCS System Definition, CCS System Architecture Description and supporting documents. The document is intended as an over-arching document and an introduction to the CCS architecture. System Pillar primarily uses the ARCADIA methodology at all levels. This document incorporates all outputs from Task 2 (CCS). It does not replace existing System Pillar outputs, but provides a summary and reference to them. This document also highlights the CCS architecture requirements to fulfil the relevant System Pillar targets, outcomes and objectives.

1.2 Glossary

Refer to System Pillar Glossary

2 CCS System Concept

2.1 CCS Overview

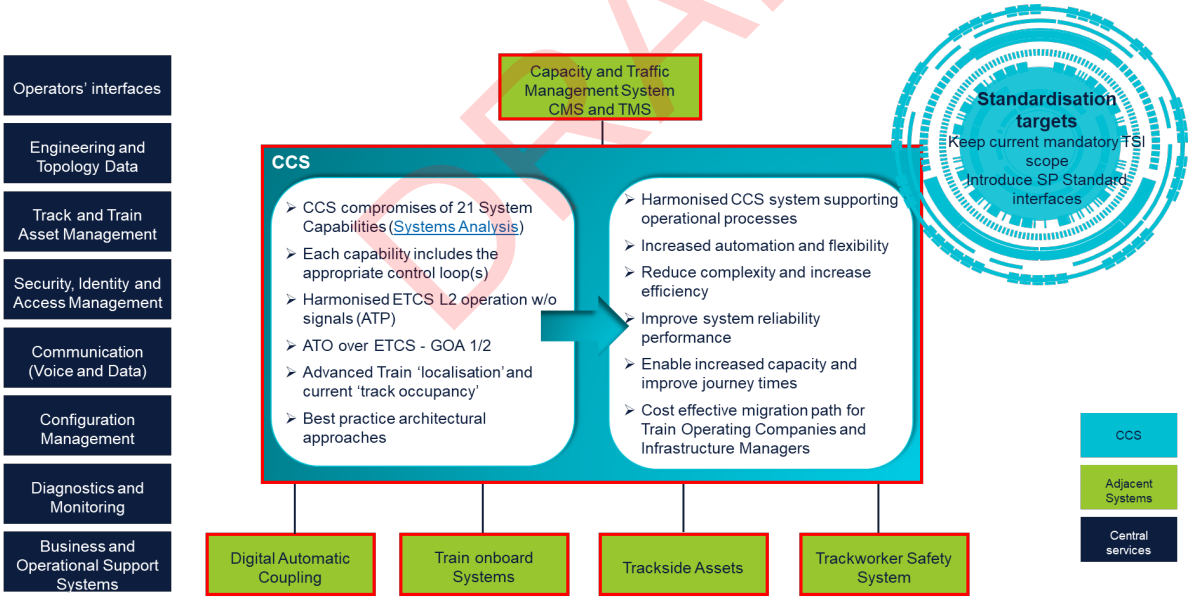


Figure 1 - CCS Overview

[FIGURE 1 TO BE REPLACED with a CCS PHYSICAL ARCHITECTURE]

2.2 CCS System Purpose and Functional Scope

Purpose
The CCS System is a next-generation digital signalling control and command platform to deliver safe, efficient, and automated train operations. The first specification release supports ETCS Level 2 and

Automatic Train Operation (ATO) (up to GoA 2), and is aligned with the Single European Railway Area (SERA) vision. The CCS system scope is bound by the CCS System Capabilities and the system boundary defied by Logical Interfaces . **[**SPT2ARC-4520 **]**

CCS Functional Scope
CCS Functional scope focuses on operational and system usage and future versions will include mission profiles, maintenance and support scenarios. The functional scope is expressed a CCS capabilities in the table below:

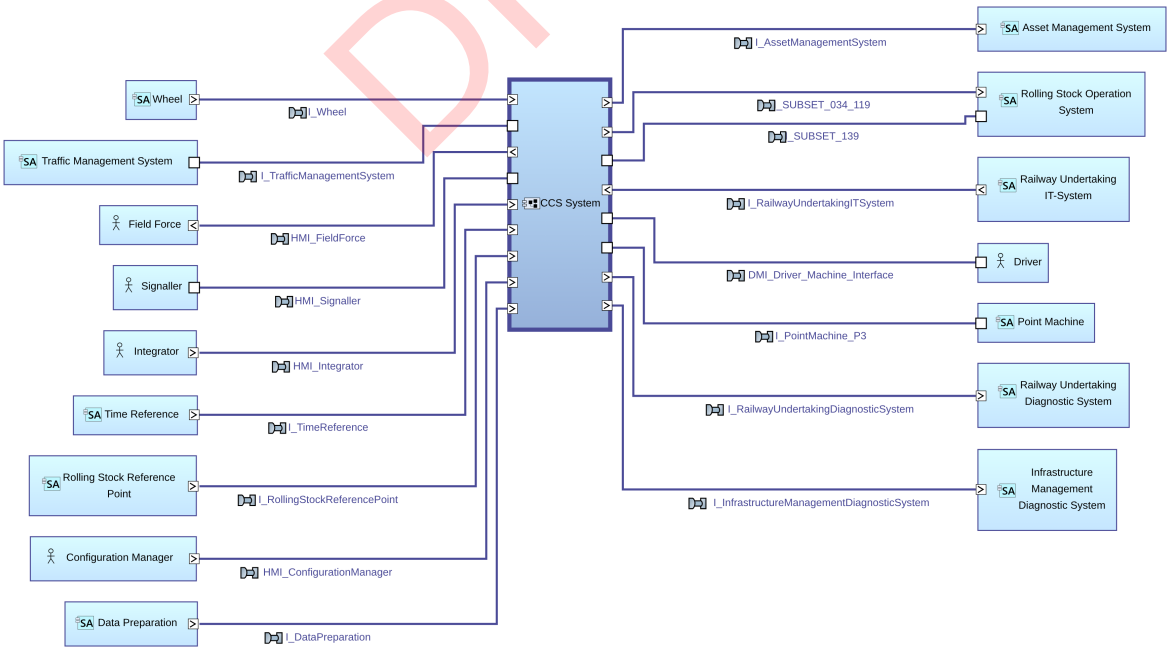
CCS Capabilities	Description
Prepare Train Departure and start	
Perform operational plan movement	· Executes train movements based on a centralised operational plan. · Ensures trains follow scheduled paths and timings. · Supports movement restrictions and dynamic updates.
Localise train in railway infrastructure	· Tracks train positions using onboard and trackside data. · Provides real-time updates to drivers and signallers. · Enables accurate traffic planning and conflict resolution.
Set point position	· Controls track switches (points) for route setting. · Ensures correct alignment for train paths. · Responds to both planned and manual requests.
Grant Movement Permission	· Controls safe access to track sections. · Grants movement authority based on infrastructure and traffic. · Releases track sections once cleared. · Shortens permissions dynamically without disrupting safety.
Perform Train Movement ·	· Controls and supervises train motion in real time. · Supports both manual and automatic driving. · Ensures trains stop accurately at planned locations. · Safety-critical aware using rolling stock, loading gauge, infrastructure characteristics (points, switches, level crossings), rules/permissions, usage restrictions and station information.
Train Arrival	
Approaching Stop Location	
Splitting and Joining Trains	
Pass a level crossing	
Transition into and out of ETCS areas	
Activate level crossing / Deactivate level crossing	· Controls road-rail interfaces safely. · Automatically protects crossings when trains approach. · Reopens crossings once trains have passed.
Activate usage restriction / Deactivate usage restriction	· Implements temporary operational constraints. · Applies speed limits, track closures, or other restrictions. · Supports both planned and emergency scenarios.

CCS Capabilities	Description
Drive train automatically	· Controls Automatic Train Operation driving moves up to GoA2. · Controls traction and braking following the operational plan. · Reduces driver workload and improves punctuality.
Additional Functional Highlights	· Semi-automatic/manual or fully automated plan execution. · In-cab signalling and driver advisory support via a harmonised DMI. · Trains operate seamlessly across geographical national borders eliminating national (local) signalling systems. · Advanced Train Protection System: Data driven *full* train supervision and control using dynamic train braking distances. · Speed Supervision covering all normal driving moves: Monitors compliance with speed profiles and enforces limits are exceeded (including temporary speed restrictions). · Brake and Traction Control: Interfaces with rolling stock to manage braking and traction, including under special conditions like winter or low adhesion. · Emergency Handling: Supports emergency brake commands and safe standstill supervision. · System Monitoring: Evaluates asset health and supports predictive maintenance. · Interoperability: Built on ETCS Baseline 3, with future readiness for Baseline 4 and FRMCS.

[SPT2ARC-4685]

2.2.1 CCS System Context

The SPMS-2098 - CCS System is a vital framework in railway operations, ensuring the safe and efficient movement of trains. By utilising precise signalling and train protection mechanisms, it helps to prevent collisions and mitigate other operational risks. The SPMS-2098 - CCS System enables seamless and secure train operations across diverse railway networks, prioritising safety and reliability.



[

Figure 2 Context Diagram of CCS System

,

Interface	Direction	Partner
• SPMS-2198 - HMI_Signaller	bidirectional	• SPMS-2090 - Signaller
• SPMS-2197 - I_SUBSET_034_119	bidirectional	• SPMS-2094 - Rolling Stock Operation System
• SPMS-2199 - HMI_FieldForce	outgoing to	• SPMS-6160 - Field Force
• SPMS-2201 - I_Wheel	incoming from	• SPMS-2101 - Wheel
• SPMS-2205 - I_DataPreparation	incoming from	• SPMS-2088 - Data Preparation
• SPMS-2206 - HMI_ConfigurationManager	incoming from	• SPMS-2103 - Configuration Manager
• SPMS-5133 - I_RailwayUndertakingITSystem	incoming from	• SPMS-5084 - Railway Undertaking IT-System
• SPMS-2202 - I_PointMachine_P3	bidirectional	• SPMS-2100 - Point Machine
• SPMS-2204 - DMI_Driver_Machine_Interface	bidirectional	• SPMS-2096 - Driver
• SPMS-2195 - I_SUBSET_139	bidirectional	• SPMS-2094 - Rolling Stock Operation System
• SPMS-2200 - I_TrafficManagementSystem	bidirectional	• SPMS-2097 - Traffic Management System
• SPMS-2196 - I_RollingStockReferencePoint	incoming from	• SPMS-2091 - Rolling Stock Reference Point
• SPMS-6229 - I_AssetManagementSystem	outgoing to	• SPMS-6204 - Asset Management System

Interface	Direction	Partner
• SPMS-6230 - I_InfrastructureManagementDiagnosticSystem	outgoing to	• SPMS-6202 - Infrastructure Management Diagnostic System
• SPMS-6231 - I_RailwayUndertakingDiagnosticSystem	outgoing to	• SPMS-6203 - Railway Undertaking Diagnostic System
• SPMS-6266 - I_TimeReference	incoming from	• SPMS-6265 - Time Reference
• SPMS-6516 - HMI_Integrator	incoming from	• SPMS-6240 - Integrator

, SPMS-2098 **]**

2.2.2 CCS Functional Architecture

Functional View
The CCS system capabilities features are analysed to form a structural view representing the logical functions, their internal relationships and how they are connected to fulfil the system objectives and operational need. The structural view is refined further to show how they are decomposed into logical blocks, allocating functions accordingly i.e. who does what, how they talk to each other, and how they work together to fulfil the overall CCS system's purpose. Structuring the system logically before considering physical implementation. Figure 3 describes the CCS system functions and Figure 4 the functional allocation, within the CCS system, to different CCS logical blocks (TrainCS, TrafficCS etc.).

[SPT2ARC-4964 **]**

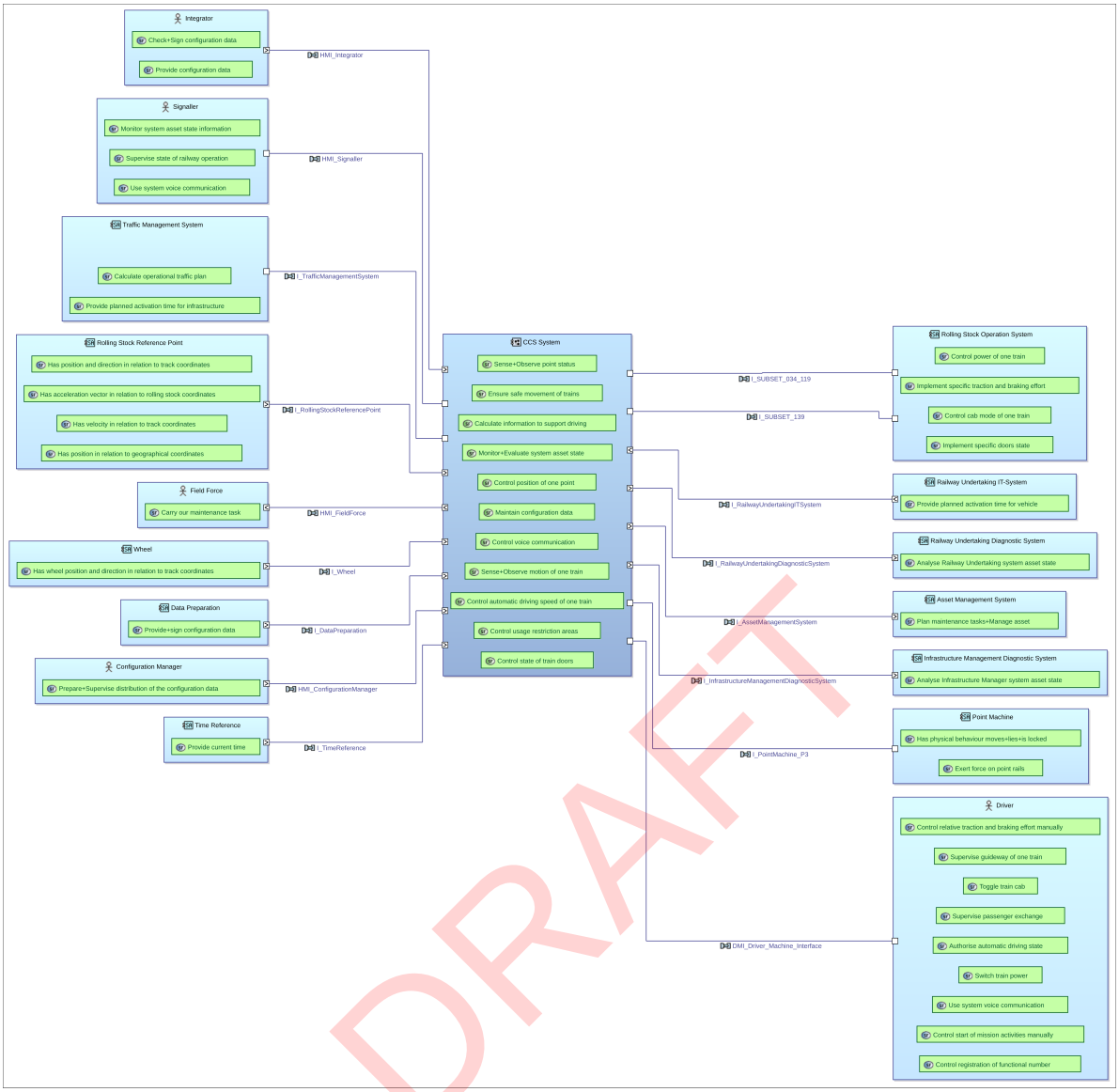


Figure 3 Diagram [SAB] CCS System [Function allocation]

Figure 4 Diagram [LAB] CCS System [Function allocation]

2.3 CCS System Behaviour

Overview

System behaviour is the dynamic use of the defined CCS functions and processes. System Pillar has modelled this dynamic behaviour using the ARCADIA methodology approach to supervisory control i.e. control loops. Control loops ensure the safe and efficient movement of trains by continuously monitoring and controlling the state of the railway infrastructure and train operations. Railway supervisory models control infrastructure, authorise train movements, and perform real-time monitoring. Ensuring smooth and conflict free train movements across the network - regulating traffic especially when degraded or emergency situations occur. CCS system designed a number of control loops as described in this section. **[**SPT2ARC-4966 **]**

CCS Control Loops

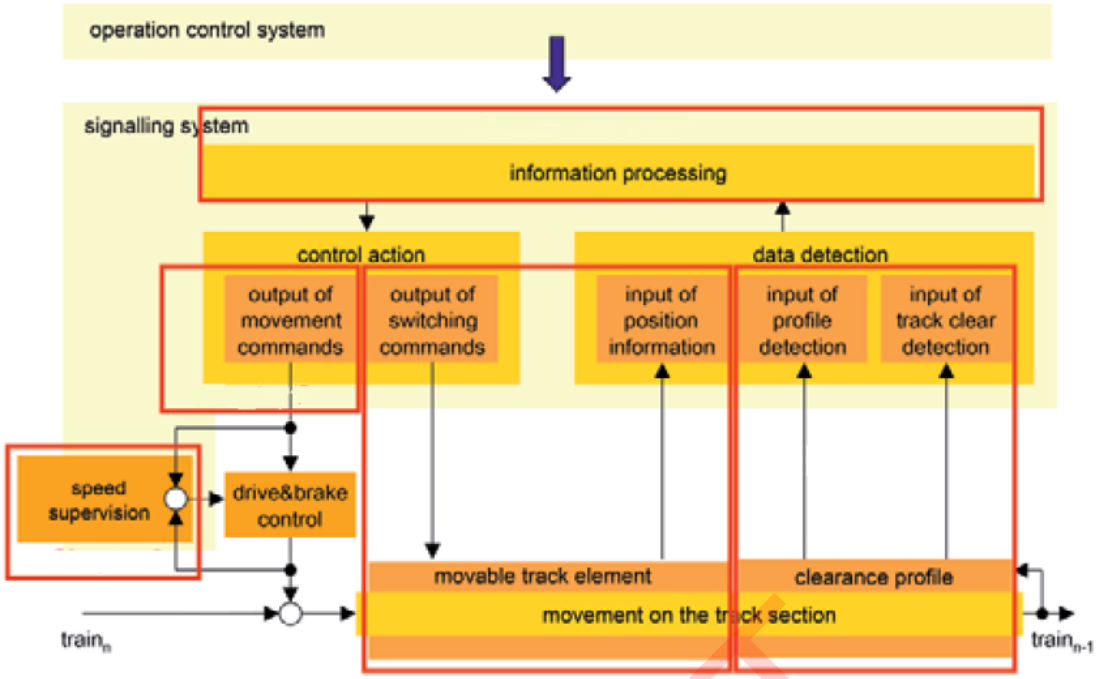


Figure 5 - CCS Control Loops Theory Overview - courtesy of Railway Signalling & Interlocking International Compendium (ERA publication)

Over a period of time CCS system processes are triggered by events that could occur at any time. Using information transmission and information processing consideration of safety, reliability and availability are important to regulate traffic and ensure the safe separation of trains. Figure 5 describes the controlled movement of a train across a track section including movable track elements and the state of the clearance profile (clear space surrounding the rails occupied by a train). A measured value detection takes place in the CCS Control Loop of the following elements

1. Movable track elements position information
2. Present state information of the track clear detection (clear or occupied)
3. Information on other obstacles

Measurement values are safely and logically processed and control values are used for movable track elements, so they are locked in position, before a corresponding movement authority can be issues to a train.

CCS System (System Level 3) interacts with external actors with several control loops:

1. Traffic Management System (TMS) provides the Operational Plan and CCS returns actual train movement data to enable TMS to dynamically update the Operational Plan.
2. CCS commands Point Machines (Trackside Assets) and it returns the resulting confirmation.
3. Signaller operational person could perform the same as Traffic Management to manually control trains.

Further information on the systems engineering approach to control loops can be found in the SEMP / project/SPPROCESS/collection/7/wiki/SEMP%20Annexes/SEMP%20Annex%20M2%20Viewpoint%20guidelines
[SPT2ARC-5000 **]**

2.3.1 Perform Train Movement

Perform Train Movement capability is a combination of the following control loops simultaneously working together. The operational plan execution drives the main CCS control loop 'Perform Operational Plan

Movement' (time based control loop), but there are also event driven control loops based upon sensor feedback. The combination of time and event based control loops provides the CCS supervisory control.

2.3.2 Perform Operational Plan Movement and Movement Permission

[LAB] Grant and release movement permission (Operational plan) [Control loop]

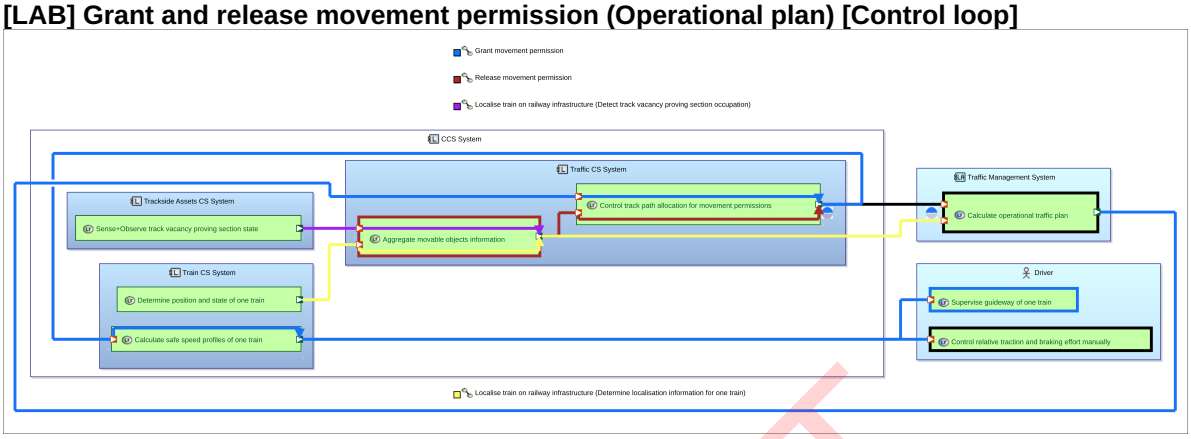


Figure 6 Diagram [LAB] Grant and release movement permission (Operational plan) [Control loop]

[SPMS-5803 **]**

[LAB] Grant and release movement permission (Signaller) [Control loop]

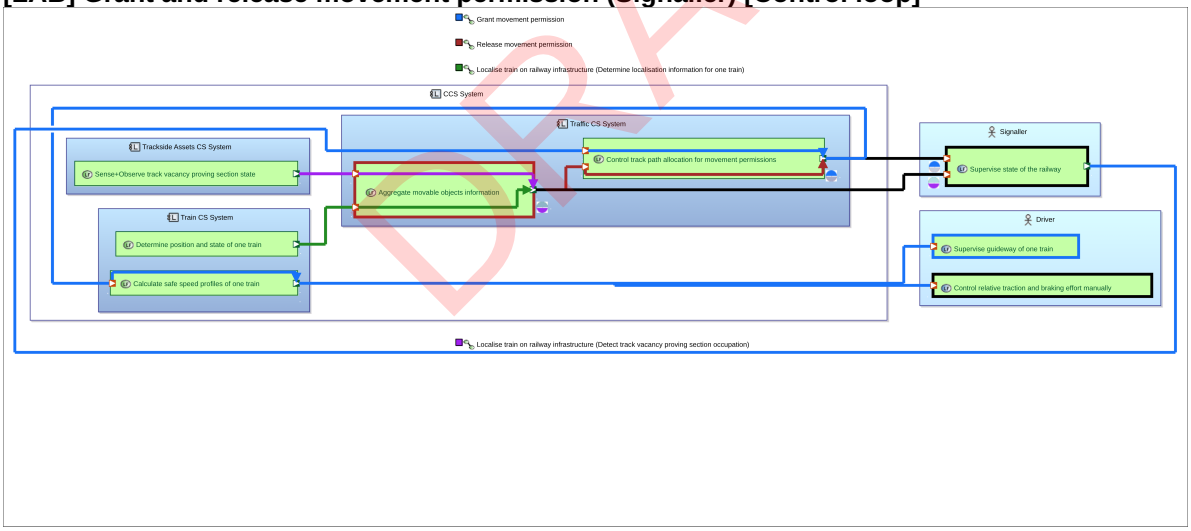


Figure 7 Diagram [LAB] Grant and release movement permission (Signaller) [Control loop]

[SPMS-5870 **]**

[LAB] Shorten movement permission (Operational plan) [Control loop]

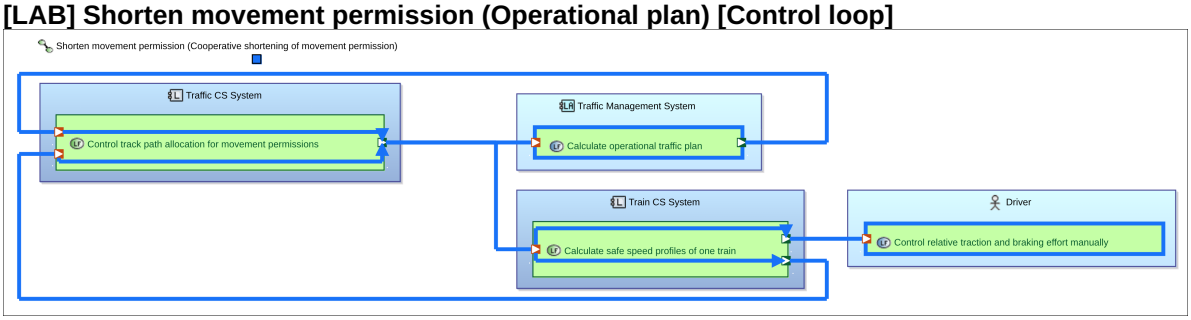


Figure 8 Diagram [LAB] Shorten movement permission (Operational plan) [Control loop]

[SPMS-5692 **]**

2.3.3 Localise train on railway infrastructure

[LAB] Localise train on railway infrastructure [Control loop]

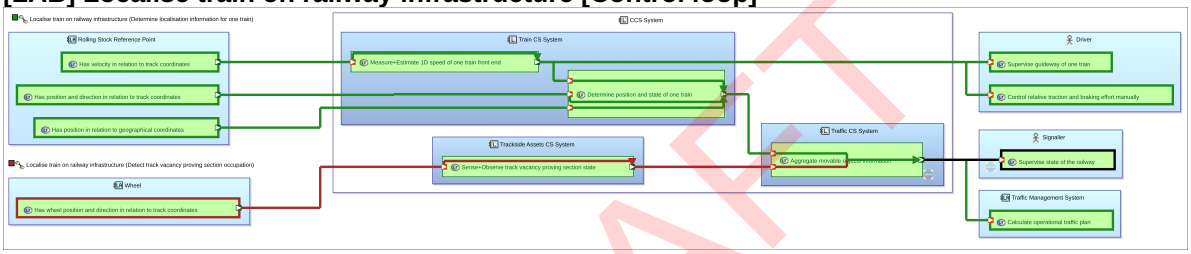


Figure 9 Diagram [LAB] Localise train on railway infrastructure [Control loop]

[SPMS-5809 **]**

2.3.4 Set Point Position

[LAB] Set point position (Operational plan) [Control loop]

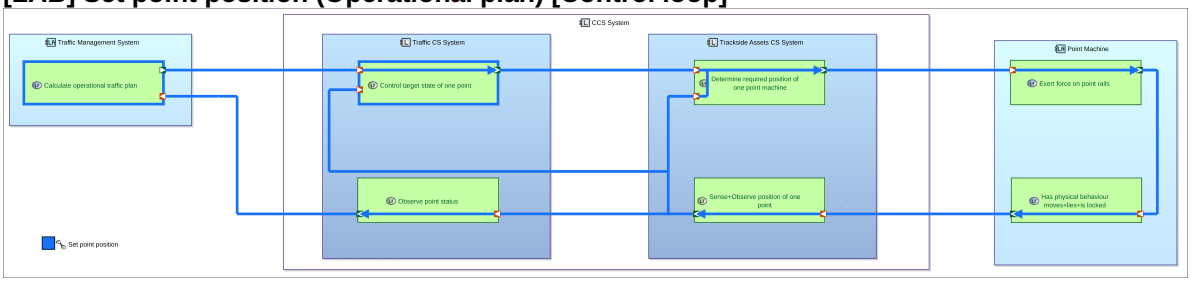


Figure 10 Diagram [LAB] Set point position (Operational plan) [Control loop]

[SPMS-5826 **]**

[LAB] Set point position (Signaller) [Control loop]

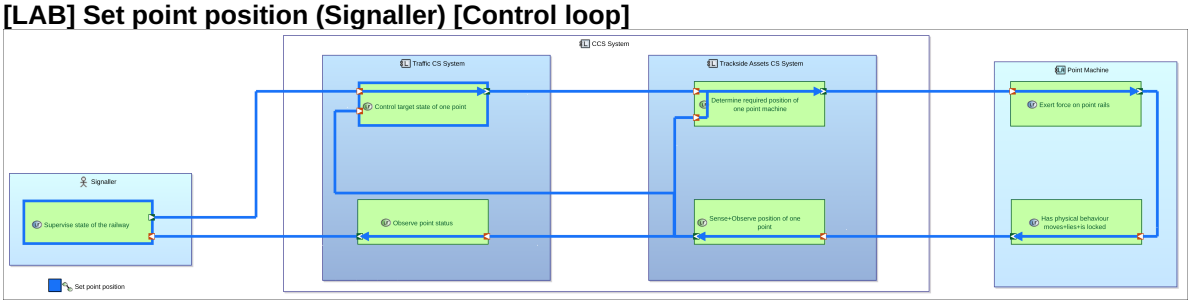


Figure 11 Diagram [LAB] Set point position (Signaller) [Control loop]

[SPMS-5434]

2.3.5 Activate and Deactivate Usage Restriction

[LAB] Deactivate usage restriction [Control loop]

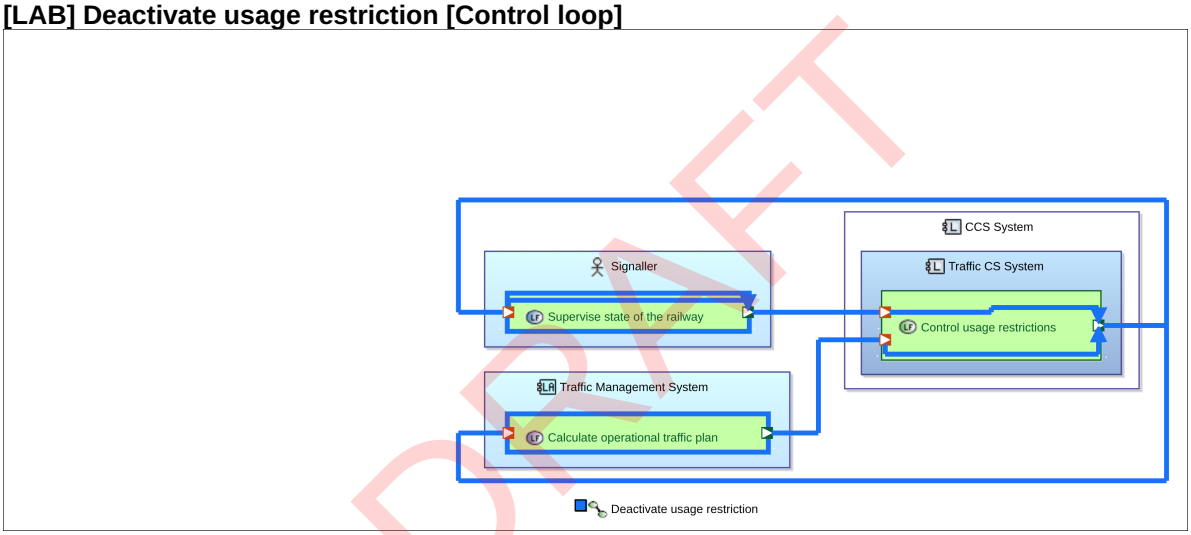


Figure 12 Diagram [LAB] Deactivate usage restriction [Control loop]

[SPMS-5801]

2.3.6 Drive Train Automatically

[LAB] Drive train automatically [Control loop]

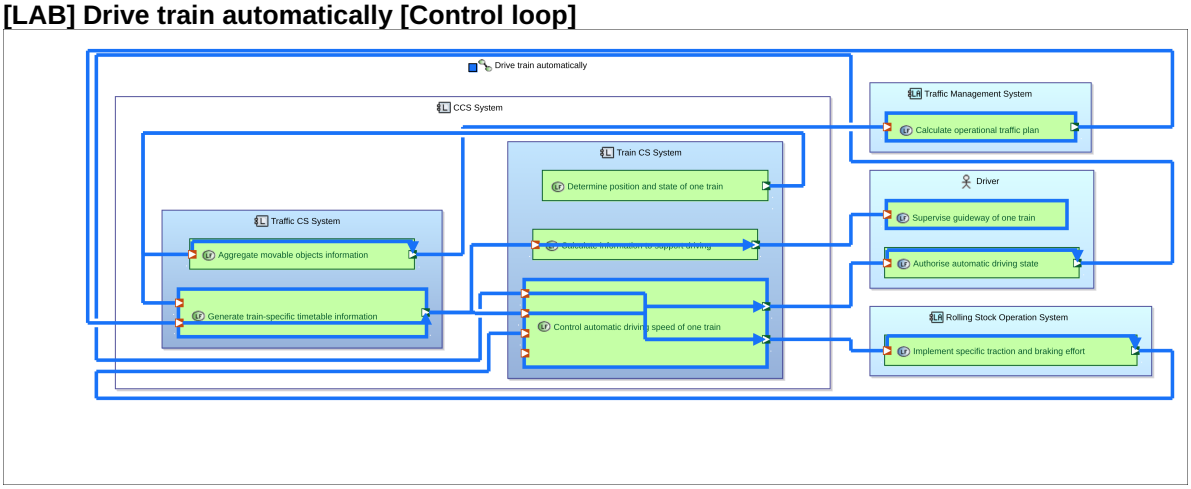


Figure 13 Diagram [LAB] Drive train automatically [Control loop]

[SPMS-5804 **]**

2.4 CCS Environment under Consideration

2.4.1 Physical Issues

Not yet considered.

2.4.2 System Interface Issues

Not yet considered.

2.4.3 Legislative and Economic Issues

Not yet considered.

3 PRAMS Legacy, Policy and Targets

This part is under development and will be applicable to all SP Domains for the development of their safety activities. Please refer to:

- *SPPRAMS/Phase 1/ERJU - PRAMS - System Concept : 714331*
- SPPRAMSS-4332 - Policy and strategy for achieving Safety
- SPPRAMSS-26 - Current PRAMS Policy and Targets
- ERJU Safety Guideline

4 Architecture Concerns

CCS Architecture Concerns

An architecture concern is an 'interest' in the CCS system relevant to one or more stakeholders, typically guiding the CCS System Architecture that address aspects such as costs, functionality, performance, security, interoperability, and maintainability. A number of CCS architecture concerns have been agreed in the System Pillar and the wider sector and are highlighted below:

1. Adopt a layered and functional architecture, commonly used in other industry sectors including aviation and automotive industries.
2. Use a modular architecture divided into manageable modules that can be updated or replaced independently.
3. Minimise railway specific modules e.g. using commodity computing and network systems, sourced from the wider global supply chain, without any railway specific modifications.

4. Harmonised CCS system at a European level enabling a Single European Railway Area (SERA) using the same operational processes across Europe.
5. SERA means little or no national or local deviations, enabling a wider supplier base to supply the same CCS products to different railways organisations with little or no changes.
6. SERA backwards compatible with existing ETCS Baseline 3 train and trackside implementations including the trackside to train air-gap TSI interfaces.
7. Cost effective and attractive migration from current CCS systems to the System Pillar CCS system. Standard evolution path to evolve and upgrade to future CCS System versions.
8. Futureproof CCS systems allowing new innovations to be incorporated into the CCS System e.g. integrate satellite navigation systems for train location, avoiding 'Vendor Lock-in'.
9. Minimise safety functions with a clear separation of safety functions from non safety functions. Ideally safety functions reside in a separate (sub)system). Minimise impact on safety functions when configuration data changes.
10. Efficient data management for CCS system configuration data changes minimising cost and time i.e. reducing the need for safety authorisations.

Details on how these CCS Architecture concerns are addressed can be found in the System Pillar Systems Engineering Management Plan [ref].
[SPT2ARC-4993 **]**

4.1 Standards and References

Ref#	Description
1	ERJU (Europe's Rail Joint Undertaking): Report on preparation of the System Pillar. Ares (2021)4674849 - 20/07/2021
2	System Pillar Template - System Concept
3	ARCADIA Methodology
4	CCS System Definition
5	CCS System Architecture Description
6	Systems Engineering Management Plan
7	Operational Capabilities
8	ERA publication Railway Signalling System (ref. International Signalling & Interlocking Compendium (EUrail Press). ISBN13 - 978-3962451691

5 Open Points

TBA

6 Supporting Models

Add latest SL3 diagrams