ERJU FA2 WP27 Digital Register Specification, Development, and Implementation

D27.1 – Set of requirements on the Digital Register in R2DATO

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REPORT CONTRIBUTORS

Name	Company	Details of Contribution
Harish Narayanan	Nextrail	Author
Kai Ubben	Nextrail	Author
Frederik Düpmeier	Nextrail	Contributor
Albert Ledermann	SBB	Contributor
Benedikt Wenzel	Nextrail	Reviewer
Gregorio Velasco	ADIF	Reviewer
Francesco Inzirillo	MERMEC	Reviewer
Ulrich Kaelberer	GTS-D	Reviewer
Anders Ekberg	TRV/Chalmers	Reviewer
Thomas Renner	DB	Reviewer
Christian Sadowski	DB	Reviewer
Rao Xiaolu	SBB	Reviewer
Adrien Gharios	SNCF	Reviewer
Said El-Fassi	SNCF	Reviewer
Benoit Abisset	Alstom	Reviewer
Andreas Steingröver	Siemens	Reviewer
Gelavizh Ahmadi	SMO	Reviewer
Peter Sassenhagen	SMO	Reviewer
Bastian Simoni	Alstom	Reviewer
Jan Koning	NS	Reviewer
Simon Chadwick	Siemens	Reviewer
Bažant Lubor	AZD	Reviewer

EXECUTIVE SUMMARY

To realise a centralised static reliable infrastructure data management system as well as to facilitate selective systems as a part of ERJU R2DATO like Automatic Train Operation Transactor (ATO-AT), Traffic Management System (TMS), Plan Execution (PE), Moving Block System(MBS), Absolute Safe Train Positioning (ASTP), Perception On-Board (PER-OB), Automatic Processing Module On-Board (APM-OB), Automatic Driving Module (ADM) to access and function with reliable static infrastructure data, the system Digital Register as part of WP27 in FA2 R2DATO was introduced.

In the framework of WP27, the deliverable D27.1 specifies the initial set requirements for Digital Register. The scope of the deliverable, in a nutshell, is set to focus on the generation and publishing of the reliable static infrastructure data to the consuming systems (the ones mentioned in above paragraph). Moreover, the above stated goal/scope had been envisaged in several European and national implementation projects like RCA, OCORA, TAURO, X2Rail4, Safe Rail Map, etc. Ergo, these were used as inputs for the deliverable D27.1.

The topic ‘Digital Register’ being relatively new and the respective terminologies being highly volatile, this deliverable concretises several terms and definitions along with the relations between them.

Furthermore, due to existing interplays with several system in framework of ERJU R2DATO, a stakeholder analysis as a part of D27.1 was performed to identify the relevant work packages in ERJU R2DATO who have a prime stake in data that Digital Register generates and publishes. In addition, due to missing preliminary specification phases like concept and system definition, an extensive scope and boundary definition is a part of this deliverable.

Apropos requirements, a semiformal method of definition of requirements using Capabilities and functional flow diagrams is used i.e., for the defined scope, the boundaries, system capabilities, processual functional flows, functions, and messages were defined. Based on identified functions out of the processual functional flows, the system requirements were defined and allocated to respective systems/actors. The current state of requirements (see Capabilities, Processual Functional Flows, and Functional Requirements) in this document are considered plausible, complete, and can be shared with relevant stakeholders as a status quo of WP27.

As mentioned, the deliverable D27.1 only presents an initial set of requirements on Digital Register, there is a whole lot more to be defined like interface requirements, non-functional requirements, etc. to attain a state of completeness on the requirements level for Digital Register. Owing to that, in the framework for WP27, there is D27.3 planned to provide an updated set of requirements on the Digital Register during the month 36 (i.e., July 2025) of the project timeline. The current state of D27.1 will be updated with the above-mentioned requirements and released as a part of D27.3.

ABBREVIATIONS AND ACRONYMS

APM	Automatic Processing Module
ASTP	Absolute Safe Train Positioning
ATC	Automatic Train Control
ATO	Automatic Train Operation
CCS	Command, Control, and Signalling
CDM	Common Data Model
CS	Control and Supervision
DBS	Digitalisierung Bahnsystem
DR	Digital Register
DSD	Digitale Schiene Deutschland
ERJU	Europe's Rail Joint Undertaking
ETCS	European Train Control System
EUG	ERTMS Users Group
FA	Flagship Area
FFFIS	Form Fit Function Interface Specification
FP	Flagship Project
GoA	Grade of Automation
IM	Infrastructure Manager
IP	Innovation Pillar
MB	Moving Block
MBS	Moving Block System
MDM	Maintenance and Diagnostic Management
OB	On-Board
OC	Object Controller
OCORA	Open CCS On-board Reference Architecture
PE	Plan Execution
PER	Perception
PRAMSS	Performance, Reliability, Availability, Maintainability, Safety, Security
PREP	Preparation
PUB	Publish
R2DATO	Rail to Digital and Automated Train Operation
RAMS	Reliability, Availability, Maintainability, Safety
RCA	Reference CCS Architecture
RU	Railway Undertaking
SA	4rackside Assets
SD	Sub Domain
SP	System Pillar
TAURO	Technologies for the Autonomous Rail Operation
TCCS	Transversal CCS
TE	Technical Enabler
TMS	Traffic Management System
TRL	Technical Readiness Level
TS	Trackside
TSI	Technical Specification for Interoperability
WP	Work Package

TABLE OF CONTENTS

Acknowledgements 2
Report Contributors 2
Executive Summary 3
Abbreviations and Acronyms 4
Table of Contents 5
List of Figures 7
List of Tables 7
1 Introduction 8
1.1 Definitions 8
1.1.1 Data Object Relations 14
2 Context 15
2.1 Stakeholders 16
3 Scope of Digital Register in WP27 19
3.1 In Scope: What shall DR do? 19
3.2 Not in Scope: What shall DR not do? 20
4 Environment and Boundary 20
4.1 Wider Environment/Overall Architecture 20
4.2 System Environment and Boundary 21
4.3 Interacting Systems 23
4.3.1 Actors 23
4.3.2 System Interfaces and Transferred Data 25
5 Capabilities and Processual Flows 28
5.1 Capabilities 29
5.1.1 System Capability SysC1: Generate Domain Data 29
5.1.2 System Capability SysC2: Provide Domain Data to Trackside 30
5.1.3 System Capability SysC3: Perform Activation of Domain Data in Trackside 30
5.1.4 System Capability SysC4: Deploy Domain Data to On-Board 30
5.2 Processual Functional Flows 31
6 System Requirements 36
6.1 Functional Requirements 36
6.1.1 General Requirements 36
6.1.2 System Functions 37
6.1.3 Actor Functions 49
7 Exported Constraints 55
8 Open Points 57

9 Conclusions 58
References 58

LIST OF FIGURES

Figure 1: Min. & Max. Map reference data illustration 12
Figure 2: Min. & Max. Map Area illustration 13
Figure 3: Data object relations 15
Figure 4: Life cycle of data in Digital Register 19
Figure 5: Overall Architecture overview 21
Figure 6: System environment and boundary 22
Figure 7: Capabilities overview 29
Figure 8: Functional flow for SysC1: Generate Domain Data 32
Figure 9: Functional flow for SysC2: Provide Domain Data to Trackside 33
Figure 10: Functional flow for SysC3: Perform Activation of Domain Data in Trackside 34
Figure 11: Functional flow for SysC4: Deploy Domain Data to On-Board 35

LIST OF TABLES

Table 1: Data object definitions 9
Table 2: IP stakeholders 16
Table 3: SP/IP FA areas stakeholders 18
Table 4: Interfaces overview 25
Table 5: Message flow from DR-TS/DR-OB to actors 25
Table 6: Message flow from actors to DR-OB/DR-TS 27
Table 7: List of general requirements 36
Table 8: List of system functions and requirements 37
Table 9: List of actor functions and requirements 49
Table 10: List of exported constraints 55

1 INTRODUCTION

The deliverable D27.1 “Set of requirements on the Digital Register in R2DATO” in the framework of WP27 of the ERJU R2DATO project constitutes of the requirements and specification of the Digital Register (DR) supporting a wide range of use cases for consuming systems like Automatic Train Operation Transactor, Traffic Management System (TMS), Plan Execution (PE), Moving Block System(MBS), Absolute Safe Train Positioning (ASTP), Perception On-Board (PER-OB), Automatic Processing Module On-Board (APM-OB), Automatic Driving Module (ADM). The deliverable includes specification and requirements to provide reliable (meaning complete, accurate, current, consistent, and validated), interoperable, and accessible static infrastructure information (i.e., track layout incl. geometry, track objects, track civil structures) as critical enabler for safety-related and non-safety-related use cases. Amongst the specification needs, a key priority will be on the development of processes, functions, and data representations for generating reliable static infrastructure information supporting the above defined use cases .

The deliverable is based on previous studies, concepts, and specifications defined across several national and European projects / initiatives,

1. Safe Rail Map within the German sector initiatives Digitalisierung Bahnsystem (DBS) and Digitale Schiene Deutschland (DSD) (See [1], [2], and [3]);
2. X2Rail4 (ATO up to GoA4) (See [14]);
3. Reference CCS Architecture (See [4], [5], and [13]);
4. TAURO (See [16]);
5. OCORA (See [15]);
6. EUG (See [17])

The contribution of WP 27 to other work packages within the framework of the ERJU R2DATO project was evaluated through a detailed stakeholder analysis. The results were clustered in terms of their relevancies identified towards the defined tasks in the corresponding work packages. The important contributions are defined in chapter 3.1.

The target audience of this document comprises all parties involved in the development and implementation of the Digital Register, Automatic Train Operation Transactor (ATO-AT), Traffic Management System (TMS), Plan Execution (PE), Moving Block System (MBS), Absolute Safe Train Positioning (ASTP), Perception On-Board (PER-OB), Automatic Processing Module On-Board (APM-OB).

The document starts with the conceptual chapters on the context, stakeholders, and scope. The subsequent chapters will focus first on the system definition aspects like defining the environment and boundary, the capabilities, and high-level functions; second, on the functional system specification aspects.

1.1 DEFINITIONS

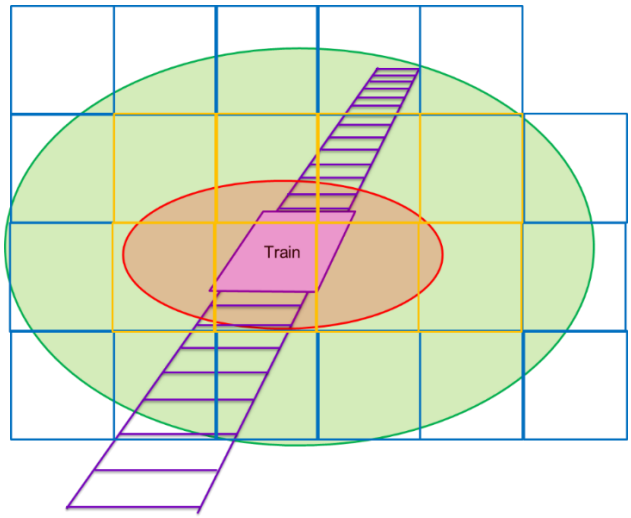
The definitions mentioned below are proposals from WP27 in IP and are needed to be aligned with TCCS SD1 in SP and other WPs in IP.

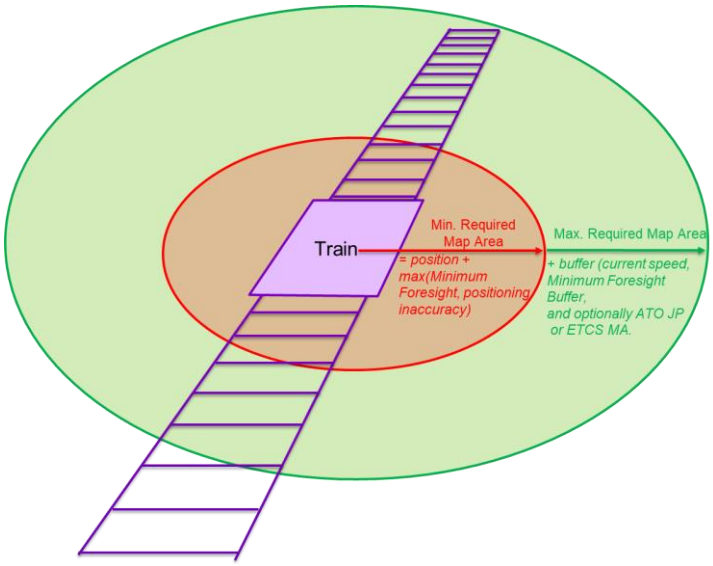
Table 1: Data object definitions

Term	Definition
Digital Register (DR)	The Digital Register is a data management system responsible for handling static infrastructure data for the systems in the railway architecture and replications of some data in Consuming Systems. Static infrastructure data refers to the data that does not change during the validity period of a single version of infrastructure data. DR as a complete system consists of trackside (DR-TS) and on-board (DR-OB) subsystems. The data processed by DR arise from engineering processes or existing railway databases and are processed according to requirements in DR. The data processed by DR is made available to Consuming Systems for application through centralised and standardised distribution processes. In addition, DR is also responsible for managing the process of a safe activation of (a) new data (version) in the Consuming System. Note: The scope of DR is comparable to the concept of Digital Map from projects like RCA, OCORA, and S2R.
Engineering Input Data (IM Data)	Refers to data from Infrastructure Manager (IM) specific digital sources required for engineering, such as: • Track layout (nominal geometry of the respective construction phase) • Track Assets (points, signals, train detection elements, etc.) • Properties (speeds, gradients, etc.) • Structures (platform, tunnel, etc.) • Logical data such as trackside train detection sections (if still available) • Acquisition Data • Configuration Data for track objects • Others (placeholder to include other possible data from IM)
Engineering Data	The Engineering Data is created based on the Engineering Input Data (IM Data) but generic (IM-unspecific). Typically, the data are not adapted to cope with specific views demanded by different Consuming Systems. The Engineering Data contains all the base data (i.e., track topology and topography) for deriving the Domain Data during the compile process. Besides providing base data for the Domain Data generation, the Engineering Data shall also cover the needs for the configuration of Consuming Systems (e.g., Parameter Data). The Engineering Data must fulfil engineering rules that are influenced by requirements of the Domain Data model and the Consuming Systems. The Engineering Data contains only the updated resulting data (i.e., not several variants/versions of the same track) that is needed for the next compiling and

	provisioning of Domain Data and operation at a certain point in time in the Consuming Systems.
Domain Data (Proposal)	The Domain Data refers to use case specific data for the Consuming Systems for a specific application. These can be broadly classified as Trackside Domain Data and On-Board Domain Data. Domain Data being application specific they can be further detailed as Map Data (incl. On-Board Map Data), Segment Profiles, and Parameter Data. As a part of the configuration process, the Consuming Systems need to get the required Domain Data from DR. The Domain Data is static and does not change during the validity period of a Domain Data version. Potential updates of Domain Data will be realised by a centralised provisioning process including activation of the new Domain Data version. Open Point: the complete configuration requires extended Parameter Data such as Software, Security config. The definition/wording must be aligned with System Pillar. Note: it is subject to discussion if Domain Data will also cover dynamical aspects (and if so: which one or how). However, in the context of this Specification, Domain Data can be limited to static aspects only.
Map Data	Map Data is a detailed digital representation of the railway network that contains all information necessary for planning and performing railway operations, such as infrastructure characteristics, location and details of Field Elements, etc. The Map Data is static and remains unchanged until the next provisioning of Map Data. Changes of Map Data are required after each relevant infrastructure update. The Map Data is part of On-Board and Trackside Domain Data. The structure of Map Data varies accordingly.
On-Board Map Data	On-Board Map Data is a specialised form of Map Data for On-Board application.
Segment Profile	A Segment Profile is a one-dimensional object that describes a single and consecutive section of track and corresponds to the Track Centreline of that section of track. A Segment Profile has a Start Point and an End Point, which correspond to the boundary points of the section of Track Centreline of that Segment Profile. A Segment Profile defines a set of static infrastructure data required by the ATO on-board to compute the Operational Speed Profile. The Segment Profile is part of Trackside Domain Data. These data are derived from Map Data according to the data structure as defined by ATO over ETCS Subset 126 and considered as Domain Data for ATO-AT.

	Note: While the basis of a Segment Profile is also Map Data, it shall be translated according to the already existing TSI standard (ATO over ETCS Subset 126) in contrast to other use cases of Map Data. Therefore, Segment Profile is mentioned explicitly in addition to the underlying Map Data.
Parameter Data	Parameter Data refers to a static data set required to configure systems with primary information before being put into operation. The Parameter Data is part of Trackside Domain Data and does not change during the validity period of a Parameter Data Version. Within the configuration process, Parameter data, as a part of the Trackside Domain Data for configuration, is also distributed to systems. These data consider national and (supplier)specific operative environments. Thus, they form the specific application of the generic system. The following list gives some examples for Parameter Data related to different fields of application of the Domain Data: • MBS: National safety rules, safety patterns for supervision of the safety logic, and the configuration of safety checks; • TMS: Min/max extent of Movement Permissions; • Track Asset: Drive engine type of the point machine/other track equipment, threshold for turnaround time, communication parameters (e.g. Protocol, IP address, hardware address; • ATO: ATO Transactor default contact information, national values.
Operational Data (Proposal)	Operational Data is dynamic Data that is not provided by DR but transmitted between Consuming Systems as part of messages, commands, requests, etc. Operational Data can refer to or contain required parts of Map Data to provide specific information for receiving Consuming Systems about the current status of the Map Data objects (i.e., Operating State, Movement Authorities e.g., point states or trackside train track detection section states) that are overlaid on the Map Data. This state information is not constant but varies as per train movements and overlaid accordingly. The Operational Data also contains dynamic track infrastructure restrictions/properties, i.e., usage restriction areas, temporary low adhesion zones, temporary speed restriction (TSR) areas.
Map Reference Data	Explicit reference to a certain version and region of on-board Map Data. It includes information containing Map Version Data, Map ID Data and Map Integrity Data required to validate on-board Map Data.
Map Integrity Data	Relevant information (protection data such as hash) to reveal potential transmission or processing faults.

Minimum and Maximum Map Reference Data	The Minimum Map Reference Data is a part of the Map Data that is connected to the Minimum Required Map Area. The Minimum Map Reference Data is illustrated by the orange boxes in the image below. The Maximum Map Reference Data is a part of the Map Data that is connected to the Maximum Required Map Area. The Maximum Map Reference Data is illustrated by the blue boxes (including the orange boxes) in the image below.  **Figure 1: Min. & Max. Map reference data illustration** Note: Usage of boxes in the illustration is just an example to provide a means of interpretation of the concept. The actual implementation can vary accordingly.
Minimum and Maximum Required Map Area	The Minimum Required Map Area is a geo-positioned set of data defined by using a configured minimum foresight (or estimated positioning inaccuracy if this value is higher than the configured minimum foresight due to a bad confidence) around the estimated train position. The Maximum Required Map Area is a Geo-positioned data consisting of the Minimum Required Map Area and a buffer in-front of/around the train. The buffer is calculated using the current position and speed of the train, a configured minimum foresight buffer, and if required can also consider ATO Journey Profile or ETCS Movement Authority. The Minimum Foresight Buffer is the minimum (foresight) buffer according to On-Board Consuming System needs. The highest value amongst all On-Board systems will be used to define the generic Maximum Required Map Area. The Minimum Foresight is the minimum foresight according to needs of the on-board Consuming Systems (e.g., PER-OB/APM-OB needs several 100 meters around or along the track for generating a reliable positioning information). The highest value amongst all On-Board systems will be used to define the generic Minimum Required Map Area. Note: This concept of required Map Area providing rough Geo-position around the train is required for On-Board system only for the initial Map Data request

	to the trackside. The successive Map Data requests / extensions can be performed using adjacent area reference information, Journey Profiles or Movement Authorities.  **Figure 2: Min. & Max. Map Area illustration**

Reliable Data	Reliable Data refers to a typical characteristic of data which satisfies the qualities of being trustworthy/low probability of incorrect information/low fault rate of the information, current (not obsolete), complete, and accurate.
	
	The attribute "reliable" is not limited or coupled exclusively to safety-related functions since a sufficient level of quality is also required to guarantee a good performance, high availability, and reliability of non-safe functions such as realised by ATO or TMS. Hence, the data quality attribute 'Reliable' means safety-related or non-safety-related data that satisfies the Consuming System's data quality requirements.
	
	The data per se would have a safe/non-safe characteristic based on the use of formalised/non-formalised processes for data generation. i.e., Formalised meaning with appropriate safety reports, required acceptance rates, and compliance to EN5012x norms.
	
	To make it more concrete,
	
	• Complete: All data (i.e., tracks and elements/objects) within the scope of the application are present, and all attributes are populated.
	• Accurate/Correct: All data is correct regarding the following sub-attributes:
	  ○ Technical correctness: the data is valid in the sense that they conform to the rules (e.g., right element type, the minimum distance between balise groups)
	  ○ Positional correctness: the data is correct in the sense that they conform to the real existing infrastructure (positional error ≤ accepted positional error e.g., for defined uncertainty, confidence intervals)

	• Current: The data represents the valid information for the right time. • Consistent: No ambiguities or contradictions between different topical aspects, versions, or adjacent regions of data.
Consuming System	It is a colloquial term used to define all the systems (trackside and on-board) that need / are end consumers of the Domain Data. These systems are primarily identified and defined in the system environment definition. This document uses the term 'Consuming System' in both generic and specific way i.e., according to context the term used can be trackside Consuming System, on-board Consuming System, or Consuming System. The trackside consuming systems consume trackside Domain Data and on-board consuming systems vice versa.

1.1.1 Data Object Relations

The diagram below illustrates the relations between the data object definitions:

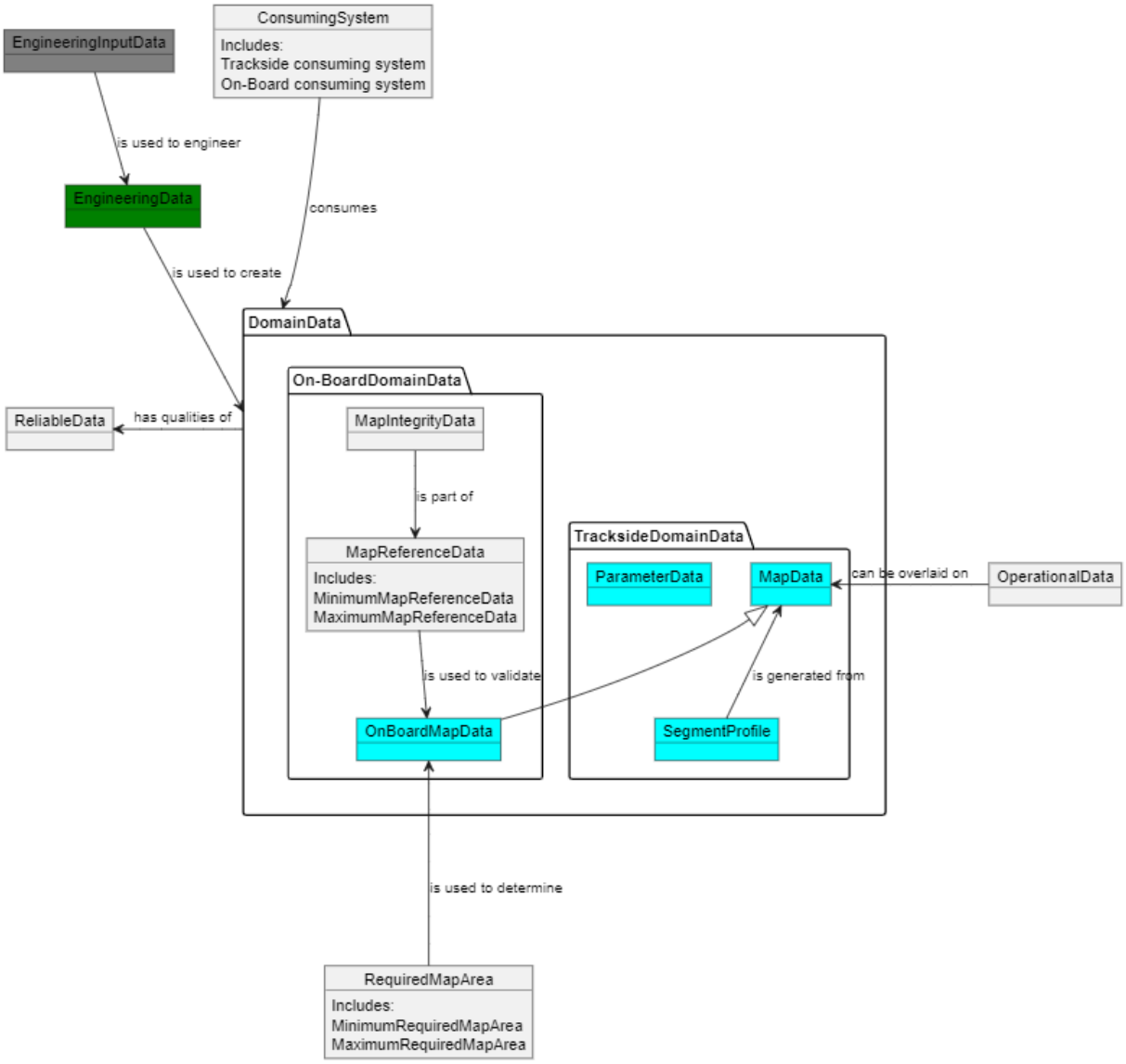


Figure 3: Data object relations

2 CONTEXT

Europe's Rail Joint Undertaking (ERJU) aims at creating a uniform approach across Europe for the harmonisation of Railway operations. Achieving this brings together Infrastructure Managers (IM's), Railway Undertakings (RU's) and industrial partners to work within two work groups; the System Pillar (SP) and the Innovation Pillar (IP). The task of the System Pillar is to consolidate the work that predates the start of the ERJU project and formulate a common specification basis to be proposed as addendums to the existing interoperability specifications. The Innovation Pillar is more focused on the technology development, exploration of different architectures and implementation of prototypes for testing the feasibility of various proposals. As such, the combination of the two Pillars forms a comprehensive effort to align and standardise the railway of the future on a European level.

Within the scope of the Innovation Pillar, the Flagship Area 2 (FA) "Digitalisation and Automation in Train Operations (R2DATO)" aims to develop the Next Generation Automatic Train Control (ATC)

and deliver scalable automation in train operations, up to GoA4, in order to enhance infrastructure capacity on the existing rail networks.

ERJU IP WP 27 in context of R2DATO holds a major stake towards enabling digital technologies. The Digital Register, a single source of truth, and a future-proof infrastructure data platform that is expected to be ready with a Technical Readiness Level (TRL) of 6, whereby DR shall be demonstrated in a relevant environment. Ergo, the WP27 focusses on satisfying the readiness level by defining requirements and specification of the DR (WP27.1) as well as the implementation of the requirements and interfaces towards the Moving Block system (WP27.2), Data Factory (WP27.3), and On-Board systems (WP27.4).

Linked activities in SD1/3 in SP Domain TCCS (Transversal Command Control Supervision) and WP 27 in FP1 MOTIONAL:

The SD1, Engineering and Domain Data Management, scope focuses on specifying a standardised data model (the System Pillar Data Model) for various applications like to define Engineering Data, Domain Data and Operational Data. The goal is to use the standardised data model (incl. Interface descriptions) for handling different information like infrastructure, timetable, and vehicle data etc. for railway applications. In addition, SD1 also focuses on the definition of harmonised methods for data preparation and, in collaboration with SD3, the distribution of configuration information to the Consuming Systems.

The SD3, Configuration Management, focuses on definitions of methods and a protocol for the configuration of systems of the railway CCS environment, including the handling of data to be shared by the system components during the configuration process (e.g., a software update, the provision of Parameter Data). In addition, it also defines the configuration management set of functions to be provided as a basis for a standardised management process on network and vehicle level for the configuration management of systems components (both trackside and on-board).

The WP27 in FP1 MOTIONAL focuses on the specification of a CDM (Common Data Model) for engineering of infrastructure data for railway applications.

2.1 STAKEHOLDERS

The tables below list out different stakeholders in scope of IP and SP (incl. other Flagship Projects (FP)) for the WP27. These stakeholders were identified through an elaborate stakeholder analysis.

The important stakeholders from IP within Flagship Area 2 were identified as the following:

Table 2: IP stakeholders

Stakeholder IP FA 2		Link to WP27
WP	Title	
WP 5	Automation Processes Use Cases and User Requirements	The WP5 continues the work of X2R4 ATO up to GoA4 and adds further use cases and user requirements of the whole railway sector. Therefore, WP 27 is needed to provide required data for ATO applications.

WP 6	Automation Processes Specifications	The WP6 will define and develop an architecture and a system specification for the technical enablers including TE9 Digital Register. Therefore, WP 27 is needed to provide required data for ATO applications.
WP7	GoA 3-4 Data factory Specification and Implementation.	The WP 7 defines a Data Factory for real time Perception Systems. DR stores static input data for the Perception Systems and provides it to the vehicles. Within the scope of WP27.3, WP27 has to provide object catalogue requirements for this task.
WP9	Prototype development of automating functions	The WP 9 defines functional prototypes for automating functions (TE 1) will be developed, tested, and validated against the defined system architecture specification. Therefore, WP 27 is needed to provide required data for ATO applications.
WP10	Prototype development of Automated Driving (ATO Technologies)	The overall objective is to create a technical enabler suitable to demonstrators, taking into account the experiences realized during S2R test (e.g., pilot line and laboratory from the X2R1/5). The aim is also demonstrating the ATO system functionalities up to GoA4, interoperability and interchangeability. Therefore, WP 27 is needed to provide required data for ATO applications
WP11	Prototype development of perception system	The WP 11 will focus on the detailed design, development, and validation of the Perception system (TE-06). Therefore, WP 27 is needed to provide required data for perception system applications
WP (21)/22	Absolute Safe Train Positioning – System Architecture, Design and RAMS	The WP 22 focusses on the definition of a system architecture for Absolute Safe Train Positioning (ASTP). DR provides static input data for ASTP such as track geometry and landmarks. Therefore, WP 27 is needed for the specification of the architecture and external interfaces as well as the definition of the requirements of data that are to be aligned with the developments of ASTP – System Architecture, Design and RAMS. This is especially relevant for task WP27.4 (Airgap) and WP27.3 (Object Catalogue)
WP (13/14)/44	Moving Block ETCS Level 3 Demonstrator – Specification	The WP 44 focuses on the preparation of a demonstrator for ETCS level 3 “Moving Block”. DR provides static input data to the Moving Block System such as Map Data and Parameter Data. Therefore, one of the tasks of WP 27 is to develop the requirements generated by the system pillar and TE Moving Block and TE Digital Register into a deployable product specification by recognising the detailed functional, system and logical breakdown for the demonstrator system, including the relevant interfaces.

WP 45	Moving Block ETCS L3 Demonstrator – Realisation	The objective of WP 45 is to demonstrate a modular trackside protection system enabling moving block operations with generic safety core up to TRL 6 in R2DATO. One of the tasks of WP 27 is to provide topology of the testing location with standardised mapping characteristics.

The relevant stakeholders from System Pillar or other Flagship Areas (FA) of Innovation Pillar were identified as follows:

Table 3: SP/IP FA areas stakeholders

SP/IP FA Areas	Description	Link to WP27
System Pillar	Standardisation as input to TSI	The requirements and specifications of DR contribute as input towards the TSI and architecture needs for harmonisation.
SP Domain TCCS (SD1)	Engineering and Domain Data Management	DR shall use a standardised data format to provide infrastructure data to systems. Ergo, SD1 has a key role as a stakeholder here to enable a two-way coordination of Engineering and Domain Data model needs between IP and SP.
SP Domain TCCS (SD3)	Configuration Management	DR shall also distribute Parameter Data as a part of the configuration process to the systems. Ergo, SD3 has a key role as a stakeholder here to enable a two-way coordination of configuration data management between IP and SP.
SP Domain TM	Traffic Management System	The requirements and specifications of DR contribute towards the data needs of the TMS incl. data publishing and processing requirements.
SP Domain Traffic CS	Traffic Control and Supervision	The requirements and specifications of DR contribute towards the data needs of Traffic CS incl. data publishing and processing requirements.
SP Domain SA CS	Trackside assets control and supervision (OC)	The requirements and specifications of DR contribute towards the data needs of SA CS incl. data publishing and processing requirements.
SP Domain TCS	Train Control and Supervision	The requirements and specifications of DR contribute towards the data needs of Train CS incl. the different demands of onboard systems.
IP FP1	MOTIONAL – Network management planning and control & Mobility Management in a	The requirements and specifications of DR contribute towards the common data model needs, i.e., regarding input engineering data and processes, including data validation.

	multimodal environment	Note: the synchronisation with FP1 is done together with SP TCCS SD1.

3 SCOPE OF DIGITAL REGISTER IN WP27

The Digital Register, as the central infrastructure database system for future railway systems, handles static infrastructure data over its full life cycle. The life cycle can be broadly divided into the Preparation (PREP) Phase and the Publish (PUB) phase.

Before the start of the PREP phase, the IM specific input data are collected and stored for the PREP phase. The data handled in this pre-phase is referred to as Engineering Input Data (IM Data).

PREP Phase: This phase covers different high-level processes like data preparation, where the data is collected, imported, aggregated, validated, and compiled for the next phase. The data which is handled in this phase is referred to as Engineering Data. This data is used as input for the compilation process. The detailed descriptions and requirements of each phase are defined in chapter 5.2.

PUB Phase: This phase covers different high-level processes like publishing of data (to trackside and on-board) wherein the data is distributed, loaded, and activated for specific application in Consuming Systems. The data which is handled in this phase is referred to as Domain Data. The detailed descriptions and requirements of each phase are defined in chapter 5.2.

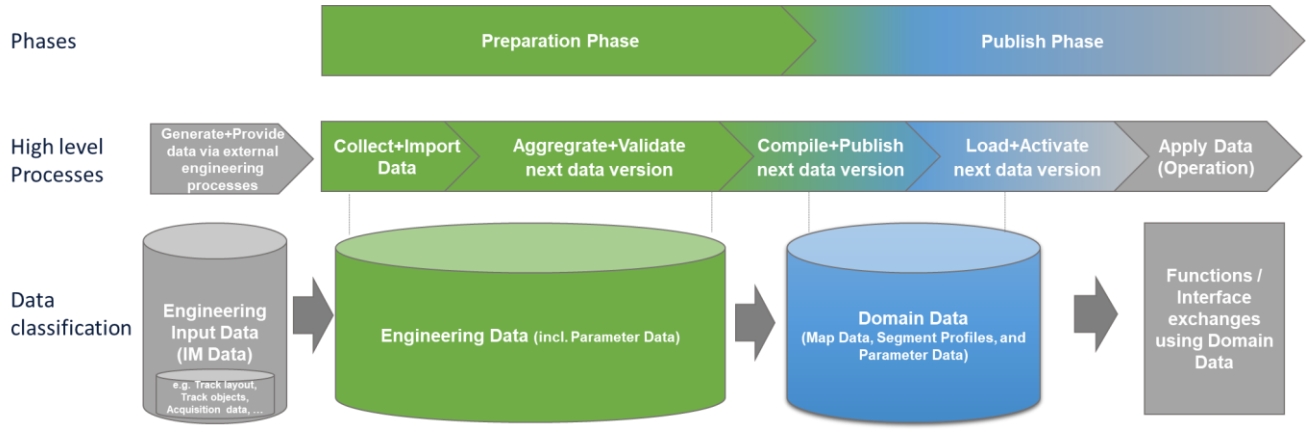


Figure 4: Life cycle of data in Digital Register

Figure 4 illustrates the lifecycle of data in Digital Register within framework of IP FA2 WP27. Based on these phases, the sections below provide an overview of what the Digital Register shall 'do' and 'not do'. The relevant interfaces and actors are described in chapter 4, and the 'In scope' aspects are later developed into capabilities and functions in chapter 5.

3.1 IN SCOPE: WHAT SHALL DR DO?

1. Import received Engineering Input Data that are generated and provided by external engineering processes into a standardised data model format as Engineering Data.

   Note: This standardised data model format is to be aligned with SD1 System Pillar

2. Aggregate and Validate Engineering Data (including Parameter Data) based on rules checks/acquisition data.

3. Compile validated Engineering Data into consuming system specific Domain Data using generic transformation rules.
4. Distribute Domain Data (including Parameter Data) to the Consuming Systems based on a generic distribution process.
5. Ensure that all Consuming Systems use the right version of Domain Data as active version. (e.g., synchronisation of Domain Data, versioning, activation, and storage).

3.2 NOT IN SCOPE: WHAT SHALL DR NOT DO?

1. Publish/store/process “Dynamic” Domain Data (e.g., Temporary Speed Restriction zones, States of trackside elements, etc.) to the Consuming Systems.
2. Provide rolling stock/vehicle data (e.g., Maximum Traction effort, Acceleration and Braking parameters of locomotives) to the Consuming Systems.
3. Acquire data, e.g., by track recording or aerial surveys.

4 ENVIRONMENT AND BOUNDARY

In this chapter, the environment, and the boundaries of the Digital Register are described.

4.1 WIDER ENVIRONMENT/OVERALL ARCHITECTURE

This chapter provides an overview of the Digital Register within the overall architecture of the future trackside and on-board CCS. Figure 5illustrates the most relevant systems with interfaces to DR. This overall architecture is drafted using inputs from previous projects like RCA, X2R4 ATO, and OCORA.

DR consists of a trackside (DR-TS) and on-board (DR-OB) system. DR-TS provides interfaces for receiving IM Data from the IMs and sending Domain Data to trackside Consuming Systems, especially TMS. MBS, and ATO-AT. Furthermore, it has an interface with DR-OB to provide Domain Data for the vehicles.

DR-OB is part of the Repository On-Board. The Repository On-Board, as the name suggests, is an on-board repository to store Domain Data in the train. The Digital Register contributes to the data collection of this repository by providing the required Domain Data (or Map Data) for on-board Consuming Systems like Absolute Safe Train Positioning, Perception, and the Automatic Processing Module. Since within scope of IP FA2, no further on-board stakeholders with regards to Domain Data were found, the on-board Consuming Systems marked in blue in Figure 5 are considered to be the only initial on-board Domain Data Consuming Systems. The overview on this level is imperative to outline the mapping/integration possibilities amongst these architectures.

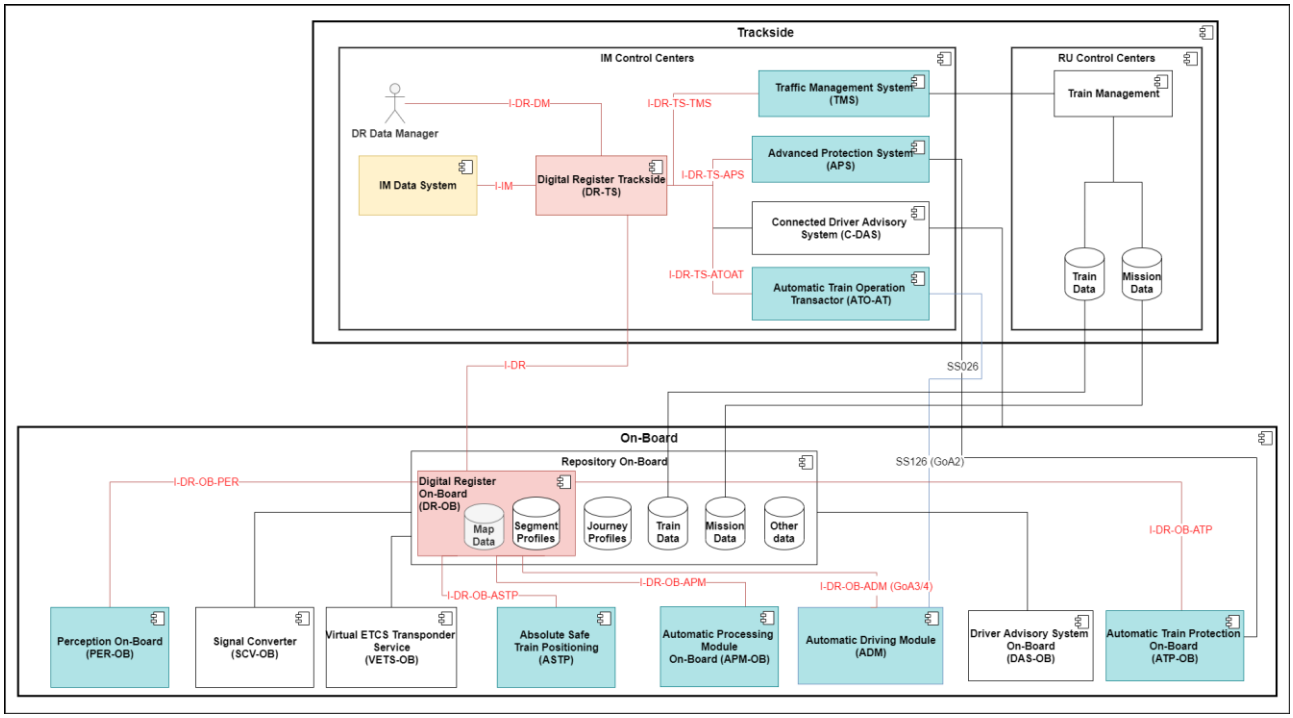


Figure 5: Overall Architecture overview

Using this overall architecture as a foundation, a cut out architecture for Digital Register adhering to the scope of WP27 can be abstracted as marked in red in Figure 5 and defined in detail in Figure 6 below. WP27 envisages Digital Register On-Board to be a part of Repository On-Board depicting a strict separation from other Domain Data within the repository that are obtained from RU's or other operational data like Journey Profiles.

4.2 System Environment and Boundary

Figure 6 presents the system environment and the system boundary of DR, cut out from the overall architecture in Figure 5.

DR provides Domain Data to trackside and on-board Consuming Systems (blue entities in Figure 6). It is imperative to differentiate between the on-board and trackside Consuming Systems since the process definitions (explained in chapter 5.2) are different. This requirement specification (work package) focus on TMS, PE, MBS, and ATO-AT as trackside Consuming Systems and Absolute Safe Train Positioning (ASTP), Perception On-Board (PER-OB), Automatic Processing Module On-Board (APM-OB), Automatic Driving Module (ADM) as on-board Consuming Systems (cf. chapter 2.1).

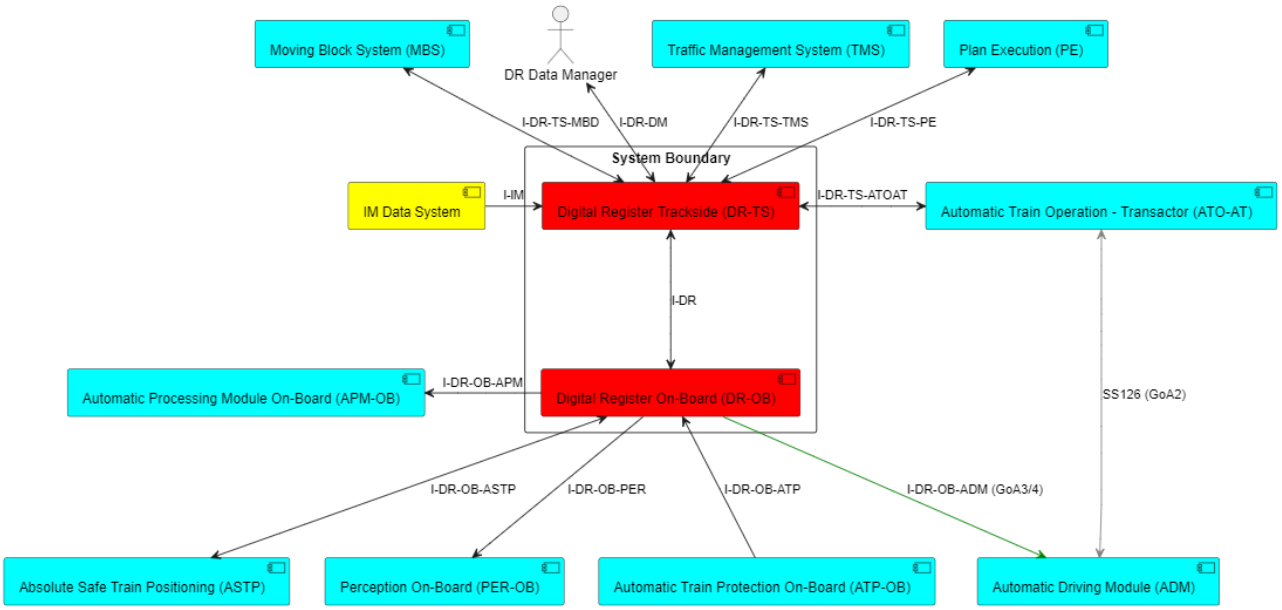


Figure 6: System environment and boundary

To cope with the different needs of trackside and on-board Consuming Systems in relation to the distribution process and to keep the communication between trackside systems and the railway vehicles simple, DR as a complete system consists of a trackside (DR-TS) and an on-board (DR-OB) subsystem.

DR-TS collects, imports, aggregates, and validates the Engineering Data and compiles it to Domain Data. Furthermore, DR-TS provides the Domain Data to all trackside Consuming Systems for application as well as to DR-OB via an airgap interface for further distribution to on-board Consuming Systems.

DR-OB obtains Domain Data (in the context of on-board referred to as Map Data) from DR-TS via I-DR and provides the Map Data to further Consuming Systems on the train (like Absolute Safe Train Positioning, Perception, etc.). Therefore, DR-OB has interfaces with all Consuming Systems on the train that need Domain Data.

The system environment also illustrates colour coded differentiation (Green and Gray) between interfaces for the ATO relevant systems. This is done to provide flexibility during data provision for GoA2 and GoA3/4 applications. Accordingly, the interface I-DR-OB-ADM shall be used for GoA3/4 applications. The interface SS126 shall be used for GoA2 application. This interface SS126 between ATO-AT and ADM is not in scope of this document.

Important notes:

1. Automatic Train Protection On-Board (ATP-OB) is also a part of the system environment for Domain Data handling purposes, but not a consumer of Domain Data.
2. The actors mentioned in Figure 6 can have interfaces between each other (e.g., ASTP and PER-OB) for transmitting relevant data. The definition of these interfaces/functionalities is not part of this document.
3. The interface between DR-TS and the trackside assets like (Point, LX, Axle Counter, …) responsible for providing of Parameter Data to the track assets for configuration, are due to

ongoing coordination/discussion regarding scope of Maintenance and Diagnostic Management (MDM) within SP TCCCS SD3. Ergo, the interface is currently not indicated in the Figure 6: System environment and boundary. This interface will conform to EULYNX SMI. Any new changes from the discussions would be brought in and amended in this document.

4.3 INTERACTING SYSTEMS

4.3.1 Actors

4.3.1.1 Traffic Management System (TMS)

Traffic Management System (TMS) is responsible for the optimised planning of railway operations. It plays a crucial role for DR in planning activation times of Domain Data updates. TMS plans the Domain Data updates along the time axis with so-called Operational Plans[1] and sends them to MBS for execution. For instance, TMS plans and sends the Domain Data update time window to DR for execution.

In addition to planning, the TMS is also responsible for controlling and monitoring of the railway operations. This broadly involves conflict management by detecting the dependencies between different Operational Plans and track assets to generate feasible requests.

4.3.1.2 Plan Execution (PE)

Plan Execution (PE) is responsible for executing the operational plans of the TMS. To execute the Operational Plans, PE generates specific the requests to be sent to MBS at the right point in time. PE also checks for deviations in Operational Plans using the feedback on the operating state received from MBS. In context of DR, PE is responsible for calculating a time window for the activation of a new Domain Data version for use by the Consuming Systems and triggering the activation process at the right point in time.

4.3.1.3 Moving Block System (MBS)

The Moving Block System [11] is defined as a black box encompassing the functionalities of the different MBS systems, such as**Erreur ! Signet non défini.** Safety Logic, Object Aggregator, Field Object Transactor, Movement Authority Transactor, Mobile Object Transactor, etc. MBS is a generic form for functions of the future railway system architecture that are located today in the Interlocking (IXL), Radio Block Centre (RBC), and trackside functions needed for controlling train operations. MBS is responsible for the safe allocation of infrastructure resources and has interfaces , e.g., to PE, to switchable field elements, to legacy and future train detection systems and to the railway vehicles via the ATP system. For more information refer to [18].

MBS works in an abstract way with its geometric logic. Therefore, the required Domain Data for MBS also differs from the legacy interlockings (i.e., no pre-configured fixed routes). MBS, in interplay with PE and DR, plays a crucial role in the activation process of Domain Data updates. It to ensure that it is safe to perform the Domain Data update.

[1] The Operational Plan is the result of the planning process performed by the TMS. It describes either a planned Operational Movement, Operational Restriction, or Operational Warning Measure through a temporal sequence of Operational Events to be executed by MBD/ATO in an Area of Control [8] .

4.3.1.4 Absolute Safe Train Positioning (ASTP)

The Absolute Safe Train Positioning is the system responsible for measuring the position and speed of the train. To assist this functionality, the system requires Domain Data which helps it to localise the train position in the 1D domain data.

4.3.1.5 Perception On-Board (PER-OB)

The Perception On-Board is the system responsible for detecting the objects on and along the track. To assist this functionality, the system requires Domain Data as well as position information from ASTP to detect obstacles on the track.

4.3.1.6 Automatic Processing Module On-Board (APM-OB)

The Automatic Processing Module (APM) component is in the train and should substitute driver and train attendant responsibilities for reacting in case of incident. It manages mission execution, safe reflexive reactions, evaluated reactions and safety procedures in cooperation with ISM. To assist this functionality, the system requires Domain Data.

4.3.1.7 Automatic Train Protection On-Board (ATP-OB)

The Automatic Train Protection On-Board is the on-board counterpart of the Automatic Train Protection system. The ATP-OB assists with the safe deactivation of the Domain Data.

4.3.1.8 Automatic Train Operation – Transactor (ATO-AT)

ATO-AT refers to the trackside counterpart of the ATO system. ATO-AT requires Domain Data in a specialised format i.e., Segment Profiles for automatic train operation. ATO-AT transacts the Segment Profiles to the On-Board counterpart (i.e., ADM) which is eventually used along with Journey Profiles by ADM to control and operate the train automatically.

4.3.1.9 Automatic Driving Module (ADM)

Automatic Driving Module is responsible for driving the driving the train automatically. This component is equivalent to ATO-OB.

4.3.1.10 DR Data Manager

The human DR Data Manager controls the processing of data for boundary cases for DR. This so-called processing of boundary cases includes the DR Data Manager performing manual tasks like:

- Control the import of Engineering Data.
- Control the process states, i.e., of Domain Data compiling.
- In the case of errors/issues (i.e., matching, transformation): Process and solve issues in coordination with surrounding engineering and approval processes.
- Trigger the publishing process for a new Domain Data version.
- Authorise the activation of a new Domain Data version for all Consuming Systems.

In addition, certain situations might emerge where the DR Data Manager would want to modify Domain Data like, i.e., adding Timing Points, renaming/splitting a track edge. These adaptions are

then released, compiled into a new version of Domain Data, and ready to be published to the Consuming Systems.

4.3.1.11 IM Data System

Infrastructure Manager Data System can be any person or firm responsible for the management of all infrastructure data, traffic management, and control-command and signalling in alignment with key term definition in Directive 2012/34/EU that is relevant for producing Domain Data. The IM Data System typically refers to relevant existing and planned infrastructure databases and data sources within the IM's (e.g., ETCS and ATO engineering data) providing available Engineering Input Data (see definition in chapter 1.1). The Engineering Input Data is initially imported and used for the generation of Domain Data by DR. Feedback of data to the IM Data System is not foreseen.

4.3.2 System Interfaces and Transferred Data

The following three tables provide an overview of the interfaces to DR-TS and DR-OB as well as definitions of the transferred data from actors to DR-TS/DR-OB and vice-versa.

Note: Table 5 and Table 6 below also include the transferred data between the DR-TS and DR-OB respectively to improve the understanding of the data flows and ensure completeness.

Table 4: Interfaces overview

Nr	Name of Interface	Interface Endpoints
1.	I-DR	DR-TS and DR-OB
2.	I-DR-TS-MBS	DR-TS and MBS
3.	I-DR-TS-PE	DR-TS and PE
4.	I-DR-TS-TMS	DR-TS and TMS
5.	I-DR-TS-ATOTS	DR-TS and ATO-AT
6.	I-DR-OB-APM	DR-OB and APM-OB
7.	I-DR-OB-ASTP	DR-OB and ASTP
8.	I-DR-OB-PER	DR-OB and PER-OB
9.	I-DR-OB-ATP	DR-OB and ATP-OB
10.	I-DR-DM	DR-TS and DR Data Manager
11.	I-IM	DR-TS and IM Data System

Table 5: Message flow from DR-TS/DR-OB to actors

Nr	Transferred data	Description	Interface

1.	Domain Data (incl. Map Data)	Message sent from DR-TS to trackside Consuming Systems as well as DR-OB and DR-OB to on-board Consuming systems containing the required Domain Data.	I-DR-TS-MBS, I-DR-TS-TMS, I-DR-TS-PE, I-DR-TS-ATOAT, I-DR, I-DR-OB-APM, I-DR-OB-ASTP, I-DR-OB-PER, I-DR-OB-ATP, I-DR-OB-ADM
2.	Map Reference Data	Message sent from DR-TS to DR-OB containing the required On-Board Map Reference Data.	I-DR
3.	Domain Data version acknowledgement	Acknowledgment message sent from DR-TS to trackside Consuming Systems acknowledging that the systems have the actual version of Domain Data.	I-DR-TS-MBS, I-DR-TS-TMS, I-DR-TS-ATOAT, I-DR-TS-PE
4.	Domain Data Activation Request	Request message sent from DR-TS to TMS to update operational plan with activation of a new version of Domain Data.	I-DR-TS-TMS
5.	Activation command	Command sent from DR-TS to trackside Consuming Systems to initiate the activation of a (new) Domain Data version within the Consuming Systems.	I-DR-TS-MBS, I-DR-TS-TMS, I-DR-TS-ATOAT, I-DR-TS-PE
6.	Activation commit status	Status message sent from DR-TS to trackside Consuming Systems as well as DR Data Manager indicating the completion/abortion of the activation process.	I-DR-TS-MBS, I-DR-TS-TMS, I-DR-TS-ATOAT, I-DR-TS-PE
7.	Compile state	Status message providing the compilation status of Domain Data from DR-TS to DR Data Manager	I-DRDM
8.	Deactivation command	Command sent from DR-OB to on-board Consuming Systems to deactivate a version of Map Data.	I-DR-OB-APM, I-DR-OB-ASTP, I-DR-OB-PER, I-DR-OB-ATP, I-DR-OB-ADM
9.	Compilation issues	Message sent from DR-TS to DR Data Manager containing the issues encountered during compilation.	I-DRDM

10.	Validation issues	Message sent from DR-TS to DR Data Manager containing the issues encountered during validation.	I-DRDM

Table 6: Message flow from actors to DR-OB/DR-TS

Nr	Transferred data	Description	Interface
1.	Domain Data Request	Request message with relevant version information (if available) sent from Consuming Systems or DR-OB to DR-TS to obtain the Domain Data.	I-DR-TS-MBS, I-DR-TS-TMS, I-DR-TS-ATOTS, I-DR, I-DR-OB-APM, I-DR-OB-ASTP, I-DR-OB-PER, I-DR-OB-ATP, I-DR-OB-ADM, I-DR-TS-PE
2.	Map Reference Data request	Request message with relevant version information (if available) sent from DR-OB to obtain the On-Board Map Reference Data.	I-DR
3.	Domain Data acknowledgment	Acknowledgment message sent from trackside Consuming Systems to DR-TS to confirm the receival and preloading of the (new) Domain Data (version) within the Consuming System.	I-DR-TS-MBS, I-DR-TS-TMS, I-DR-TS-ATOAT, I-DR-TS-PE
4.	Activation acknowledgment	Acknowledgment message sent from trackside Consuming Systems to DR-TS as feedback acknowledging the activation of the Domain Data.	I-DR-TS-MBS, I-DR-TS-TMS, I-DR-TS-ATOAT, I-DR-TS-PE
5.	Domain Data restriction usage acknowledgement	Acknowledgment message sent from MBS to DR-TS and TMS as feedback acknowledging the setting up/ deletion of a usage restriction of Domain Data for the activation process.	I-DR-TS-MBS
6.	Domain Data activation time	Message providing an activation time window from TMS to DR-TS for the activation of a (new) Domain Data version.	I-DR-TS-TMS
7.	Publish trigger	Trigger message sent from DR Data Manager to DR-TS for initiating the publishing of the Domain Data	I-DRDM

8.	Import trigger	Trigger message sent by DR Data Manager to DR-TS to initiate the import process of new Engineering Input Data.	I-DRDM
9.	Authorisation command	Authorisation command sent by the DR Data Manager to DR-TS to authorise the activation of a new Domain Data version.	I-DRDM
10.	Engineering Input Data	Message sent from IM Data System to DR-TS containing the Engineering Input Data.	I-IM
11.	Deactivation trigger	Trigger message sent from ATP-OB to DR-OB to initiate the deactivation of a version of Domain Data.	I-DR-OB-ATP, I-DR
12.	Required map area	Message sent from ASTP to DR-OB providing the required area for the needed on-board Map Data.	I-DR-OB-ASTP
13.	Data adaptations	Message sent from DR Data Manager to DR-TS containing data adaptations for the compilation or validation issues.	I-DRDM

5 CAPABILITIES AND PROCESSUAL FLOWS

This chapter introduces the system capabilities (use cases) and the high-level flows outlining the interactions. The system capabilities described below were first introduced as a part of European initiatives (see [4][5]) and national implementation projects (see [1], [2], [3], and [12]). The definition of capabilities also involves a direct mapping of its functionalities towards the high-level phases and process definitions defined in Figure 4 chapter 3.

The system capability definition in this document provides some additional context addressing the relevant high-level phases, processes, and the subsystem allocations amongst the typical descriptors like (pre-)postconditions and descriptions. This is done to improve the functional understanding of the capabilities.

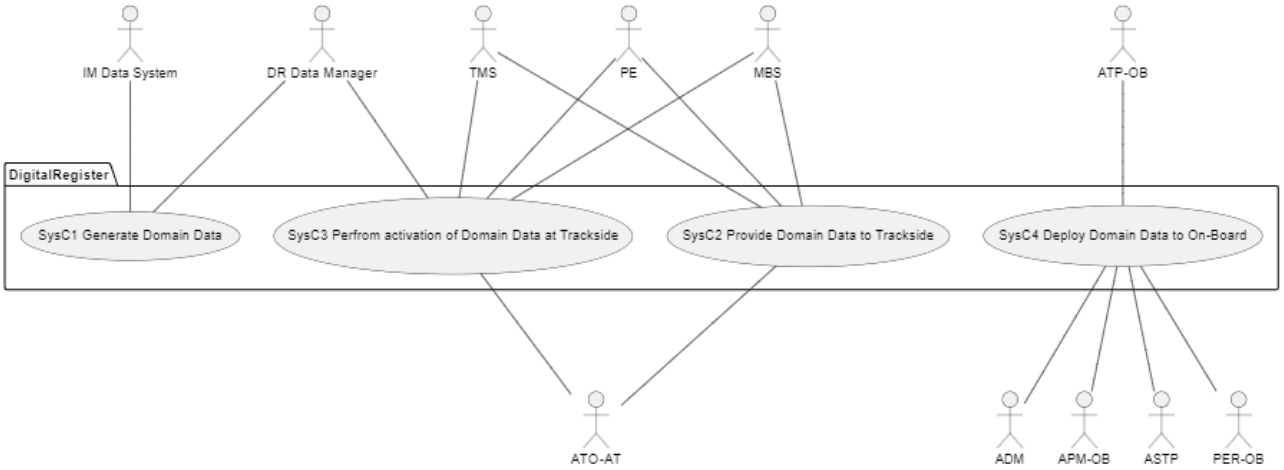


Figure 7: Capabilities overview

5.1 CAPABILITIES

5.1.1 System Capability SysC1: Generate Domain Data

High-level phase: Preparation

High-level process: Collect and Import; Aggregate and Validate; Compile

Pre-condition: A new set of Engineering Input Data is available for import.

Description: The SysC1 enables the DR-TS to import and aggregate Engineering Input Data, validate the resulting Engineering Data, and compile it into a new version of Domain Data for a trackside or on-board consuming system.

In addition, the capability also requires interactions with the actor DR Data Manager:

- The import of new Engineering Input Data is triggered and controlled by the DR Data Manager.
- The issues risen during the compilation process are handled by the DR Data Manager.
- The actual publishing of a version of the compiled Domain Data is triggered and controlled by the DR Data Manager. This involves the check for successful validation and compilation by the DR Data Manager as a pre-requisite for the publishing process.
- After the initial publishing of Domain Data or after initialisation of the system based on Engineering Data, the functionality provided by this capability is also used for potential adaptions of Domain Data. These adaptions are very basic modifications such as adding new timing points, renaming/splitting track edges, etc. After the adaptions are released, a new version of Domain Data is re-compiled and ready to be published.

Post-condition: The generated version of Domain Data is ready to be distributed to the Consuming Systems. The distribution is further explained in System Capability SysC2: Provide Domain Data to Trackside and System Capability SysC4: Deploy Domain Data to On-Board.

Allocation: Digital Register Trackside (DR-TS)

5.1.2 System Capability SysC2: Provide Domain Data to Trackside

High-level phase: Publish

High-level process: Publish and Load

Pre-condition: The generated version of Domain Data is available in DR-TS for distribution. There is an established connection between DR-TS, DR-OB, and the Consuming Systems.

Description: The SysC2 enables DR-TS to maintain multiple Domain Data versions and at the right point in time distribute the current (and upcoming) versions of Domain Data either upon a request or as a planned update of Domain Data or for initial publishing to DR-OB and/or the trackside Consuming Systems.

In addition, this capability also enables DR-TS to distribute Map Reference Data corresponding to Domain Data to the DR-OB.

Post-condition: The Domain Data is distributed to functions within DR-TS and DR-OB, functions within the trackside and on-board Consuming Systems, and is ready to be activated in trackside Consuming Systems. The activation is further explained in System Capability SysC3: Perform Activation of Domain Data in Trackside.

Allocation: Digital Register Trackside (DR-TS)

5.1.3 System Capability SysC3: Perform Activation of Domain Data in Trackside

High-level phase: Publish

High-level process: Activate

Pre-condition: The version of Domain Data to be activated is distributed to trackside Consuming Systems. There is an established connection between DR-TS and the Consuming Systems.

Description: The SysC3 enables the Digital Register to perform at the right point in time the harmonised activation of the required version of Domain Data to be used by the trackside Consuming Systems. In addition, this capability also requires interaction with the actor DR Data Manager and TMS to initiate and authorise the activation process, as well as with the actor MBS to set up the required usage restrictions (cf. chapter 4.3.1.3). The authorisation for activation of Domain Data is issued by the DR Data Manager and sent to TMS for initiating the activation process.

Post-condition: The current version of Domain Data is activated in all trackside consuming systems.

Allocation: Digital Register Trackside (DR-TS)

5.1.4 System Capability SysC4: Deploy Domain Data to On-Board

High-level phase: Publish

High-level process: Publish, Load, and Activate

Pre-condition: The current version of Domain Data is activated in DR-TS.

Description: The SysC4 enables the Digital Register to provide Domain Data to the on-board Consuming Systems. In addition, the capability includes the validation and deactivation of Domain Data for the on-board Consuming Systems.

Post-condition: The current version of Domain Data is provided to all on-board Consuming Systems.

Allocation: Digital Register Trackside (DR-TS), Digital Register On-Board (DR-OB)

5.2 PROCESSUAL FUNCTIONAL FLOWS

To define the functional requirements in chapter 6, this chapter describes the basic processual functional flows of DR. These processual functional flows define a detailed process on how the different functions of DR interact with each other for each system capability introduced in chapter 5.1. It follows the high-level process defined in chapter 3.

Note: The entities in the flows are colour coded as follows:

1. Green entities refer to SysC1
2. Orange entities refer to SysC2
3. Yellow entities refer to SysC3
4. Blue entities refer to SysC4[2]
5. Grey entities are defined for completeness and are not part of any system capability

[2] Functional flows for SysC4 uses ‘Map data’ as terminology instead of ‘On-Board Domain Data/On-Board Map Data’. This is done to avoid unnecessary naming changes and use as it is, the existing concepts from RCA.

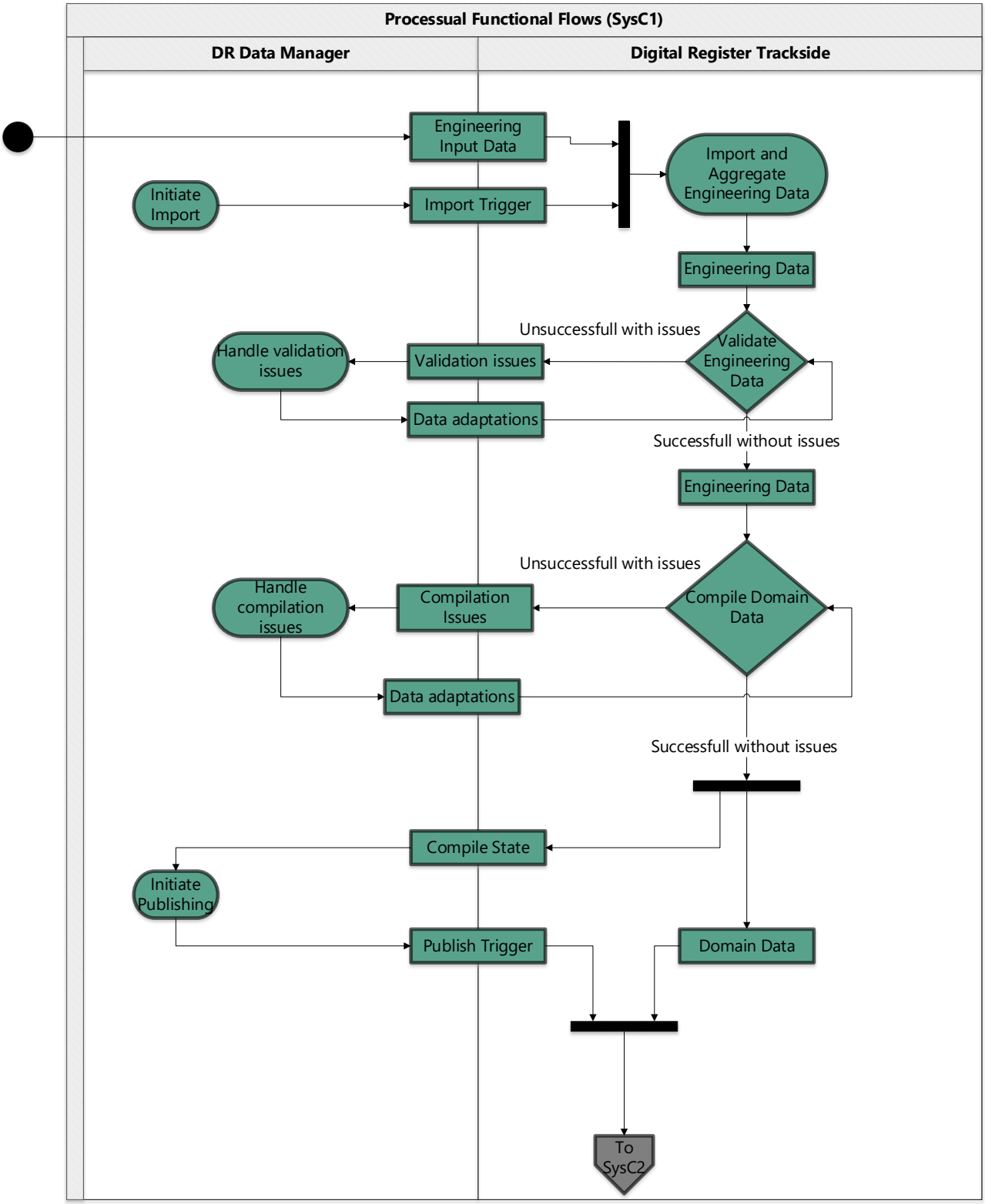


Figure 8: Functional flow for SysC1: Generate Domain Data

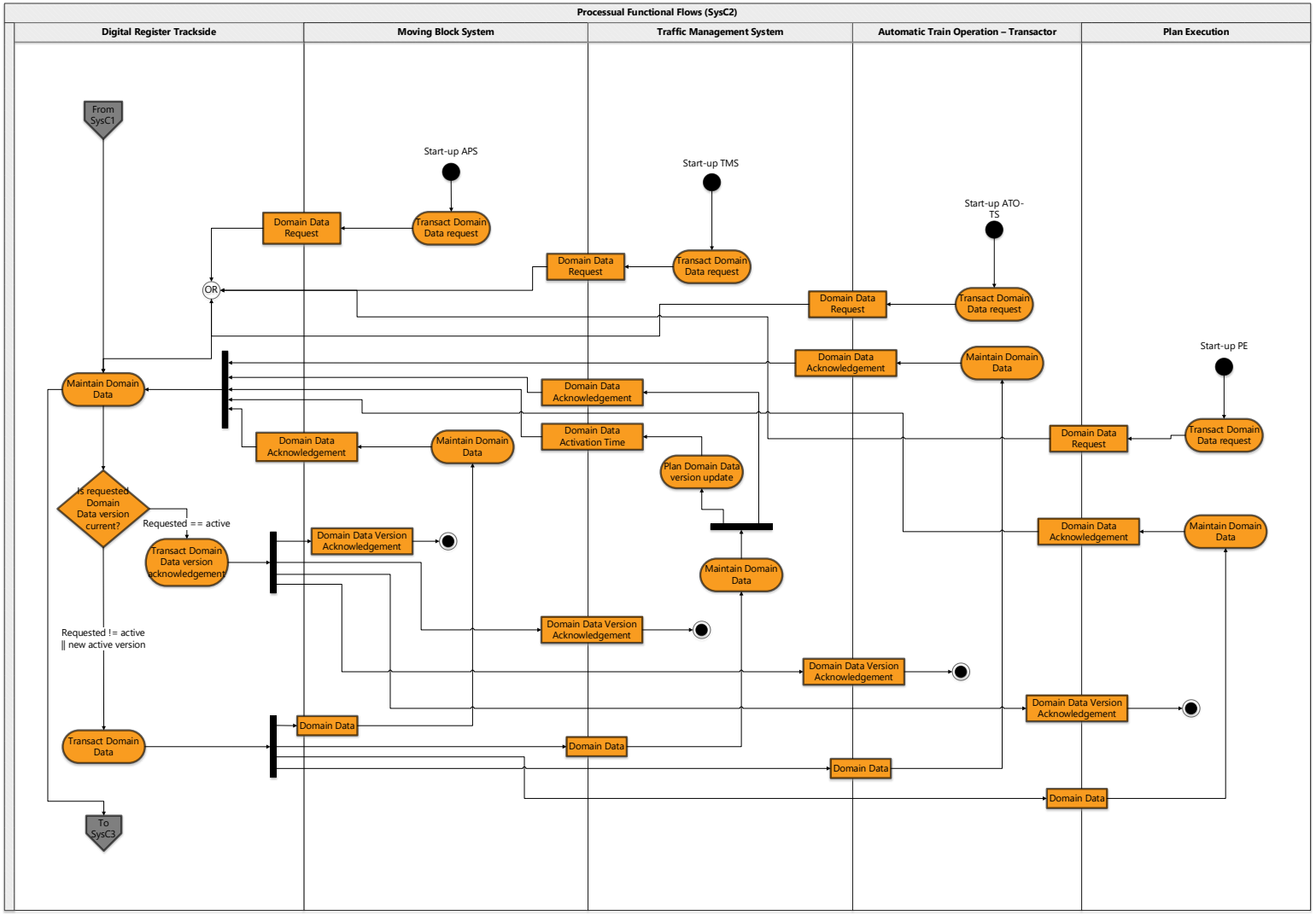


Figure 9: Functional flow for SysC2: Provide Domain Data to Trackside

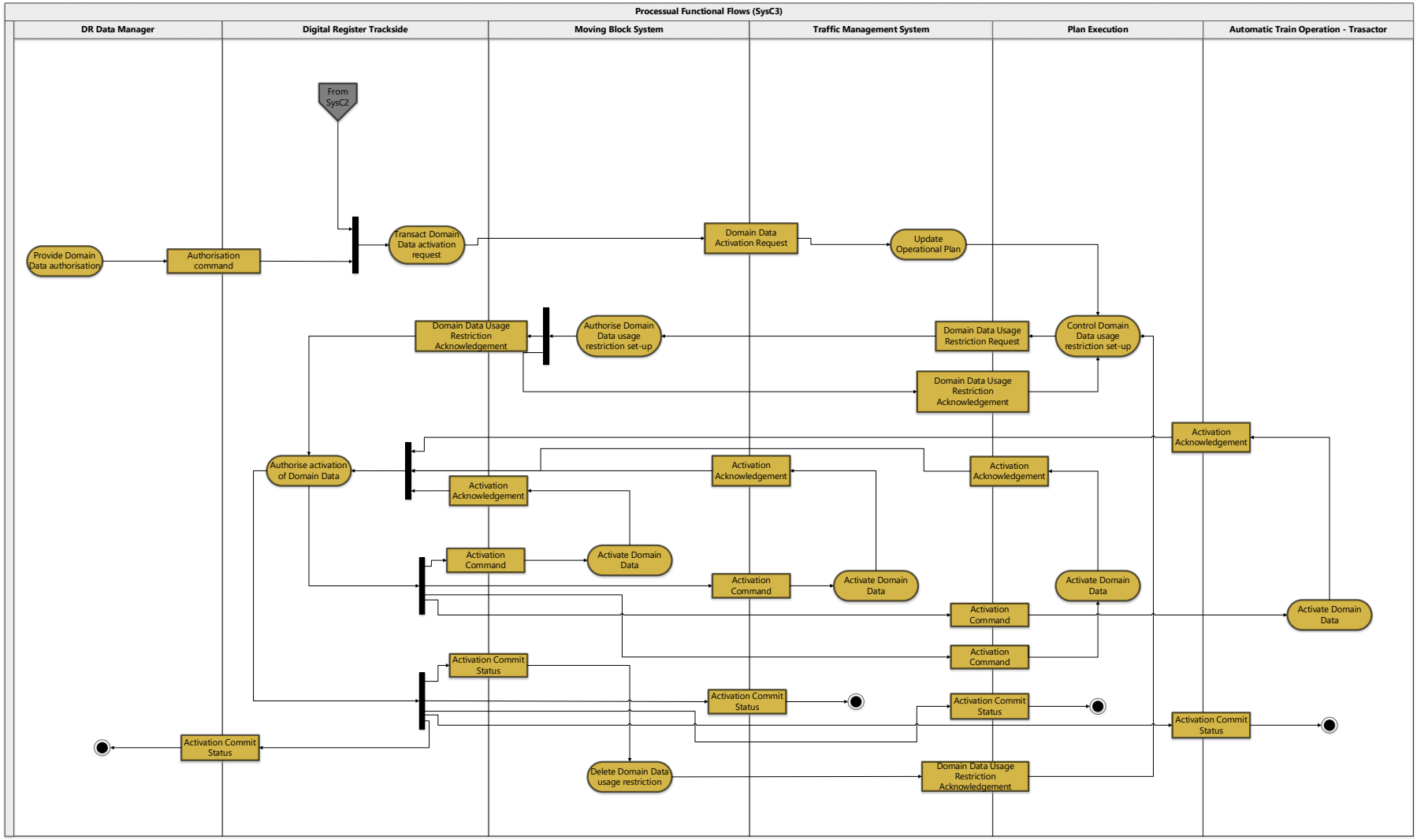


Figure 10: Functional flow for SysC3: Perform Activation of Domain Data in Trackside

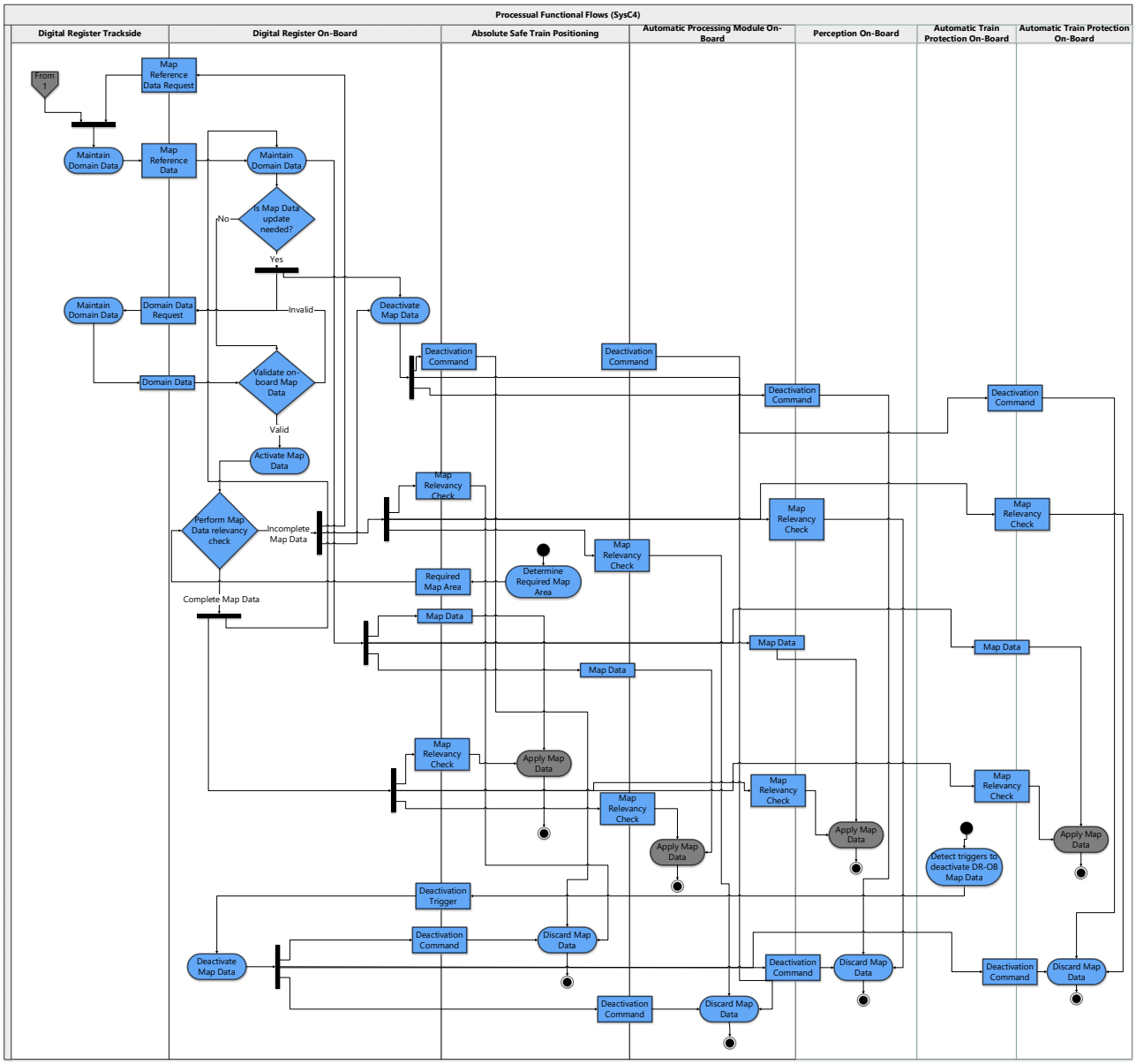


Figure 11: Functional flow for SysC4: Deploy Domain Data to On-Board

6 SYSTEM REQUIREMENTS

This chapter specifies the system requirements for the subsystems DR-TS and DR-OB. The requirements are specified in a tabular format with sufficient explanations within relevant sub chapters.

6.1 FUNCTIONAL REQUIREMENTS

This chapter specifies the functional requirements in form of functions that were identified and defined as a part of the processual functional flows in chapter 5.2. The functional requirements are defined with respective allocations to (sub-)systems/actors and the system capabilities. In addition, for each function, the requirement on input and output data flows is also specified.

6.1.1 General Requirements

Table 7: List of general requirements

ID	Requirement Text	Remarks
DR-SRS-1.	DR-TS shall ensure that Domain Data is compiled and managed congruent to the versions of Engineering Data i.e., each version of Engineering Data shall have a corresponding version of compiled Domain Data.	
DR-SRS-2.	DR-TS shall provide a stable and reliable version management for providing (current and upcoming versions of) Domain Data. E.g., versioning using a suitable numbering scheme. This ensures that the data is identifiable with regards to the type of change, e.g., whether it is a new project, a modification, or a bug fix.	
DR-SRS-3.	DR-TS shall provide information about the actual changes between two consecutive Domain Data versions (diff), such as deletion, insertion, replacements of specific elements, edges, or other parts of the Domain Data.	
DR-SRS-4.	DR-TS shall enable a rule engine for the validation process of Engineering Data that allows project specific adaptions or extensions.	

DR-SRS-5.	DR-TS shall be implemented as a cooperative tool, which allows the automatic checks to be combined with manual checks by a human validator (in this case DR Data Manager).	
DR-SRS-6.	DR-TS shall set up anchor points in Domain Data which serve as cross-system compatible borders for partial Domain Data changes. This is to be defined as per system needs and restrictions.	
DR-SRS-7.	DR-TS shall allow complete or incremental provisioning methods – fitting to the needs of different network sizes (small regional networks up to whole countries).	

6.1.2 System Functions

Table 8: List of system functions and requirements

ID	Allocated to System	Function Title	System Capability	Description	Input	Output
SysF1.	DR Data Manager	Initiate import	SysC1	DR Data Manager shall trigger the import process of Engineering Input Data.	-	Import Trigger (to DR-TS)
SysF2.	DR-TS	Import and aggregate Engineering Data	SysC1	DR-TS shall receive Engineering Input Data from IM Data System. DR-TS shall store the imported Engineering Input Data for internal processing. DR-TS shall aggregate Engineering Input Data received from one or multiple external source(s) into a common set of Engineering Data.	Engineering Input Data (from IM Data System) Import Trigger (from DR Data Manger)	Engineering Data (internal)

				This DR-TS function shall not be executed unless an Import Trigger was received from DR Data Manager.		
SysF3.	DR-TS	Validate Engineering Data	SysC1	DR-TS shall check the consistency of Engineering Data (e.g., check data quality, check against rule set, ensure pre-validated input, compare multiple sources). When the processing was not successful, DR-TS shall report any validation Issue (data issues or issues during validation) to the DR Data Manager. When the processing was successful, DR-TS shall start the compilation (SysF5). The validation rules shall be based on generic engineering rules, structural definitions, consistency conditions, and checks for quality attributes.	Engineering Data (internal)	Engineering Data (internal) Validation Issue (to DR Data Manager)
SysF4.	DR Data Manager	Handle validation issues	SysC1	The DR Data Manager shall review and solve each reported validation Issue.	Validation Issue (from DR-TS)	Data Adaptations (to DR-TS)
SysF5.	DR-TS	Compile Domain Data	SysC1	DR-TS shall transform Engineering Data into the Consuming System specific Domain Data.	Engineering Data (internal)	Domain Data (internal) Compilation Issue (to DR Data Manger)

				DR-TS shall verify the resulting Domain Data regarding defined rules and data definitions (e.g., structure, relations, mandatory objects/attributes, completeness of layers). When the processing was not successful, DR-TS shall report any Compilation Issue (data issues or issues during processing) to the DR Data Manager. DR-TS shall provide a user interface to the DR Data Manager, so that the DR Data Manager can review data issues and provide Data Adoptions to solve a Compilation Issue. When processing was successful, DR-TS shall report the Compile State to the DR Data Manger.	Data Adoption (from DR Data Manger)	Compile State (to DR Data Manger)
SysF6.	DR Data Manager	Handle compilation issues	SysC1	The DR Data Manager shall review and solve each reported Compilation Issue.	Compilation Issue (from DR-TS)	Data Adaptations (to DR-TS)
SysF7.	DR Data Manager	Initiate publishing	SysC1	The DR Data Manger shall trigger publishing of Domain Data based on a received Compile State.	Compile State (from DR-TS)	Publish Trigger (to DR-TS)

SysF8.	DR-TS	Maintain Domain Data	SysC2	DR-TS shall load a newly generated Domain Data version within DR-TS. DR-TS shall archive the existing Domain Data version (amount of history versions to be defined in later phases). DR-TS shall differentially update the existing Domain Data version with the newly generated Domain Data. DR-TS shall define a Domain Data version as an active. DR-TS shall receive a request for Domain Data from the Consuming Systems. DR shall monitor the loading of Domain Data from the Consuming Systems. DR-TS shall receive feedback on the loading/distribution state of Domain Data from the Consuming Systems. DR-TS shall receive Domain Data Activation Time from TMS DR shall distribute Domain Data based on the received Domain Data Activation Time to the Consuming System.	Domain Data (internal) Domain Data Acknowledgement (from MBS|TMS|ATO-AT|PE) Domain Data Activation Time (from TMS) Domain Data Request (from MBS|TMS|ATO-AT|PE) Publish Trigger (From DR Data Manager)	Domain Data (internal)

				DR-TS shall not publish Domain Data to any Consuming System unless an Publish Trigger was received from the DR Data Manager (see SysF7 “Initiate publishing”). DR-TS shall determine whether an (partial) update of the Domain Data is required, based on a comparison of the Domain Data version transferred in the received Domain Data Request and the Domain Data version, currently active at DR-TS. The following cases are applicable: Case 1: When the requested version in the Domain Data Request is not the same as the active Domain Data version, then DR-TS sends the current active Domain Data Version to the Consuming System. Case 2: When the requested version in the Domain Data Request is the same as the active Domain Data version, then DR-TS sends the Domain Data version acknowledgement to the Consuming System. Case 3: When DR-TS determines an Domain Data update, then DR-TS		

				updates the current active version in DR-TS AND sends the updated active Domain Data version to the Consuming System.		
SysF9.	DR-TS	Transact Domain Data	SysC2	When a Consuming System requires an update of Domain Data as per case 1 or case 2 defined in SysF8, DR-TS shall transact the current active version of Domain Data to the Consuming System.	Domain Data (internal)	Domain Data (to MBS|TMS|ATO-AT|PE)
SysF10.	DR-TS	Transact Domain Data version acknowledgement	SysC2	When a Consuming System does not require an update of Domain Data as per case 3 defined in SysF8, DR-TS shall transact a Domain Data Version Acknowledgement to the Consuming System.	-	Domain Data Version Acknowledgement (to MBS|TMS|ATO-AT|PE)
SysF11.	DR Data Manager	Provide Domain Data authorisation	SysC3	The DR Data Manager shall authorise the usage of a new Domain Data version before the activation process of this version can start. The DR Data Manager shall ensure that all preconditions (e.g., post construction activities the track is to be free of objects and people) are fulfilled before authorising a new Domain Data version.	-	Authorisation command (to DR-TS)

SysF12.	DR-TS	Transact Domain Data activation request	SysC3	When Authorisation command is received from DR Data Manager as well as completed Domain Data distribution process, DR-TS shall transact the Domain Data Activation Request to TMS.	Authorisation command (from DR Data Manager)	Domain Data Activation Request (to TMS)
SysF13.	DR-TS	Authorise activation of Domain Data	SysC3	When the Domain Data usage restriction acknowledgement is received from MBS, DR-TS shall authorise the change in required version of Domain Data for the consuming systems and shall send the activation commands for the new Domain Data version to all Consuming Systems. DR-TS shall monitor the incoming activation acknowledgements. When the Activation acknowledgements are received from all the consuming systems, DR-TS shall send Activation commit status to all the consuming systems to commit the activation process.	Domain Data usage restriction acknowledgement (from MBS) Activation acknowledgement (from MBS|TMS|ATO-AT|PE)	Activation commit status (to MBS|TMS|ATO-AT|PE) Activation command (to MBS|TMS|ATO-AT|PE)
SysF14.	DR-OB	Perform Map Data relevancy check	SysC4	DR-OB shall perform a Map relevancy check between the available minimum/maximum required Map Reference Data in DR-OB and	Required Map Area (from ASTP)	Map Data (internal) Map Reference Data Request (to DR-TS)

				required minimum/maximum required Map Area based on current train position to ensure completeness/availability of Map Data in train. DR-OB shall ensure consuming systems in train always have the current active version of Map Data. DR-OB shall always ascertain with Map relevancy check that the current available Map Data in DR-OB corresponds to at least the minimum required map area. The following cases are applicable: Case 1: Required Map Area from ASTP AND Minimum and Maximum required Map Reference Data corresponds to Map Data in DR-OB then, 1. DR-OB shall classify the Map Data to be complete 2. DR-OB shall send Map Data corresponding the required area to		Deactivation command (internal) Map relevancy check (to ASTP|APM-OB|PER-OB|ADM)

				consuming systems. Case 2: Required Map Area from ASTP AND Minimum and Maximum required Map Reference Data does not correspond to Map Data in DR-OB then, 1. DR-OB shall classify the Map Data to be incomplete 2. DR-OB shall send request for Map Data using Map Reference Data from DR-TS. 3. DR-OB shall send deactivation command to consuming systems		
SysF15.	DR-TS	Receive on-board Map Reference Data trigger	SysC4	DR-TS shall receive triggers from MBS or/and TMS which provide sufficient information to DR-TS to determine the necessity of Map Data updates for a train.	Triggers from external trackside[3]	Triggers from external trackside (internal)

[3] This is not an exchange item and is provided here to ensure completeness.

				Examples of such triggers can be Movement Authority/Permission or Journey Profile or Operational Plan (train route part).		
SysF16.	DR-OB	Maintain Domain Data	SysC4	DR-OB shall determine the required update of Map Data version, based on the received Map Reference Data from DR-TS and the available Map Reference Data version in DR-OB The following cases are applicable: Case 1: When the Map Data for the received Map Reference Data available in DR-OB, then DR-OB validates the available Map Data. Case 2: When the Map Data for the received Map Reference Data is not available in DR-OB, then DR-OB shall send request for Map Data using Map Reference Data from DR-TS. Case 3: When a Map Reference Data update is received from DR-OB, then 1. DR-OB shall send request for Map Data using Map Reference Data from DR-TS.	Map Reference Data (from DR-TS) Map relevancy check (internal)	Domain Data request (to DR-TS) Deactivation command (internal) Map Data (to ASTP|APM-OB|PER-OB|ADM)

				2. DR-OB shall send deactivation command to consuming systems. When a completeness is detected in DR-OB as per Case 1 defined in SysF14, DR-OB shall transact complete and actual valid version of Map Data to consuming system. DR-OB shall request the Map Data corresponding Map Reference Data as per Case 2 and Case 3 defined in SysF16 OR as per Case 2 defined in SysF14 from DR-TS.		
SysF17.	DR-OB	Validate on-board Map Data	SysC4	DR-OB shall validate the received Map Data according to the following factors: 1. Content of the Map Reference Data i.e., if the Map Data corresponds to Map Reference Data. 2. If the integrity of Map Data is confirmed i.e., Hash sums match The following cases are applicable based on the above evaluation: Case 1: When the Map Data corresponds to the Map Reference	Map Data (from DR-TS)	Map Data (internal) Map Data request (internal)

				Data AND integrity of Map Data is confirmed, 1. DR-OB shall classify the Map Data as valid. 2. DR-OB shall start the on-board activation process for the received Map Data. Case 2: When the Map Data does not correspond to the Map Reference Data AND integrity of Map Data is/is not confirmed, 1. DR-OB shall classify the Map Data as invalid. 2. DR-OB shall request the Map Data again from DR-TS.		
SysF18.	DR-OB	Activate Map Data	SysC4	When valid Map Data is detected in DR-OB as per Case 1 defined in SysF17, DR-OB shall activate the new Map Data version.	Map Data (internal)	Map Data (internal)
SysF19.	DR-OB	Deactivate Map Data	SysC4	When a deactivation trigger is received as per ActF19, Case 2 in SysF14, and Case 3 in SysF16 OR Connection disconnection between DR-TS and DR-OB is lost (excluding radio holes and other expected	Deactivation Trigger (from DR-TS|ATP-OB| internal)	Deactivation command (to ASTP|APM-OB|PER-OB|ADM)

				events), DR-OB shall deactivate the Map Data in DR-OB.		

6.1.3 Actor Functions

Table 9: List of actor functions and requirements

ID	Allocated to Actor	Function Title	System Capability	Description	Input	Output
ActF1.	MBS	Transact Domain Data request	SysC2	MBS shall request Domain Data from DR-TS.	-	Domain Data Request (to DR-TS)
ActF2.	TMS	Transact Domain Data request	SysC2	TMS shall request Domain Data from DR-TS.	-	Domain Data Request (to DR-TS)
ActF3.	PE	Transact Domain Data request	SysC2	PE shall request Domain Data from DR-TS.	-	Domain Data Request (to DR-TS)
ActF4.	ATO-AT	Transact Domain	SysC2	ATO-AT shall request Domain Data from DR-TS.	-	Domain Data Request (to DR-TS)

		Data request				
ActF5.	MBS	Maintain Domain Data	SysC2	MBS shall receive and load Domain Data from DR-TS. MBS shall send feedback, acknowledging the receival and loading of Domain Data, to DR-TS. MBS can have multiple loaded Domain Data versions at a time. MBS shall have only one Domain Data version as an active version as per the Domain Data activation process.	Domain Data (from DR-TS)	Domain Data Acknowledgement (to DR-TS)
ActF6.	TMS	Maintain Domain Data	SysC2	TMS shall receive and load Domain Data from DR-TS. TMS shall send feedback, acknowledging the receival and loading of Domain Data, to DR-TS. TMS can have multiple loaded Domain Data versions at a time. TMS shall have only one Domain Data version as an active version as per the Domain Data activation process.	Domain Data (from DR-TS)	Domain Data Acknowledgement (to DR-TS)
ActF7.	PE	Maintain Domain Data	SysC2	PE shall receive and load Domain Data from DR-TS. PE shall send feedback, acknowledging the receival and loading of Domain Data, to DR-TS.	Domain Data (from DR-TS)	Domain Data Acknowledgement (to DR-TS)

				PE can have multiple loaded Domain Data versions at a time. PE shall have only one Domain Data version as an active version as per the Domain Data activation process.		
ActF8.	ATO-AT	Maintain Domain Data	SysC2	ATO-AT shall receive and load Domain Data from DR-TS. ATO-AT shall send feedback, acknowledging the receival and loading of Domain Data, to DR-TS. ATO-AT can have multiple loaded Domain Data versions at a time. ATO-AT shall have only one Domain Data version as an active version as per the Domain Data activation process.	Domain Data (from DR-TS)	Domain Data Acknowledgement (to DR-TS)
ActF9.	TMS	Plan Domain Data version update	SysC2	When a new Domain Data version is received from DR-TS, TMS shall plan the required Domain Data activation windows (time slots) for update of Domain Data version in the Consuming Systems. TMS shall avoid conflicts with train movements when replanning the operational plan to include a Domain Data update.	Domain Data (from DR-TS)	Domain Data Activation Time (to DR-TS)
ActF10.	TMS	Update operational plan	SysC3	When the Domain Data Activation Request is received from DR, TMS shall update the pre-planned operational plan to include the update/activation of the new Domain Data version	Domain Data Activation Request (from DR-TS)	Updated operational plan (to PE)

				within its operational plan as per planned time windows in ActF9.		
ActF11.	PE	Control Domain Data usage restriction set-up	SysC3	When the Activation Time is reached and all preconditions (Distribution Acknowledgment and Authorisation Command were received) are fulfilled, PE shall send Usage Restriction (Area) request(s) to MBS for those infrastructure elements / Domain Data objects that are affected (to be changed/deleted) by activating the new Domain Data version.	Updated operational plan (from TMS)	Domain Data usage restriction request (to MBS)
ActF12.	MBS	Authorise Domain Data usage restriction set-up	SysC3	MBS shall set up the requested Usage Restriction (Area)(s). MBS shall set the affected (to be changed/deleted) Domain Data objects to a restrictive state. MBS shall ensure that no infrastructure element / Domain Data object is in use (e.g., assigned to a train movement/movement permission, executing a status change etc.).	Domain Data usage restriction request (from PE)	Domain Data usage restriction acknowledgement (to DR-TS | PE)
ActF13.	MBS	Activate Domain Data	SysC3	MBS shall activate the new Domain Data version after receiving the activation command from DR-TS. MBS shall deactivate the previously active Domain Data version by mere swapping of old and new version of Domain Data.	Activation command (from DR-TS)	Activation acknowledgement (to DR-TS)

ActF14.	TMS	Activate Domain Data	SysC3	TMS shall activate the new Domain Data version after receiving the activation command from DR-TS. TMS shall deactivate the previously active Domain Data version by mere swapping of old and new version of Domain Data.	Activation command (from DR-TS)	Activation acknowledgement (to DR-TS)
ActF15.	PE	Activate Domain Data	SysC3	PE shall activate the new Domain Data version after receiving the activation command from DR-TS. PE shall deactivate the previously active Domain Data version by mere swapping of old and new version of Domain Data.	Activation command (from DR-TS)	Activation acknowledgement (to DR-TS)
ActF16.	ATO-AT	Activate Domain Data	SysC3	ATO-AT shall activate the new Domain Data version after receiving the activation command from DR-TS. ATO-AT shall deactivate the previously active Domain Data version by mere swapping of old and new version of Domain Data.	Activation command (from DR-TS)	Activation acknowledgement (to DR-TS)
ActF17.	MBS	Delete Domain Data usage restriction	SysC3	When the Activation commit status is received from DR-TS, MBS shall delete the Usage Restriction (Area)(s) that were set up for the activation process of the new Domain Data version.	Activation commit status (from DR-TS)	Domain Data usage restriction acknowledgement (to PE)
ActF18.	ASTP	Determine Required Map Area	SysC4	ASTP shall determine and transact required minimum/maximum Required Map Area to DR-OB based on its position. Note: This function is only used for initial Map Data request. The successive Map Data requests / extensions can be performed using adjacent area	-	Required Map Area (to DR-OB)

				reference information, Journey Profiles or Movement Authorities.		
ActF19.	ATP-OB	Detect triggers to deactivate DR-OB Map Data	SysC4	ATP-OB shall detect different triggers to ensure deactivation of Map Data in DR-OB. The following are considered as triggers: 1. Shut down or restart of CCS-On-Board system 2. Loss of connection between RBC and On-Board.	-	Deactivation Trigger (internal)
ActF20.	ASTP	Discard Map Data	SysC4	When a deactivation command is received as per **Erreur ! Source du renvoi introuvable.**, ASTP shall discard the active Map Data version.	Deactivation command (from DR-OB)	-
ActF21.	PER-OB	Discard Map Data	SysC4	When a deactivation command is received as per **Erreur ! Source du renvoi introuvable.**, PER-OB shall discard the active Map Data version.	Deactivation command (from DR-OB)	-
ActF22.	APM-OB	Discard Map Data	SysC4	When a deactivation command is received as per **Erreur ! Source du renvoi introuvable.**, APM-OB shall discard the active Map Data version.	Deactivation command (from DR-OB)	-
ActF23.	ADM	Discard Map Data	SysC4	When a deactivation command is received as per **Erreur ! Source du renvoi introuvable.**, APM-OB shall discard the active Map Data version.	Deactivation command (from DR-OB)	-

7 EXPORTED CONSTRAINTS

This chapter provides a list of exported constraints towards to the actors identified in chapter 4.3.1.

Table 10: List of exported constraints

ID	Constraints	Allocation
ExpCon1.	The Engineering Input Data shall contain the information, whether it's validated or non-validated data.	IM Data System
ExpCon2.	In case of non-validated data, IM shall also provide the Acquisition Data to be able to validate the imported IM Data by comparing it to the Acquisition Data.	IM Data System
ExpCon3.	During provision of the Engineering Input Data, control mechanisms for integrity protection shall be provided. These shall be an acceptable set of measures that can even be used by the IMs to sufficiently mitigate the risk of manipulation beginning with the import of the Engineering Input Data.	IM Data System
ExpCon4.	As basis for safe operation, it shall be ensured by the IM Data System that the Engineering Input Data provided to DR corresponds to the real topology known outside.	IM Data System
ExpCon5.	To ensure safe activation of Domain Data, IM Data System shall trigger DR Data Manager to authorise the activation of Domain Data.	IM Data System
ExpCon6.	The ATP-OB shall operate in radio based ETCS levels as a train control system for all Map Data applications.	ATP-OB
ExpCon7.	The ASTP shall ensure a safe operation along with acceptable performance of the train in case of unavailability (or discontinued support) of Map Data. Note: Acceptable performance needs to be defined considering the CR1389.	ASTP
ExpCon8.	The on-board Consuming Systems shall always use the up-to-date version of Map Data as provided by DR-OB.	ASTP, PER-OB, APM-OB

ExpCon9.	The ASTP shall send reports to Diagnostic and Monitoring concerning localisation events (e.g., divergence between localisation and Map Data, based on detected issues during sensor fusion).These reports shall be analysed by Digital Register and data shall be updated, if necessary.	ASTP

8 OPEN POINTS

1. Need for Safety critical and non safety crictical functions.
2. Effects of incremental data updates on the interface specficaitions. i.e., How to handle the interface data structure in case of incremental updates.
3. Should the Minimum and Maximum Required Map Area cover 2D or 3D view? To be clarified with Perception System.
4. Content of Required Map Area to be defined together with ASTP
5. Add interface messages for receiving OB Map updates based on triggers from MBS and TMS (MA, JP, OP). See SysF33 Receive on-board Map Reference Data trigger
6. Detailed requirement definition for data aggregation, validation, and compilation.
7. Add a capability for User Management (registration/deregistration) to register consumers in DR. Optional content of the request (to discuss):
    a. Request contains a flag to indicate if the consumer needs a new version directly (like TMS) or only before activation
    b. Request contains a flag to indicate if an acknowledgement for a new version isb mandatory or optional (in case of optional, DR doesn't need to wait for the acknowledgement in order to perform the activation)
8. Define list of applicable ETCS modes for usage of Map Data in OB systems.
9. How is the Parameter Data handled/structured in the scope of WP27?
10. Should DR need/store more than 2 (current and upcoming) versions data?
11. Detailing on the manual process of DR Data Manager
12. Analyse: Required time taken from end of construction phase (incoming new version of data in DR-TS) to active state of domain data for use in DR-OB. E.g. If construction activities are finished at 1600hrs and first train run is on the track is at 1615hrs. Can this train run use new version of map data? Or does the data processing take hours and trains cannot run with map data until then?
13. Analyse: How long the Map Data is supposed to be active after considering the communication session between ETCS-OB and RBC as lost. This is needed because immediate deactivation of Map Data can lead to erronerous uncertainity intervals in ASTP.
14. Analyse: Time as a criteria to define validity of Map Data. i.e. Map Data is valid for 5 hrs and after that it is deactivated automatically.
15. Analyse: The need for redundant information (e.g., border track edges) in the adjacent map areas.

9 CONCLUSIONS

The deliverable D27.1 specifies the initial set of functional requirements for the Digital Register Trackside and Digital Register On-Board focusing on providing reliable data to the trackside and on-board consuming systems. The specified requirements are constrained to the defined scope and environment/boundaries, and are defined based on the inputs from several European and national implementation projects like RCA, OCORA, TAURO, Shift2Rail, Safe Rail Map, etc.

The deliverable D27.1 also identifies and specifies primary capabilities of the Digital Register trackside and on-board system. The functional aspects of these capabilities are elucidated by defining detailed processual functional flows. These flows depict the functional interactions along with exchanged messages between the systems. Using the functions and messages part of these flows, detailed functional requirements were defined and allocated to systems/actors.

Over the course of specification and review processes several functional/technical aspects arose which due to time constraints could not be included in the deliverable D27.1 but were defined as list of open points (see chapter 8). These open points would be addressed as a part of D27.3 ‘Updated requirements and specification of Digital Register’.

In addition, to achieve a complete set of requirements of Digital Register, the interface requirements, non-functional requirements (e.g., PRAMSS), technical requirements, data conversion requirements, etc. would also be specified as a part of D27.3.

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