RCA

Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

Digital Map - System Definition

Preliminary issue

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1. Introduction

1.1. Release Information

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1.3. Disclaimer

- The (Digital) MAP as cross-cutting topic requires coordination with RCA for Trackside CCS Domain, OCORA for On-Board CCS Domain and other Cross-Cutting Domains like Lineside CCS Assets, Traffic Management, Track Worker Safety, etc.
- The MAP process is divided into the phases "Prepare Map Data", "Publish Map Data to Trackside", and "Publish Map Data to On-Board"
- This Digital Map document is focused on the phase "Publish Map Data to On-Board".
- In general, Digital Map does not define its own Subsystem(s), rather Digital Map functionalities will be allocated to several RCA subsystems. Therefore, Digital Map uses "DM Trackside" and "DM On-Board" as functional clusters (not systems) to describe the Digital Map functionalities.
- Besides the target system RCA, the Digital Map context also considers the legacy architecture, which is based on the existing ERTMS/ETCS along with the introduced game changers of independent On-Board Vehicle Localisation component and Virtual Balise.
- While the RCA System Definition [RCA.Doc.35] defines the overall RCA system, this Digital Map System Definition is created additionally as base for the following Digital Map PHA [4] and to also consider the potential integration of Digital Map into legacy system architectures (at least to integrate the functionality of publishing Map Data to On-Board systems). However, all identified functions should be also integrated into the overall RCA system. Therefore, the content and the assumptions have been aligned with the overall RCA architecture and other clusters.

1.4. Purpose of the document

This document involves the basic system level understandings, the boundaries, detailed functionalities, interfaces, Life cycle aspects, and exported requirements.

1.5. Target audience

The target group consists of members of the RCA/OCORA.

1.6. Related Documents

The following documents provide related references:

[1] RCA Digital Map Concept [RCA.Doc.46] – published with BL0R2
[2] RCA System Architecture [RCA.Doc.35] - published with BL0R2
[3] RCA Digital Map – Evaluation Publish Onboard Map Approaches [RCA.Doc.56] - published with BL0R3
[4] RCA Digital Map PHA [RCA.Doc.58] - published with BL0R4
[5] RCA Terms and Abstract Concepts [RCA.Doc.14] - published with BL0R4
[6] RCA Realisation of RCA Goals [RCA.Doc.48] - published with BL0R2
[7] RCA MAP Concept (Overall Solution Concept) [RCA.Doc.54] - published with BL0R4

1.7. Definitions and Acronyms

For the detailed information on the terms and abbreviations refer to RCA *Terms and Abstract concepts* [5].

1.7.1. Definitions

The definitions provided here are to assist with better understanding and readability of the document.

1. Digital Map (DM): *see RCA Terms and Abstract concepts [5]*
2. Map Data: *see RCA Terms and Abstract concepts [5]*
3. Digital Map Trackside (DM-TS): *see also chapter 6.1*

   The functional cluster of Digital Map which is part of the trackside CCS responsible for publishing Map Data to the train.

4. Digital Map On-Board (DM-OB): *see also chapter 6.2*

   The functional cluster of Digital Map which is part of On-Board CCS responsible for managing and publishing Map Data to the On-Board consumer of Digital Map.

5. Map Version Data:

   Unique version id of (part of) the Map Data.

6. Map Id Data:

   Unambiguous/unique reference to a certain part of the whole Map Data (id).

7. Map Integrity Data:

   Suitable information (protection data such as hash) to reveal potential transmission or processing faults.

8. Map Reference Data:

   Set of information containing Map Version Data, Map Id Data and Map Integrity data required to validate Map Data.

1.7.2. Acronyms

CCS: Control-Command and Signalling

DCM: Device & Configuration Manager

DM-OB: Digital Map On-Board

DM-TS: Digital Map Trackside

MOT: Movable Object Transactor

OCORA: Open CCS On-Board Reference Architecture

PHA: Preliminary Hazard Analysis

PREP: Preparation

PROD: Production

PUB: Publish

PUB-TS: Publish Trackside

PUB-OB: Publish On-Board

RCA: Reference CCS Architecture

VL: Vehicle Locator

2. Objectives of Digital Map

"Digital Map is a set of functionalities providing track and trackside infrastructure information in the form of structured Map Data." [5]

2.1. Functional clusters under consideration

The functional clusters under consideration are Digital Map Trackside and Digital Map On-Board as introduced in the RCA Doc.46 Digital Map Concept.

These functional clusters are used to realise the Digital Map functionalities, as defined in the RCA Doc.46 Digital Map Concept. The primary goal here being provision of Map Data to the trains.

Apart from that Digital Map functional clusters,

1. Contribute towards realisation of localisation goals (as per ETCS-CR1368) of the RCA.
2. Shall also be integrable with existing legacy architectures and other introduced game changers like virtual balise.

It is also to be noted that migration scenarios are not considered as part of Digital Map but as part of consuming systems which use the Map Data. The consuming systems should determine for themselves on a migration strategy for a proper consumption of the Map Data.

2.2. Life cycle of Map Data

As introduced in the RCA Doc.46 Digital Map Concept [1] and RCA.Doc.54 MAP Concept [7], the Map Data has a full-fledged life cycle from the Preparation of the data till publishing to the consuming systems. The life cycle of the Map Data can be broadly divided into two parts,

Part 1: The engineering, preparation (validation and compilation) aspects build up this part of the Digital Map. This is also known as PREP phase.

Part 2: The production phase (or PROD phase) manages the publishing of Map Data to the On-Board and trackside consumers. The PROD phase includes a Publish Phase (or PUB Phase). The PUB phase is divided into two i.e. Publish Trackside phase (PUB-TS) and Publish On-Board phase (PUB-OB). The publish phases are responsible for distribution of Map Data to respective trackside and on-board systems. They also include the activation/deactivation of the Map Data within the systems including assurance of satisfaction of localisation needs.

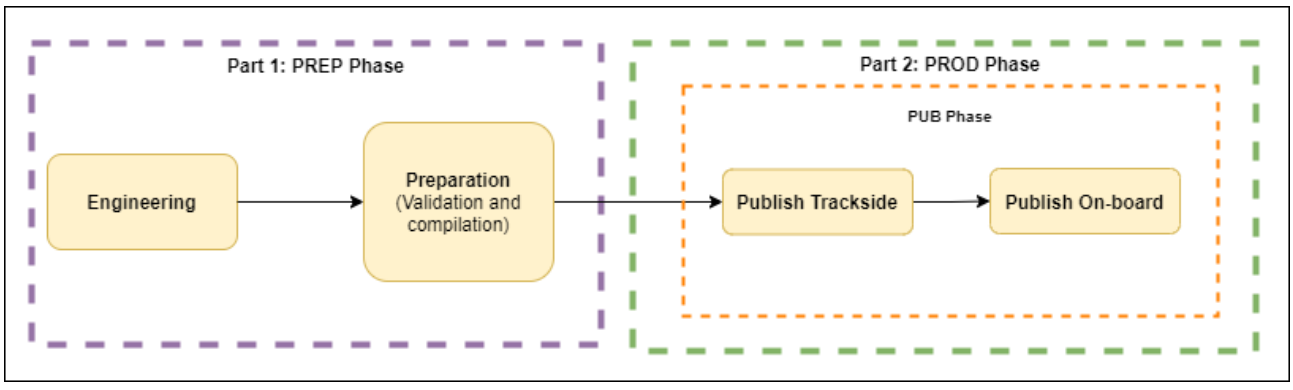

Figure 1: Life cycle of Map Data

These life cycle aspects of Map Data define in-detail the mission profiles of Digital Map. The relevant in/out of scope aspects of the life cycle are defined in chapter 2.3 as a part of mission profiles.

2.3. Mission profile

The following can be derived as the mission profiles for the Digital Map (more process description in RCA MAP Concept [7]),

1. PREP phase
   ➔ Consisting of Preparation aspects (Validation, Compilation, etc.) of Map Data.

2. PUB-TS phase
   ➔ Consisting of Publish Map Data to trackside system aspects.
   ➔ Consisting of ensuring usage of Map Data for Trackside functionalities i.e. train protection.
3. PUB-OB phase
   ➔ Consisting of Publish Map Data to On-Board system (according to required map area) aspects.
   ➔ Consisting of Maintaining of Map Data aspects (synchronisation of Map Data, Versioning, activation/deactivation etc.).
   ➔ Consisting of ensuring usage of Map Data for On-Board functionalities i.e. localisation.

2.3.1. In scope based on mission profiles

The within scope aspects as per the foreseen mission profiles can be narrowed down to PUB-OB phase (enclosed within orange box in Figure 1) consisting of the publishing of Map Data through the airgap interface along with maintaining of Map Data aspects and ensuring the usage of Map Data for On-Board functionalities.

2.3.2. Out of scope based on mission profiles

The following profile aspects of the Map Data are currently out of scope for the system definition:

1. PREP phase
2. PUB-TS phase

2.4. Operational Conditions of Digital Map

This chapter defines the Operational Conditions of the Digital Map only focusing on phase 'Publish Map Data to On-Board'.

2.4.1. ETCS operational conditions (Normal operational condition)

Within RCA it could be stated that the Map Data should be available in all radio-based levels (ETCS L2/L3) and modes. See Appendix.

For more information on the ETCS operational conditions and the basic train-to-track and track-to-train scenarios refer to Digital Map – Evaluation Publish On-Board Map Approaches [3] document.

2.4.2. Degraded situations

The following can be explicitly classified as situations from Digital Map perspective leading to degraded situations for the respective system hosting Digital Map functional clusters,

1 Loss of connection between the trackside and On-Board Digital Map functional clusters.
2 Unvalidated Map Data within On-Board unit.
3 Train not localised/located within an Area of Control of MT/RBC.

3. Boundaries of Digital Map

This chapter defines the boundaries of the Digital Map functional clusters which realise the airgap interface used to publish the Map Data to the On-Board. Based on the initial understandings from the concept phase, the following boundaries are identified.

The Digital Map boundary encompasses the two main Digital Map functional clusters (groups) namely, Digital Map trackside (DM-TS) and Digital Map On-Board (DM-OB). DM-TS and DM-OB are not to be understood as components or systems rather just a functional cluster (group) consisting of relevant Digital Map functions. The detailed functionalities of Digital Map will be analysed and allocated to the trackside and On-Board functional clusters of the Digital Map respectively.

The initial set of functionalities along with their possible allocations to the clusters are defined in-detail in Chapter 6 and Chapter 7.

The figure below depicts the boundaries of the Digital Map functional clusters with respective interfaces to systems and actors,

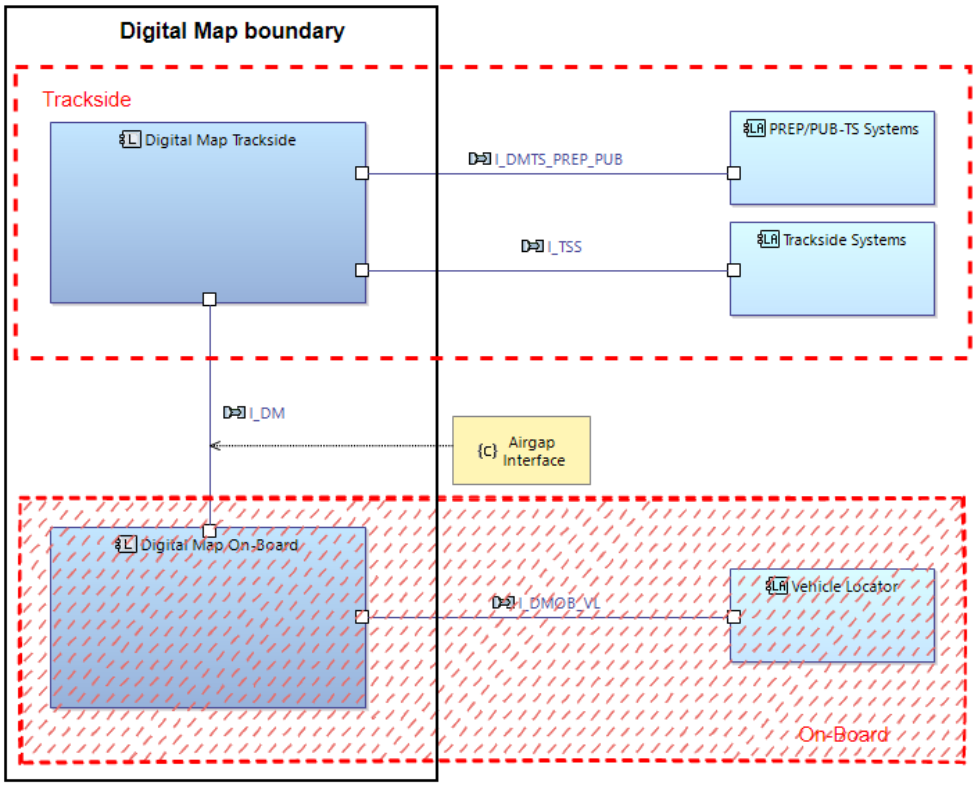

Figure 2: Digital Map boundaries

On the trackside the Digital Map Trackside functional cluster (DM-TS) constitutes the trackside Digital Map functionalities (see chapter 6.1). Keeping in mind the lifecycle of the map data from chapter 2.2, the functional cluster Digital Map Trackside corresponds to an aspect within the Publish On-Board phase. It also encompasses the interfaces to the PREP/PUB-TS systems and other trackside systems. These systems (shown in light blue within Trackside) classify as actors for DM-TS.

On the On-Board side the Digital Map On-Board functional cluster (DM-OB) constitutes the trackside Digital Map functionalities (see chapter 6.2). It is to be noted that the vehicle/On-Board is primarily considered a black box in this document. Even though the DM-OB functional cluster or RCA subsystems such as Vehicle Locator[1] are mentioned here, the decision on existence of such subsystems relies on OCORA. Owing to this fact, the corresponding aspects in Figure 2 (within On-Board) are illustrated as hatched.

Note: For definitions on Vehicle Locator refer to RCA System Architecture [2].

4. Description of Digital Map interfaces

This chapter provides an overview on the interfaces part of the Digital Map boundaries.

4.1. I_DM

This is a bi-directional interface between Digital Map Trackside and On-Board, which publishes Map Data to the trains and is responsible for transmission of other applicative aspects like Map Data requests and Map Reference Data. The communication here is ensured through a radio connection. This interface shall be based on the assumptions and requirements from RCA Digital Map Evaluation Publish On-Board Map Approaches [3] and documents from next phases for Digital Map such as Digital Map PHA [4].

In RCA, as per conclusions from the Digital Map – Evaluation Publish On-Board Map Approaches [3] document, this interface could be realised as a part of the SCI-MD between MOT and VL.

[1] Independent of the actual On-Board architecture the Vehicle Locator (VL) in this context represents the functional cluster/group that consumes the Map Data for localisation purposes.

4.2. I_DMOB_VL

This is a bi-directional interface between the Digital Map On-Board and Vehicle Locator (function). This interface is used to provide the Map Data to the localisation component in the train.

4.3. I_DMTS_ PREP_PUB

This is a bi-directional interface between the Digital Map Trackside and PREP/PUB-TS systems. This interface is used to provide the necessary Map Data to the Digital Map Trackside for further distribution.

4.4. I_TSS

This is a bi-directional interface between the Digital Map Trackside functional cluster and other trackside subsystems. This interface considers other necessary inputs from trackside systems that act as trigger events within the DM-TS. These events might support with map data distribution or version update of Map Data, etc. For example, operational plan, MP request, Journey profile, etc.

5. Description of Digital Map actors

This chapter provides the description Digital Map actors, which help providing Map Data according to the localisation needs incl. transmission of Map Data to DM-OB.

5.1. PREP/PUB systems

These refer to the system that shall be part of the PREP and the PUB-TS phase. As stated, in chapter 2.2 the PREP systems are responsible for preparation/validation/compilation of Map Data. This compiled Map Data is then transmitted to the DM-TS through a PUB-TS phase. These systems are connected to DM-TS using the I_DMTS_PREP_PUB interface.

The PREP phase within RCA can be overseen by subsystems such as Engineering and Data Prep (EDP), Topo4 (see also [7]).

The PUB-TS phase within RCA can be overseen by Device and Configuration Management (DCM).

5.2. Trackside systems

The trackside systems refer to cluster of systems which should provide operation relevant inputs to the Digital Map trackside functional cluster. These inputs can be used evaluate the necessary requirements/triggers to determine the need for Map Data in the DM-TS. These systems are connected to DM-TS using the I_TSS interface.

5.3. Vehicle Locator (On-Board function)

Vehicle Locater refers to a possible actor function that uses the Map Data to satisfy the localisation needs to the train unit. This function is connected to DM-TS using I_DMOB_VL interface.

Note: In this context Vehicle Locator is a functional cluster/ that consumes the Map Data for localisation purposes .

6. Description of Digital Map functional clusters

This chapter provides the description Digital Map functional clusters, which encompasses the Digital Map functionalities and realise the track-train airgap interface.

6.1. Digital Map Trackside (DM-TS)

Digital Map Trackside is the trackside counterpart that provides the Map Data to all systems needing Map Data for application. The current focus of DM-TS lies on transmission of Map Data to Digital Map On-Board over the airgap interface.

The scope of DM-TS is to obtain the Map Data from external sources and distribute it to the On-Board unit of the train. To ensure smooth distribution of Map Data, the Map Data also needs to be managed within the DM-TS. This is done by versioning the Map Data and maintaining the map versions within the trackside. Furthermore, the trackside also plays a major role in assuring synchronised Map Data versions between the trackside and On-Board (DM-OB) counterparts. This is ensured using a predefined reference data i.e. map Id + integrity information + version data.

In addition, the trackside handles Map Data requests, updates, and provides corresponding Map Data for the same.

In RCA, as per conclusions from the Digital Map – Evaluation Publish On-Board Map Approaches [3] document, DM-TS could be realised within Mobile Object Transactor (MOT).

Note: For definitions on Mobile Object Transactor refer to RCA System Architecture [2].

6.2. Digital Map On-Board (DM-OB)

Digital Map On-Board is the On-Board counterpart that provides the Map Data to other consumers within the train. These functional clusters will have interfaces with all the On-Board systems that need Map Data. The current focus of DM-OB lies on satisfying the localisation needs of the train.

The scope of DM-OB is to obtain the Map Data from DM-TS and further provide it to the end consumers within vehicle. Similar to trackside, On-Board also needs to maintain the Map Data within the vehicle. But due to safety criticality of the Map Data, the Map Data versions between On-Board and trackside needs to be synchronised and potentially asynchronous states must be safely detected (see deactivation below). Furthermore, the DM-OB evaluates the need within the vehicle for Map Data and correspondingly requests Map Data (or updates).

Activation of Map Data is also a crucial part before application of Map Data within vehicle which ensures that the Map Data is not corrupted, and the correct map version is authorised. The activation can only be performed when DM-OB has a synchronised Map Data based on the Map Reference Data.

The activation process eventually assures,

1. Integrity of Map Data
2. Presence of validated (activated) Map Data
3. Usage of correct Map Data version for operation.

A subsequent deactivation process is also a part of DM-OB. DM-OB is responsible to deactivate the required version of Map Data in train. This is ensured by determining the need to deactivate a version of Map Data due to external triggers like system shutdown, Map Data updates, disconnection, etc. (see below Table 1).

In RCA, as assumed in the Digital Map – Evaluation Publish On-Board Map Approaches [3] document, DM-OB could be realised e.g. within Vehicle Locator (or by another dedicated On-Board system). The actual allocation is the responsibility of OCORA/On-Board domain. RCA does not define which On-Board system implements the DM-OB functionality.

Note: For definitions on Vehicle Locator refer to RCA System Architecture [2].

7. Description of Digital Map functionalities

This chapter provides the overview of Digital Map functionalities that needs to be ensured by the trackside and On-Board. The functionalities are based on the requirements of the functional clusters from chapter 5.

7.1. Processual functional flow

The processual flow of Digital Map defines a detailed process on how different functions of DM-OB or DM-TS functional groups interact with each other. This process includes the following aspects,

1. Requesting of Map Data/Reference Data
2. Provision of Map Data/Reference Data
3. Validation of Map Data
4. Downloading of Map Data
5. Activation of Map Data
6. Providing Map Data to On-Board consumer
7. Deactivation of Map Data

In Figure 3: Process for provision/validation/activation of On-Board Map Data, Figure 4: Process for downloading of Map Data and Figure 5: Process for deactivating Map Data, the functions related to a single

activity are grouped within the blue boxes and identified with IDs accordingly. These IDs are to be seen in Table 1: Digital Map functions.

The white boxes within the blue boxes define in detail the functionalities related to an activity which exist on either side i.e. DM-TS and DM-OB.

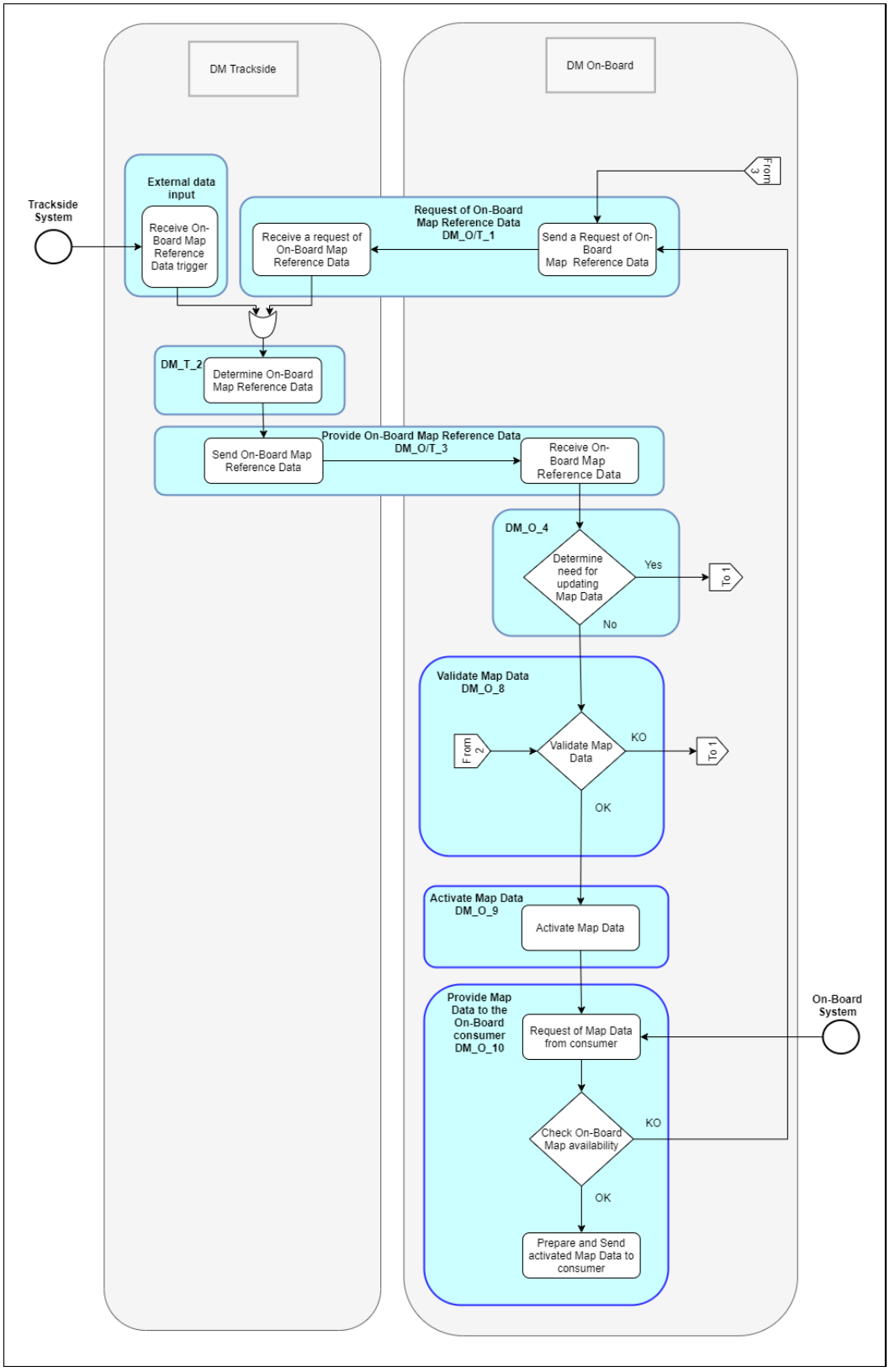

Figure 3: Process for provision/validation/activation of On-Board Map Data

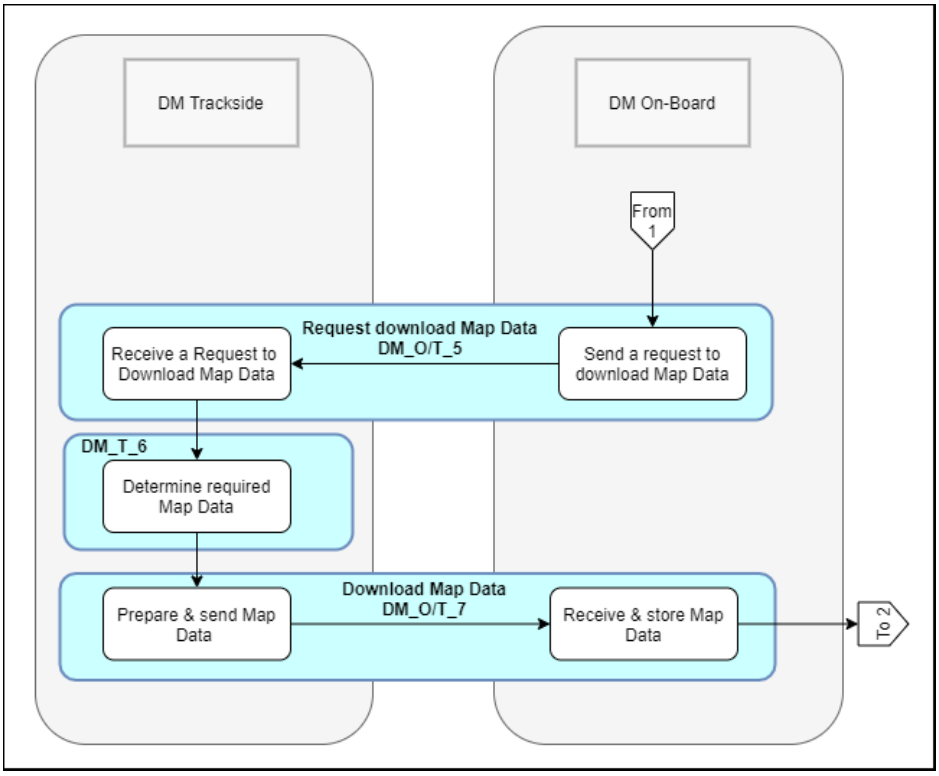

Figure 4: Process for downloading of Map Data

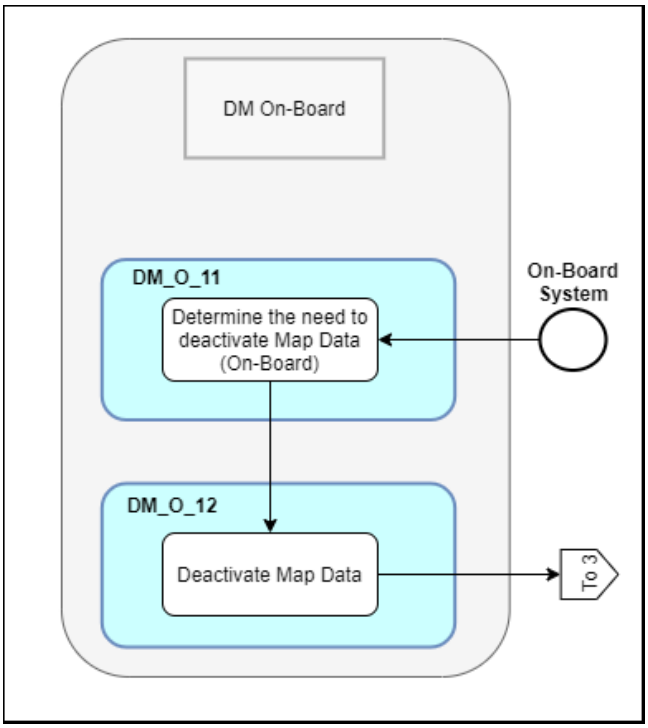

Figure 5: Process for deactivating Map Data

This process flow is developed based on the initial understandings from the RCA Doc.35 System Architecture [2] , RCA Digital Map Evaluation Publish On-Board Map Approaches [3]. The functions that are part of these processes are identified based on the selected Map Service approach (see [3] Figure 7) and listed in Table 1: Digital Map functions. They are allocated to DM Trackside (DM-TS) or/and DM On-board (DM-OB).

Additionally, the link between the Digital Map system function and the sequence steps in evaluation document [3] are defined below (see 'Function' column). These links are colour coded.

Table 1: Digital Map functions

Function ID	DM allocation	Function *link to step of [3], Figure 7* *link to step of [3], Figure 8* *link to step of [3], Figure 9*	Description
DM_O/T_1	DM On-Board/Trackside	Request of On-Board Map Reference Data *step 4 request [Onboard Map Ref] for [Required Map Area]*	This function requests the required reference data from the DM-TS. This event could also be triggered, 1. By requests from consuming systems (e.g. VL) (DM_O_10) regarding required map area 2. After a re-connect from DM-OB to DM-TS (with deactivated Map Data in DM-OB).
DM_T_2	DM Trackside	Determine required On-Board Map Reference Data *step 5 Determine required Onboard Map Ref(erence data)*	This trackside function determines the required Map Reference Data for a train unit (considering the required map area of the request).
DM_O/T_3	DM Trackside	Provide On-Board Map Reference Data *step 6 Provide Onboard Map Ref(erence data) for [Required Map Area]*	The trackside function provides a train specific requested Map Reference Data to DM-OB.
DM_O_4	DM On-Board	Determine need for updating Map Data *step 3 check activated [Onboard Map] coverage for [required Map Data]* *step 7 [Onboard Map] (data) available for [Onboard Map Ref]?*	This On-Board function determines the need for updating the Map Data within DM-OB. The Map Data update can be initiated under several pre-conditions, 1. Unavailability of the required Map Data in the train. 2. Map Reference Data received from DM-TS. 3. Change in Operational Plan/Journey Profile/Movement Authority of the train, eventually leading to new version of required Map Data. 4. Invalid/deactivated Map Data is present in the On-Board.

Function ID	DM allocation	Function *link to step of [3], Figure 7* *link to step of [3], Figure 8* *link to step of [3], Figure 9*	Description
DM_O/T_5	DM On-Board/Trackside	Request download of Map Data *step 8 request [Onboard Map] (data) based on [Onboard Map Ref]*	This function requests Map Data from DM-TS. The Map Data download request is dependent on the results of functions DM_O_4 and DM_O_8
DM_T_6	DM Trackside	Determine required Map Data *step 9 determine required [Onboard Map] (data)*	This trackside function determines the required Map Data based on a Map Data request.
DM_O/T_7	DM On-Board/Trackside	Provide Map Data *step 10 provide requested [Onboard Map] (data)*	This function provides the requested Map Data from DM-TS to DM-OB.
DM_O_8	DM On-Board	Validate Map Data *Step 11 validate available [Onboard Map] (data) against [Onboard Map Ref](erence data)*	This function validates the Map Data within DM-OB corresponding to the map version provided by DM-TS. This is done using the Map Reference Data received by DM-OB from DM-TS.
DM_O_9	DM On-Board	Activate Map Data *Step 12 activate validate [Onboard Map] data* *step 13 try download again up to x times, then abort)*	This function activates the correct version of Map Data within DM-OB as per the existing Map Data and the Map Reference Data. The activation of the Map Data based on the following pre-conditions, 1. Integrity of Map Data confirmed 2. Authorised version of Map Data corresponding to the Map Reference Data
DM_O_10	DM On-Board (& consuming system CCS-OB/VL)	Provide Map Data to consumer (here: VL) *Step 2 CCS-OB->DM-OB: request [Onboard Map] for [required map area]* *Step 14 DM-OB->CCS-OB: provide activated [Onboard Map]*	This function also evaluates the availability of required version of Map Data. In case of non-availability, this function sends a Map Reference Data trigger to DM_O/T_1. In case the Map Data is available, then it is provided to further consumers within the train unit.

Function ID	DM allocation	Function *link to step of [3], Figure 7* *link to step of [3], Figure 8* *link to step of [3], Figure 9*	Description
DM_O_11	DM On-Board	Determine the need to deactivate Map Data (On-board) *step 4 initiate disconnect from DM-TS e.g. during handover to new control area* *step 5 deactivate [Onboard Map] delivered by DM-TS instance*	This function determines the need for DM-OB to deactivate the Map Data. The deactivation of a version of Map data can be initiated under certain pre-conditions, 1. New version of Map Data is required as per the Map Reference Data. 2. Due to communication session disconnection from DM-TS (excluding radio holes and other expected events). 3. Due to shut down or restart of On-Board system. 4. Other safe triggers from On-Board systems to deactivate Map Data, such as a. Loss of connection between RBC/MT and On-board (RCA or legacy architecture) or b. "Map Data version update" information by MT (SS-026 packet) (RCA only).
DM_O_12	DM On-Board	Deactivate Map Data *step 5 deactivate [Onboard Map] delivered by DM-TS instance* *step 3 deactivate complete [Onboard Map]*	This function deactivates the previous version of Map Data within DM-OB. The deactivation of Map Data is always triggered by DM-OB as per DM_T_11. Post deactivation DM-OB can request the new version of Map Data as per DM_O/T_1
External data input	-	Receive On-Board Map Reference Data trigger	For optimisation potentials like earlier Map Data updates, this trackside function receives triggers from external trackside sources which provide sufficient information to DM-TS to determine the required of Map data updates for a train. Examples of such triggers can be Movement Authority/Permission or Journey Profile or Operational Plan (train route part)

8. Scope of Preliminary Hazard Analysis (PHA)

At the early stage of the Digital Map definition, it is a first attempt approach to identify the potential hazards and events that may lead to an accident and to carry out the risk assessment for these hazards. This allows to define barrier/mitigation measures to reduce identified risks and to derive THR or TFFR apportionments.

It should be shared that the system context used to carry out the analysis is based on the existing ERTMS/ETCS where the concepts of independent onboard vehicle localisation component, virtual balise, and digital map are introduced.

Due to new architecture, game changers, and changing environment, results from RCA/OCORA projects, Digital Map system definition and its environment may change along the way. Therefore, all these impacts have to be taken into consideration when documents, new versions will be released. For this reason, it will be desirable to check and update the PHA according to the results obtained by the RCA/OCORA projects.

The complete PHA including scope definition will be part of the document Digital Map - Preliminary Hazard Analysis [4].

9. Exported requirements

This section consists of requirements that are detailed and traced back to the RCA Digital Map Concept [1] and RCA Doc.48 Realisation of RCA Goals [6]. These set of requirements will be exported and classified as functional or Non-Functional requirements. These would be eventually used for further detailed specification of Digital Map system.

Table 2: Exported Requirements

Title	Requirement	Trace
Flexible	Digital Map functional cluster shall allow complete or incremental provisioning methods according to region passed by train – fitting to the needs of different network sizes (small regional networks up to whole countries). *Note: Both methods might be applicable exclusively or in combination (hybrid mode: offline or online initial data loading + incremental updates*.)	[1] DM.1, DM.4, DM.17 [6] Q4 [3] PPR1
Efficient	Digital Map functional cluster shall minimize the transmission data load (volume, amount/number) between track and train. *Note:* Digital Map functional cluster *shall reduce the need for synchronization, especially between trackside and On-Board systems (airgap)*	[1] DM.2 [1] DM.21 [6] Q4 [3] PPR2
Versatile	Digital Map functional cluster shall provide the Map Data for localisation support at least for mandatory ETCS levels/modes as defined in the appendix (chapter 10)	[1] DM.20 [6] T3 (always located) [3] PPR3.1
Comprehensive	Digital Map functional cluster shall provide information regarding track axes (e.g. modelled as track points including coordinates, gradient, etc.) and relevant infrastructure elements (e.g. balises) with a pre-defined level of detail (granularity)	[1] DM.19 [6] T4 (less balises) [3] PPR4

Title	Requirement	Trace
Robust	Digital Map functional cluster shall avoid operational delays due to incomplete Map Data.	[1] DM.20, DM.16, DM.14 [6] G7, Q2, Q4 [3] PPR5
Safe	Digital Map functional cluster shall ensure that the vehicle locator can rely on the valid Map Data for safety-related applications (e.g. map as sensor, map matching). Besides the initial distribution, this includes the safe update of Map Data in case of new versions.	[1] DM.5, DM.9, DM.10 Safety, Reliability [1] NFR: Safety, Reliability [6] Q1 [3] PPR6
Secure	Digital Map functional cluster shall ensure providing secure Map Data to the consuming systems avoiding undetected/ unintended manipulations.	[1] DM.18 [6] G14, Q3 [3] PPR7
Migratable	Digital Map functional cluster shall be compatible with legacy architectures as well, to provide a technical and economical migration path. According to the RCA goals [6], the solution shall allow interfacing to existing systems in the environment around the RCA protecting its existing investments.	[6] G3, Q8 [3] PPR8
Interoperable	Digital Map functional cluster shall allow a seamless cross border and cross IMs traffic . Therefore, they shall rely on interfaces that are part of standardization (e.g. RCA, OCORA, EULYNX, ERTMS, TSI…) only.	[1] DM.7 [3] PPR9
Adaptable	Digital Map functional cluster shall ensure that future use cases (e.g. perception systems) with additional data needs can also be realised.	[1] DM.6 [6] G4, Q7 [3] PPR10
Low LCC	Digital Map functional cluster shall minimize usage of system components and apply standardized components, to simplify the architecture for implementation and operations.	[6] G1 [3] PPR11
Modifiable	Digital Map functional cluster shall allow future updates of components and extensions of Map Data at low costs and in an independent way (by avoiding impact on other systems).	[1] DM.13 [6] G1, Q5 [3] PPR12
Modular / Extensible	Digital Map functional cluster shall enable modularity of single framework in order to facilitate migration strategies allowing different configurations, which can be independently created, modified, replaced or exchanged with other modules or between different systems (i.e. by minimum number of dependencies to other systems).	[1] DM.3 [6] G2, Q6 [3] PPR13

10. Appendix

This appendix is an export out of [3] to show the ETCS levels/modes commanded by trackside in which the Digital Map Data is required.

Table 3: ETCS levels/modes and Digital Map support

Category	Associated ETCS levels/modes	Category Description
1	L2/L3 – Staff Responsible, Automatic Driving, On Sight, Full Supervision	Map Data is mandatory in these levels/modes.
2	L2/L3 – Reverse, Trip, Post Trip, System Failure, Sleeping, Non-Leading, Shunting with MA (new ETCS mode or mode profile)	Map Data is mandatory in these levels/modes as well, since it can improve the performance by maintaining a highly accurate position, which accelerates the transition to following modes such as FS.
3 (Not relevant for RCA due to no existing radio connection in these levels/modes.)	L2/L3 – Passive Shunting, Shunting without MA (new ETCS mode or mode profile) L1 – all modes	Map Data is optional but would be useful in these levels/modes, if applied.

Note: The content in the table has been amended to suit the content of this document. To get the complete picture, refer to RCA Digital Map Evaluation Publish On-Board Map Approaches [3].