

RCA



Reference CCS Architecture

*An initiative of the ERTMS users group and
the EULYNX consortium*

Digital Map - Concept

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1. Introduction

1.1 Release Information

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1.3 Purpose of the document

In December 2015, the European Union Agency for Railways (EUAR/ERA) defined different mid- and longer-term strategic challenges related to the ERTMS specifications roadmap in [5], listing the different lines of work for the development of the Command Control and Signalling (CCS) systems. The objective was to identify the optimal balance between (a) ERTMS Specification stability on one side and (b) their evolution (enhancements and errors) and ERTMS products on the other side, while safeguarding interoperability in the most economical way.

Among these so-called game changers, the sector identified the necessity of improving on-board localisation by the introduction of new positioning technologies (e.g. satellites). Several national tests and international research projects (e.g. GSA STARS, ERSAT GGC regarding the use of GNSS for railway localization) have shown, that a combination of sensors is required to ensure a more accurate and reliable (within the specified performance) odometry subsystem than the existing one and the use of additional technologies providing absolute or relative positioning in combination with Map Data can help to reduce trackside assets. In this context, on-board Map Data plays a central role as a kind of failure-free sensor, which delivers information about the track axis and relevant objects (e.g. reference points such as virtual or physical balises) to support the data evaluation and processing measured by the actual sensors. In addition, the on-board map allows to match corresponding positions in the railway system (e.g. distance on edge) based on the acquired sensor data information, i.e. for the geographical coordinates gathered by GNSS (or other) receivers or relative measurements done by IMUs.

To realize an interoperable and efficient solution, the required Map Data shall be provided via a standardized interface, not only for legacy but also for future railway architectures. Therefore, the Digital Map (DM) as a cluster has been launched as part of the RCA and OCORA to cover the specification work. Besides as an RCA and OCORA deliverable, it is also crucial to cover aspects of interoperability with the highest priority and summarize the results in a solution proposal of the CR1368 [10].

In addition, many other functions of the on-board or trackside railway systems rely on information about infrastructure, which can also be characterized as Map Data for the configuration of the systems (e.g. RCA SubSys SL, RCA SubSys AT). Therefore, Digital Map also considers these needs and are characterized as future scope of extension under Chapter 2 Scope of Digital Map

Over the course of this document the term 'Digital Map' is stated several times and is not to be confused with the actual 'Map Data' itself. The following definitions in section 1.4 shall avoid any misinterpretations.

This document aims to provide a complete conceptual view of the Digital Map, its main scope and principles, the expected environment as well as the objectives in terms of functional and non-functional requirements (NFR) that Digital Map pursues.

1.4 Terms and Abbreviations

For terms and definitions refer to RCA DM Glossary [9]. In addition, the following specific terms for Digital Map are temporally introduced here as proposals. Please note, that the final definitions of the proposed terms will be in RCA DM Glossary [9] after clarification with the other clusters.

1. Digital Map:

Digital Map is a set of functionalities providing track and trackside infrastructure information in the form of structured Map Data, including quality criteria for the data. In addition, it also ensures map management functionalities like map versioning, and download of Map Data.

2. Engineering Data:

Engineering data is a set of resulting data from the Engineering Process of Infrastructure Manager. Typically, the data are not adapted to cope with specific views demanded by each consumer. The Engineering Data contains all the base data (i.e. track topology and topography) for deriving the Map Data during the compile process. The Engineering Data must fulfil engineering rules, that are influenced by requirements of Map Data.

Engineering data contains only the updated resulting data (i.e. no several variants/versions of the same track) that is needed for the next provisioning and operation at a certain point of time in the consuming systems.

3. Map Data:

Map Data is provided to the consuming systems. During the operation, the Map Data is used to realize system specific functionalities, e.g. for support with on-board localization, generating ATO segment profiles, generating ETCS movement authorities or other specific use cases.

The Map Data includes a build-up set of edges along with associated nodes (e.g. Points, Buffer stops), the relevant infrastructure characteristics (e.g. curve radius and gradients), and location information (e.g. specific reference points, balises). The Map Data remain unchanged during operation phase until the next provisioning of Map Data.

The so-called Map Data from the Digital Map is based on the existing Topology Domain from RCA Domain Knowledge along with some additional information regarding Track Geometry and Location information.

4. Operational Data:

Operational Data is transmitted between production systems as part of messages, commands, requests, etc.. Operational Data can refer to or contain required parts of Map Data. In addition, Operational Data can contain temporary states or properties of infrastructure and its elements, that is overlaid on the Map Data:

The Operational Data is provided to consuming systems with information on the operational track infrastructure restrictions/properties i.e. usage restriction areas, temporary low adhesion zones, temporary speed restriction (TSR) areas. These restrictions/properties remain unchanged over time unless updated and can be overlaid on the Map Data.

In addition, the Operational Data is referred to the transient track assets state information e.g. point states or train track detection section states. This state information can also be overlaid on the Map Data. It is to be noted that this state information is not constant and vary as per train movements.

5. Safety-related Map Data:

Safety-related Map Data refers to the data which are utilized by system functions, which have a pre-defined safety classification i.e., from SIL1 up to SIL4. These data for SIL functions, when imprecise (out of tolerance) or incorrect might lead to a safety-related failure in the system.

Note: the term “safety-related Map Data” is used to avoid the often used, but misleading term “SIL-data”, since the data itself does not have any SIL according EN 50126”

6. Non-Safety-related Map Data:

Non-safety-related Map Data represents any other data (complementary to safety-related Map Data), which does not require any safety-related requirements/classifications. However, this data must still fulfil a certain level of required quality, e.g. to guarantee a high level of availability.

7. Reliable Data:

Reliable data refers to a typical characteristic of data which satisfies the qualities of being trustworthy/lower probability of incorrect information/lower fault rate of the information, current (not obsolete), complete, and accurate.

Reliable data is not only about *safety-related Map Data*, but also *non-safety-related Map Data* that still needs to fulfil certain criteria for a specific function of consumer/system.

1.5 Structure of the document

The document is structured as follows:

1. Chapter 2: Scope of Digital Map

Describes the scope of the of the Digital Map within the current RCA framework. Some of the possible consumers are listed and the role that the Digital Map will play in the architecture is presented.

2. Chapter 3: Context of the Digital Map

Describes the background and the historical reasons that led the creation of the RCA Digital Map cluster and the main goals the group pursuits.

3. Chapter 4: Principles of Digital Map

Describes the principles of the Digital Map function. Some high-level requirements are listed as the basis of the Digital Map specification.

4. Chapter 5: Environment of Digital Map

Presents the Environment that will be used as basis to build up the function solution.

5. Chapter 6: RAMSS and performance requirements

Provides the list of Non-Functional Requirements that are applicable for the Digital Map.

6. Chapter 7: Regulation analysis

Provides an insight on the list of regulations that are to be considered for development of Digital Map.

7. Chapter 8: Exported requirements

Provides a list of high-level requirements that are exported from this Digital Map concept document.

8. Chapter 9: Assumptions & Justifications

Provides a list of high-level assumptions at the concept phase of Digital Map.

9. Chapter 10: References

Provides a list of applicable documents and references.

2 Scope of Digital Map

As defined in section 1.4, Digital Map focuses on the *structure* and *management* functions of trackside infrastructure data. To be precise, Digital Map addresses the interplay between relevant RCA systems through definition of exchanged Map Data content for relevant RCA interfaces along with Map Data quality requirements. In addition, it also addresses the functional needs of relevant RCA systems to realize the Digital Map services incl. management functions.

2.1 Applicability of Scope

Figure 1 provides the initial scope of the Digital Map with an eye on possible scope for future extension. The scope is defined by two dimensions:

- Consumers: which systems use the data for specific functions?
- Life cycle phases of Map Data: which part of the life cycle is under consideration?
 - o Prepare – Engineering: creation of Map Data by a planning/engineering process → Engineering Data
 - o Prepare – Validation: proof sufficient quality of created Engineering Data
 - o Prepare – Compile: transform Engineering Data to Map Data as required by the subsystems (including additional validation of Map Data, if required)
 - o Provide (Publish): transmit prepared Map Data update to the operational systems

As stated above, the initial scope is focused on the phase of *Provisioning* and the customer *VL/VS* for localisation functions within the ERTMS context. Later scope extensions of Digital Map cover further phases and consumers.

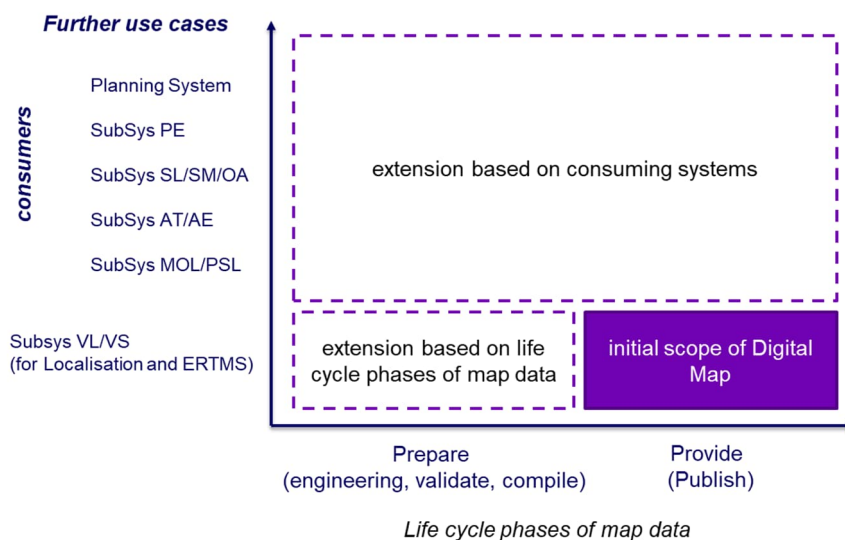


Figure 1: Initial scope of Digital Map and extensions

2.1.1 In Initial Scope

1. Providing Map Data via standardized interfaces to consuming systems.
 - a. With focus on On-board localisation, provision of Map Data to components such as Vehicle Locator (VL) [2] for Train Protection applications (improvement of ERTMS odometer performances and second order effects like the reduction of number of virtual or physical balises).
2. Defining processes during the operation phase of the systems.
3. To allow the applicability of Digital Map within legacy architectures, existing non-RCA systems (e.g. proprietary Map Servers, RBCs) are considered as a part of the scope and environment.
4. Ensuring the development of scalable requirements (e.g. data model or functions) depending on the needs of other stakeholders (RCA SubSys AT/SL/PE/AE/SM/MOL/PSL/OA) and phases.

2.1.2 Out of Initial Scope

1. Provision of Map Data to the *other* trackside and on-board systems in the RCA System Architecture [4], such as RCA SubSys AT/SL/PE/AE/SM/MOL/PSL/OA, Planning System, which will also be consumers of the Map Data contained in the Digital Map.
2. Map Data specific migration scenarios from Legacy architecture to RCA.
3. Preparation phases of Map Data.

3 Context of the Digital Map

As it was previously stated, Digital Map is one of the transversal functionalities that RCA/OCORA envisages. Map Data provided by the Digital Map may be consumed by many actors. This transversal usage of the data triggered the necessity of creating a transversal working group in which these needs, from the different consumers, could be considered.

The use of GNSS in the railway domain, was born about ten years ago with some train positioning research and innovation projects that highlighted the need of counting with a dataset to match the pseudo ranges provided by the signal in space with the rail infrastructure locations. It was in shift2rail X2R2-WP3 [6] where the sector started to develop a proposed architecture to tackle the on-board localisation problem while using GNSS as a source of information for on-board localisation to be integrated in the ERTMS system.

In parallel, railways, by means of the EUG Localisation Working Group (LWG), developed two documents owing to internal inquiries and positioning needs from rail operation. These two documents [7] and [8] set the high-level users' requirements for positioning and the accuracy targets of the on-board localisation system.

The EUG localisation working group produced, in December 2019, a change request (CR1368 [10]) for enhancing on-board localisation and reducing trackside asset, in the CCS TSI. The CR included the introduction of Digital Map functionality in the CCS specification. The problem description was accepted, and the CR was validated by the CCM process. At this point the LWG created a specific task force to design and agree on the concept of the Digital Map and its main functionalities, which are the seeds of the present cluster.

In parallel, the roadmap of RCA and OCORA included the creation of a cluster dedicated to the definition of the Digital Map functionality. Due to the background and knowledge gathered by the EUG through the activities carried out in the LWG and the special Digital Map task force, EUG was appointed responsible for this cluster.

Experts in Digital Maps, signalling, system engineering and system architecture, from the different railways are contributing to the work done in this cluster which aims to provide the definition of the Digital Map functionality and the definition of the interfaces using them.

Including the Digital Map functionalities in rail operations leads to different actions that need to be addressed, from the legal and operational point of view.

Independent of the solution or interface proposed, they need to guarantee interoperability throughout Europe. Using Map Data provided by Digital Map for the initial use case of improving ERTMS odometer performances, directly implies modifying the CCS TSI, to include the interoperability parameters of this new functionality. So, it can be used when integrated with ERTMS. This inclusion needs a safety analysis and a positive business case that will be checked and analysed by the CCS TSI CCM process. In addition, these deliveries serve as a base for the further specification work that needs to be done to provide, transport, and consume the Map Data by all systems that are part of this process or functionally rely on the Digital Map.

4 Principles of Digital Map

The development of Digital Map shall pursue the following basic principles:

Note: The following are high level requirements, which shall be refined in the later phases of Digital Map.

- A. Universal: The developed solution shall aim at covering all relevant configurations and application scenarios and shall be neutral towards implementation. [REQ]
- B. Simple: Architecture and data models shall be structured non redundant, semantically consistent, and comprehensive. [REQ]
- C. Modular: The tailoring of consumer's needs shall be done with aim at a clear separation of demands and considering operational and non-functional requirements of consumers (e.g. cut down consumer needs into groups with similar availability or safety requirements). [REQ]
- D. Regionalising: The Digital Map Data model shall allow the definition of different geographic areas. [REQ]
- E. Maintainable: The Digital Map shall keep different versions of Map Data and ensure its maintainability and updatability. [REQ]
- F. Future proof: The developed solution shall be usable for the long term and be easily extendable. [REQ]
- G. Interoperable: Digital Map shall ensure interoperability across vendor solutions or infrastructure manager. [REQ]
- H. Efficient: Digital Map shall define requirements that are not only technically feasible but also economically efficient (i.e. accuracy requirements and validity checks must not lead to unacceptable processing times or even technical barriers during the data preparation and validation. In addition, maintenance works such as tamping tracks should not lead to map updates due to too strong accuracy requirements without margin for maintenance phase) [REQ]
- I. Reliable: Digital Map shall contain Reliable Data [REQ]
- J. Validity: The management process of Digital Map during operation phase shall ensure that the correct version of a map is provided to the consumer and outdated map versions (e.g. due to obsolete Map Data) are detected and are prevented of any use by consumer/system. [REQ]

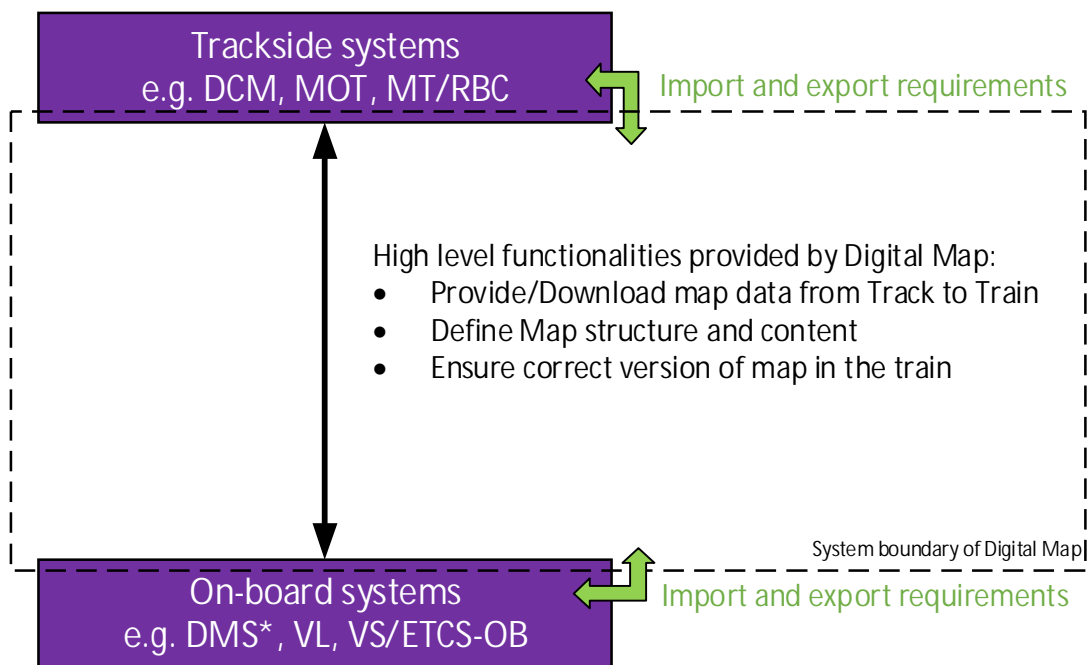
5 Environment of Digital Map

Figure 2 below represents a high-level overview of the system boundary of Digital Map. As stated in the Scope of Digital Map, the primary focus lies on providing Map Data for on-board localisation.

As per current understandings within the cluster, Digital Map is not a system rather a functionality which can be used by systems to cater for Map Data for on-board or trackside systems. Therefore, the system boundary of the Digital Map is considered as an interface between the trackside and on-board systems, which for the moment could be foreseen in several different configurations and needs to be narrowed down depending on the final architecture.

However, the systems from the aforementioned configuration are not a part of RCA Digital Map system boundary. Consequently, Digital Map imports and exports requirements (green arrows) from/to the systems for satisfaction of its functionalities.

Note: This environment is more conceptual/abstract rather concrete. The boundaries of Digital Map are subjective to changes in the System Definition phase.



*DMS – Digital Map Service by OCORA

Figure 2: Environment of Digital Map

On a high-level, Digital Map shall ensure the provision, content, structure, and management of the Map Data. The fulfilment of these functionalities shall rely on,

1. Incoming (imported) requirements from the trackside/on-board systems.
 - a. e.g. Map Data shall satisfy pre-defined data characteristics ensuring reliable data.
 - b. e.g. Map Data for localization purposes shall include information about actual geometric track alignments
2. Outgoing (exported) requirements to the on-board/track side systems.
 - a. e.g. On-board systems shall provide map services to download and use the Map Data from the trackside systems.

The requirements towards on-board systems are to be addressed along with OCORA, e.g. topics like use of Digital Map Service (DMS) as an on-board Map Data service provider. The alignment with OCORA on on-

board localisation topics would also be an important factor for future development and in relation additional incoming/outgoing requirements may emerge as it evolves.

A detailed definition on applicable systems and interfaces shall be carried out in the system definition phase of development. This preliminarily defined system environment shall be considered as an input for the detailed system definition.

For the extended scope of Digital Map (i.e. with more subsystems, whole life cycle of Map Data) additional requirements regarding preparation, providing and applying of Map Data are expected. Therefore, these requirements are considered for further development in the next steps.

6 RAMSS and performance requirements

This chapter provides an insight towards the different Non-Functional Requirements (NFR) which shall be considered throughout initial system development phases. As preliminary analysis the NFR's, which have already been defined for existing systems [8][7] and RCA [2], has been collected and classified for the Digital Map based on a specific set of criteria.

The NFR's applicable for the Digital Map shall focus on satisfying the following criteria,

1. Map structure/content e.g. data quality characteristics
2. Safety and security aspects
3. Map Data management aspects i.e. versioning or downloading.
4. Map Data availability aspects

Table 1: Applicable NFR's for Digital Map

Categories of NFR's	From existing systems	From RCA	Applicable for Digital Map?	Applicability
Safety	Y	Y	Y	Safety shall ensure providing safety-related Map Data to consuming systems. [REQ] <i>Also refer to Safety-related Map Data and to Digital Map management functionalities.</i>
Reliability	Y	Y	Y	<i>See Principle of Reliable Data</i>
Exchangeability	N	Y	N	Not applicable. Rational: Digital Map does not cover the definition of the lower-level interface layers but rather the upper-level application layer.
Accuracy	Y	N	Y	Accuracy is applicable to Map Data. Accuracy shall ensure the parameters within Map Data are confined to pre-defined accuracy values. [REQ] e.g. The position of the reference point on the map and the real position along the track shall have a justifiable tolerance value to maintain Map Data accuracy.
Availability	Y	Y	Y	Availability shall ensure that the Map Data is maximally available within the providing system for usage in case of a request from the consuming systems. [REQ]
Maintainability	Y	Y	N	Not applicable. Rational: Applicable for the physical architecture of the system itself and Digital Map only defines the functional artefacts towards the consuming/providing systems.

Categories of NFR's	From existing systems	From RCA	Applicable for Digital Map?	Applicability
				<i>Also refer to Modifiability</i>
Security	Y	Y	Y	Security shall ensure providing secure Map Data to the consuming systems avoiding undetected/ unintended manipulations. [REQ]
Capacity	Y	Y	Y	Capacity shall ensure the consuming/providing systems have sufficient minimum storage capacity to hold the Map Data for longer durations (in addition to other required data for operational purposes) as well as sufficient minimum transmission capacities over interfaces. [REQ]
Precision	Y	N	Y	Precision shall ensure the data are confined to pre-defined precision values, when subjected to repeated measurements. [REQ] e.g. A tolerance value between two sets of measured data.
Resolution	N	N	Y	Resolution shall ensure the Map Data are confined to pre-defined minimum measurable distances. [REQ] e.g. The measurable distances on map shall be confined to minimum of x decimal points.
Environmental conditions	Y	N	N	Not applicable. Rational: Applicable for the physical architecture of the system itself and Digital Map only defines the functional artefacts towards the consuming/providing systems.
Physical robustness	N	Y	N	Not applicable. Rational: Applicable for the physical architecture of the system itself.
Time Behaviour	N	Y	Y	Time behaviour is applicable for Digital Map management functions. Time behaviour shall ensure that consuming/providing systems do not lead to undesirable or unnecessary processing/response times for the Map Data. [REQ]
Scalability	N	Y	Y	Scalability shall ensure the Map Data is scalable (up or down) corresponding to

Categories of NFR's	From existing systems	From RCA	Applicable for Digital Map?	Applicability
				the required size of Map Data to be transmitted through the interface or content of the Map Data required by the specific consuming systems (scale by geographical region and by content). [REQ]
Reusability	N	Y	Y	Reusability shall ensure the characteristics/parameters/quality aspects of Map Data are reusable irrespective of consuming systems. [REQ] e.g. Map Data is used by different sub-systems of RCA and existing legacy sub-systems
Portability	N	Y	N	Not applicable. Rational: Applicable for the software architecture of system itself and Digital Map only defines the functional artefacts towards the consuming/providing systems
Adaptability	N	Y	N	Not applicable Rational: It is already covered in Modifiability
Modifiability	N	Y	Y	Modifiability is applicable to Map Data. Modifiability shall ensure the parameters defined in the Map Data are upgradable with any obsolescence/changes in existing information focusing on future data mode extensions/use cases/Consuming systems (structural updates). [REQ]
Testability	N	Y	N	Not applicable. Rational: Applicable for the software architecture of system itself.
Monitoring & Diagnostics	N	Y	N	Not applicable. Rational: Applicable for the software architecture of system itself.
Business Continuity Management	N	Y	N	Not applicable. Rational: Applicable for the overall development process of the systems itself.
Interoperability	N	Y	Y	<i>Refer to Interoperable: Digital Map shall ensure interoperability across vendor solutions or infrastructure manager. [REQ] (see chapter 4)</i>
Usability	N	Y	N	Not applicable

Categories of NFR's	From existing systems	From RCA	Applicable for Digital Map?	Applicability
				Rational: It is already covered in Reusability
Form and fit	N	Y	N	Not applicable. Rational: Digital Map does not cover the definition of the lower-level interface layers but rather the upper level application layer
Electromagnetic radiation / robustness	N	Y	N	Not applicable Rational: Applicable for the physical architecture of the system itself.
Environmental protection	N	Y	N	Not applicable Rational: Applicable for the physical architecture of the system itself.
Granularity	N	N	Y	Granularity is applicable to Map Data. Granularity shall ensure that the Map Data model is subjective to quantifiable level of detail. [REQ] e.g. Sampling of points that define the curve.

Legends: Y- Yes; N-No

7 Regulation analysis

This chapter identifies the relevant regulations, laws and norms that possibly have an impact on the development within Digital Map and/or might be adapted as a result of the development by Digital Map.

7.1 Interoperability

With the new 4th Railway Package, the rail regulation has had important changes. Interoperability regulations are the most important ones. Main legal documents that affect the train control and command systems are:

- Regulation (EU) 2016/796 on the European Union Agency for Railways. Describes the responsibilities of the European Rail Agency for system approval.
- Directive (EU) 2016/797 on the interoperability of the rail system within the European Union: describes the systems and subsystems to ensure the interoperability throughout Europe.
- Directive (EU) 2016/798 on railway safety: as its name suggests, establishes the legal framework to perform risk evaluation processes, monitoring activities and safety assessments.

From these regulations a set of Technical Specification for Interoperability are born. Each TSI describes and specifies the rail system or subsystem to guarantee interoperability.

7.2 Safety legislation/standards

According to the European directive 2016/798, compliance with the safety requirements shall be demonstrated to ensure the safe integration into the railway system and respect of the safety objectives when in service (for example, to achieve allocated THR's for the localisation functions). In this context and following the Common Safety Methods (CSM) is allowed to apply the CENELEC standards. For the rail domain the following standards apply:

- EN 50126 Railway applications - RAMS, basic requirements, and generic process
- EN 50128 Railway applications - Communication, signalling and processing systems. Software for railway control and protection systems
- EN 50129 Railway applications - Communication, signalling and processing systems. Safety related electronic systems for signalling
- EN50159-1 Railway applications - Communication, signalling and processing systems Part 1: Safety-related communication in closed transmission systems
- EN50159-2 Railway applications - Communication, signalling and processing systems Part 2: Safety related communication in open transmission systems.

7.3 Harmonization

Including the Digital Map in the current CCS architecture would lead to the amendment of the TSI and Technical Appendix. The new functionalities would be needed to be defined to ensure interoperability. This means that possibly, new subsets and some modifications to the already existing technical documents would be needed.

Within the RCA framework there exists a special cluster that will deal with the migration strategies in more detail. However, this Digital Map cluster has envisaged a proposal in which the functionalities of Digital Map could be accommodated in the current CCS TSI specification. Since as a part of current scope the Map Data is provided from trackside to on-board systems. The following relations to TSI exist and must be considered for Digital Map development.

As a part of preliminary analysis, the different existing subsets in the CCS TSI specification would be affected:

- SS026. Changes related to odometry input, speed, and position. Change in the architecture. Specification of the message to send map information.
- SS034. Train Interface FIS, to include the onboard Map Data functions.
- SS041. Performance Requirements for Interoperability. To include the requirements for Map Data.

- SS091. Safety Requirements for the Technical Interoperability of ETCS in Levels 1 and 2. To include the safety cases due to the existence of the Map Data.

Depending on the 'to be' developed architecture new subsets might be required as well, possible examples could be:

- Possible new subset to specify the SCI-VL interface between the VL and the ETCS
- Possible new subset to specify the interoperability specifications of the VL
- Possible new subset to specify the interoperability specifications of the Digital Map and its interface with the RBC.

7.4 Further regulations

In addition, the following standards or models shall be considered for Digital Map development:

- RCA Domain Knowledge (based on BNT approach) [11]
- RCA Capella modelling rules [12]
- Other general interface constraints of RCA AR cluster
- Compatibility to other standards, i.e. RTM (Rail Topo Model) and other RTM based formats such as
 - EULYNX PREP [13]
 - railML3 [14]

8 Exported requirements

This chapter contains the list of all the high-level requirements identified from the concept phase of Digital Map.

Table 2: Exported requirements from Digital Map Concept

Req. ID	Ref. Doc	Req. Type	Req. Description
DM.1	Digital Map Concept-Chapter 4	Non-Functional	Universal: The developed solution shall aim at covering all relevant configurations and application scenarios and shall be neutral towards implementation
DM.2	Digital Map Concept-Chapter 4	Non-Functional	Simple: Architecture and data models shall be structured non redundant, semantically consistent, and comprehensive
DM.3	Digital Map Concept-Chapter 4	Non-Functional	Modular: The tailoring of consumer's needs shall be done with aim at a clear separation of demands and considering operational and non-functional requirements of consumers (e.g. cut down consumer needs into groups with similar availability or safety requirements).
DM.4	Digital Map Concept-Chapter 4	Non-Functional	Regionalising: The Digital Map Data model shall allow the definition of different geographic areas
DM.5	Digital Map Concept-Chapter 4	Non-Functional	Maintainable: The Digital Map shall keep different versions of Map Data and ensure its maintainability and up-datability
DM.6	Digital Map Concept-Chapter 4	Non-Functional	Future proof: The developed solution shall be usable for the long term and be easily extendable
DM.7	Digital Map Concept-Chapter 4	Non-Functional	Interoperable: Digital Map shall ensure interoperability across vendor solutions or infrastructure manager.
DM.8	Digital Map Concept-Chapter 4	Non-Functional	Efficient: Digital Map shall define requirements that are not only technically feasible but also economically efficient (i.e. accuracy requirements and validity checks must not lead to unacceptable processing times or even technical barriers during the data preparation and validation. In addition, maintenance works such as tamping tracks should not lead to map updates due to too strong accuracy requirements without margin for maintenance phase)
DM.9	Digital Map Concept-Chapter 4	Non-Functional	Reliable: Digital Map shall contain Reliable Data
DM.10	Digital Map Concept-Chapter 4	Non-Functional	Validity: The management process of Digital Map during operation phase shall ensure that the correct version of a map is provided to the consumer and outdated map versions (e.g. due to obsolete Map Data) are detected and are prevented of any use by consumer/system.
DM.11	Digital Map Concept-Chapter 6	Non-Functional	Safety shall ensure providing safety-related Map Data to consuming systems.
DM.12	Digital Map Concept-Chapter 6	Non-Functional	Accuracy is applicable to Map Data.

			Accuracy shall ensure the parameters within Map Data are confined to pre-defined accuracy values.
DM.13	Digital Map Concept-Chapter 6	Non-Functional	Modifiability is applicable to Map Data. Modifiability shall ensure the parameters defined in the Map Data are upgradable with any obsolescence/changes in existing information focusing on future data mode extensions/use cases/Consuming systems (structural updates).
DM.14	Digital Map Concept-Chapter 6	Non-Functional	Precision shall ensure the data are confined to pre-defined precision values, when subjected to repeated measurements.
DM.15	Digital Map Concept-Chapter 6	Non-Functional	Reusability shall ensure the characteristics/parameters/quality aspects of Map Data are reusable irrespective of consuming systems.
DM.16	Digital Map Concept-Chapter 6	Non-Functional	Time behaviour is applicable for Digital Map management functions. Time behaviour shall ensure that consuming/providing systems do not lead to undesirable or unnecessary processing/response times for the Map Data. Safety-related Map Data
DM.17	Digital Map Concept-Chapter 6	Non-Functional	Scalability shall ensure the Map Data is scalable (up or down) corresponding to the required size of Map Data to be transmitted through the interface or content of the Map Data required by the specific consuming systems (scale by geographical region and by content).
DM.18	Digital Map Concept-Chapter 6	Non-Functional	Security shall ensure providing secure Map Data to the consuming systems
DM.19	Digital Map Concept-Chapter 6	Non-Functional	Granularity is applicable to Map Data. Granularity shall ensure that the Map Data model is subjective to quantifiable level of detail.
DM.20	Digital Map Concept-Chapter 6	Non-Functional	Availability shall ensure that the Map Data is maximally available within the providing system for usage in case of a request from the consuming systems.
DM.21	Digital Map Concept-Chapter 6	Non-Functional	Capacity shall ensure the consuming/providing systems have sufficient minimum storage capacity to hold the Map Data for longer durations (in addition to other required data for operational purposes) as well as sufficient minimum transmission capacities over interfaces.
DM.22	Digital Map Concept-Chapter 6	Non-Functional	Resolution shall ensure the Map Data are confined to pre-defined minimum measurable distances.

9 Assumptions & Justifications

The assumptions here are a collection of boundary conditions, which were collected to narrow in on a temporary decision to complete this phase and take forward the developments to next phase.

Table 3: List of assumptions from Digital Map concept

Assumption ID	Ref. Doc	Assumption Description
DM(ASM).1	Digital Map Remit	Digital Map shall allow different physical implementation of the interface (tethered map update or over-the-airgap update)

10 References

The following documents provide related references:

- [1] RCA white paper: the rationale for starting RCA (published in august 2018): available here https://ertms.be/workgroups/ccs_architecture and here <https://www.eulynx.eu/index.php/home2/37-reference-ccs-architecture-white-paper> [RCA.Doc.1].
- [2] RCA System Concept [RCA.Doc.15]
- [3] RCA/OCORA: A potential harmonized On-board and Trackside Computing Platform for Digitalised Rail Operation
- [4] RCA System Architecture [RCA.Doc.35]
- [5] ERTMS Longer Term Perspective Report 18/12/2015
- [6] D3.2 System Architecture Specification and System Functional Hazard Analysis of the of the Fail-Safe
- [7] 18E112 TL high level principles
- [8] 19E100 Localisation Performance Requirements
- [9] Digital Map Glossary [RCA DM Glossary]
- [10] 20E073 Digital Map management for localisation purposes in ERTMS domain [CR1368]
- [11] RCA Domain Knowledge [RCA.Doc.18]
- [12] RCA Methods and Tooling [RCA.Doc.33]
- [13] EULYNX PREP, snapshot model provided on <https://eulynx.eu/index.php/dataprep> (2021-03-18)
- [14] railML3, schema provided on <https://www.railml.org/files/download/schemas/3.1/documentation/railML3.html> (2021-03-18)