OCORA

Open CCS On-board Reference Architecture

OCORA Architecture - Alpha Release
Index 00 - Master Document

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1.1	Walk-through results from NS, SNCF, DB, and SBB incorporated	AL	2019-10-18
1.2	Review input NS, SCNF, DB, and SBB incorporated	AL	2019-10-29
1.3	Review input from NS and SBB incorporated	AL	2019-11-04
1.4	Review input from SNCF and NS incorporated	AL	2019-11-07
1.5	Review input from all parties incorporated	AL	2019-11-12
2.0	Review comments from November 12 TELCO meeting incorporated.	AL	2019-11-12
2.1	Alignment of Figure 5, Figure 6, and Figure 7with current views from UIC TOBA and ETSI	AL	2019-11-15
2.2	Remark under Figure 5, Figure 6, and Figure 7 added	AL	2019-11-18

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References

The following references are used in this document:

[1] OCORA Architecture - Alpha Release - Index 01 - Glossary

[2] OCORA Architecture - Alpha Release - Index 02 - Problem Statements

[3] RCA Architecture Overview, RCA Doc. 2, Versions Beta 1, 2019-08-26

1 Introduction

1.1 Document context

This document is released together with a separate glossary [1] and a document containing the problem statements [2].

This document aims to provide the reader a comprehensive reference to the approach the OCORA members envisage to achieve the objectives defined in the OCORA Memorandum of Understanding. These objectives concentrate on enabling the rapid automation and digitalisation of rail products and services in order to reduce total cost of ownership, increase productivity and customer value and control investment and operational risks. The first priority is to develop a single generic CCS on-board concept to facilitate the implementation of full operational interoperability on the European rail network. This enables the introduction of innovative technologies (starting with the so called 'game changers' like ATO and FRMCS) and satisfies the needs and requirements of railway companies (engaged in the transportation of passengers and goods) while providing, at the same time, a solid and resilient economic foundation for the European signalling industry.

Aiming at swift adoption of new technologies, OCORA cannot ignore the forthcoming revision of the TSI CCS: a first opportunity to push developments in the direction necessary for a successful future of the European railway community. That is why this document and its annexes not only concentrate on explaining general OCORA viewpoints but also consolidate these considerations in articulated "Problem Statements" [2]. At a later stage, they will be transformed into concrete "Change Requests" for the upcoming TSI CCS revision, with the full support and agreement of major representative bodies.

In order to take the reader by the hand, a step by step top down approach is applied. First introducing the basics of the OCORA perspective on a high level of detail and from there on working from a functional level to technical details. On this journey, the reader will occasionally find specific technical terms and abbreviations that are explained in the Glossary [1].

This is a first and preliminary (hence: Alpha) release of the OCORA Architecture, containing the common views and preferences of OCORA members on the development of the train borne CCS function. This publication will be followed by subsequent releases of this document (e.g. beta, gamma) and topic specific documentation. It will be developed in a modular and iterative approach that evolves within the OCORA collaboration.

1.2 Why OCORA in general?

ERTMS today is widely deployed throughout Europe. With a target of 15,000 km of tracks to be equipped by 2023 and 51'000 km by 2030. Nevertheless, ERTMS still has to achieve its main goals: cross border (or rather: cross deployment) interoperability, controllable cost, and satisfying performance levels. However, ERTMS is an important enabler for the automation and digitalisation of an interoperable railway in Europe, but it has its challenges:

1. Current control-command and signalling on-board solutions in Europe are driving significant investment and maintenance costs;
2. Solutions do not consider the differences in life cycles between its constituents or parts;
3. The ERTMS specifications are written in natural language and error-prone with different possible interpretations by different suppliers;
4. Major innovations ("game changers") around the ETCS core are to be deployed in the next decade to boost the railway sector efficiency (i.e. ATO, fail-safe train localization, next radio communication system, …).

Recognizing that a coherent, modular, upgradeable, interchangeable, reliable and secure system architecture is paramount to overcome these challenges for the overall control-command and signalling system of the European railway sector, the intent is to establish the **O**pen **C**CS **O**n-board **R**eference **A**rchitecture (referred to as "OCORA"), in coherence with and complementarity to the trackside control-command and signalling subsystem.

1.3 What is OCORA?

OCORA is first and foremost a platform for cooperation to the benefit of the European Railway sector. Guiding principles, rules and regulations agreed between OCORA members, are expressed in the OCORA Memorandum of Understanding (MoU) and the OCORA Code of Conduct (CoC).

Members collaborate on the development of an open reference architecture for on-board command-control and signalling systems that supports the mutually agreed OCORA main objectives (refer to section 1.5). Collaboration takes place in working groups. Each working group is responsible for specific tasks, topics or issues. Working group(s) and participating experts are appointed by the OCORA management team.

OCORA is not a legal entity and cannot exert owner rights. In case collaboration projects would lead to financial commitments for the members, these commitments will have to be formally agreed prior to execution.

The funding members of OCORA are:

- Deutsche Bahn AG
- Schweizerische Bundesbahnen SBB
- NS Groep N.V.
- SNCF for itself and in the name of SNCF Mobilités and SNCF Réseau
- ÖBB-Produktion GmbH

OCORA is open to any railway undertaking or train keepers willing to accept the MoU and CoC. Ideally, all members are having delegates that actively support one or several working groups.

1.4 Key OCORA principles

OCORA acts according to the principles defined in the MoU and CoC. The key principles are:

1. OCORA is first and foremost a technical collaboration platform for its members. OCORA output will be made available to any stakeholder of the railway community.
2. As expressed in the CoC, OCORA acts in full conformity with existing competition law under any circumstances and within the existing sectoral regulatory framework. CR proposals formulated by OCORA, will e.g. be registered for further treatment through existing channels like CER or EUG.
3. Although OCORA aims at standardisation of the on-board CCS function, it does not envisage to set up a formal, “de iure” standard. However, OCORA will develop for its members and third parties, specifications for procurement purposes, following the examples of e.g. EULYNX.

In the process of developing the OCORA Alpha Architecture, the principles defined in the MoU and CoC have been developed further to clearly communicate what OCORA aims to achieve.

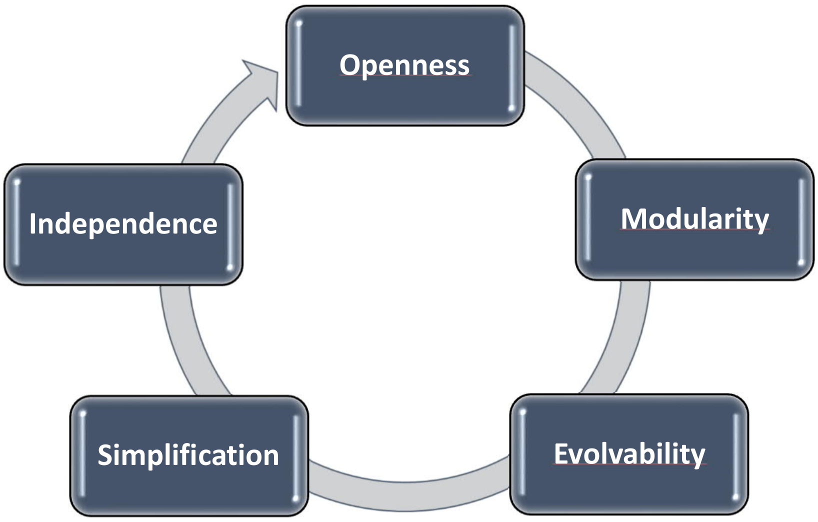

Figure 1 OCORA Key Principles

1. Openness: OCORA is an open collaborative technical platform open to all railway companies. This includes IMs and RUs. It is based on sharing and making publicly available its deliverables for the benefit of the railway sector.
2. Modularity: OCORA intends to decompose the on-board CCS subsystem into an optimal/reasonable number of standardized building blocks. System modularity is the basis for a modular safety approach and exchangeability, supporting different life cycles.
3. Simplification: OCORA plans to isolate in its architecture the functional blocks that will become obsolete in the foreseeable futures (e.g. GSM-R, class B systems, current balise technology). This is the basis to easily simplify OCORA based implementations, once the respective functions are not needed anymore.
4. Independence: OCORA intends to minimize the dependencies between different building blocks and components, such as dependencies between hardware, software and peripherals. This provides the basis for a modular product-based CCS system approach.
5. Evolvability: Recognizing that continuous updates and upgrades are paramount to the railway digitalization, OCORA intends to introduce secure upgradability and interchangeability to speed-up the integration of future innovations in a flexible manner and to provide a solid basis for introducing game changers such as FRMCS or ATO.

1.5 OCORA main objectives

OCORA members agree to collaborate in achieving the following specific objectives:

1. To define an Open CCS on-board reference architecture by e.g.:
   - Open standardisation of the ETCS/ATP and ATO train interfaces and functions and other on-board subsystems as plug and play solutions (e.g. a reference runtime platform with open interfaces).
   - Establishing the principles and necessary requirements of the OCORA initiative.
   - Aligning initiatives and ideas already started and find synergies to align scarce resources.
   - Streamlining industrialisation processes in particular the certification.

2. To foster and develop the open ETCS/ATP source initiative by utilizing and benefitting from the existing results of the “openETCS” initiative and sharing common understanding on this initiative.

3. Validate the viability and relevance of the OCORA approach by using e.g. demonstrators.

4. To promote the use of OCORA for the CCS on-board solutions in Europe in order to make it more cost effective, reliable, safe and secure by e.g.:
   - Ensuring consistency on a railway system scale between OCORA and other similar initiatives. This will be done in close coordination with sectoral organizations (e.g. CER, EIM, EPTTOLA, ...), and in close cooperation with joint undertakings, already in charge of defining certain aspects of the ERTMS (e.g. Shift2Rail, EuG, EULYNX, UNISIG, JPCR, UIC, RCA, etc.)
   - Building consensus and getting support from railway companies by means of regular information towards sectoral associations (e.g. members of the group of representative bodies)
   - Facilitating the industrialisation of OCORA results notably certification, through input to and discussions with associations, sectorial organizations, manufacturing companies and joint undertakings (e.g. UNIFE, UNISIG, Shift2Rail, ERL - European Reference Laboratories, etc.)

Achieving these objectives require a stepwise, incremental approach in which some issues can be (or need to be) addressed on a short term while others are more fundamental and therefore more time consuming. As a result, the OCORA perspective stretches over a longer period. However, future fundamental changes ask for swift and decisive action now: continuing the existing paradigm for realisation of ERTMS will stifle future changes. This is why OCORA has already developed problem statements that point out issues that have to be addressed now as a preparation for more fundamental changes in the near future. These include e.g. the lack of modularity, regulations that prevent innovation and the lack of non-functional requirements in the specifications (e.g. performance indicators).

1.6 What are expected OCORA deliverables?

Anticipated results from the OCORA collaboration as defined in the OCORA MoU are:

1. A reference architecture guiding the development of (a specification for) a consistent and modular on-board CCS system.
2. An economic evaluation supporting the OCORA architecture and approach.
3. Robust interface specifications allowing for smooth evolution and migration.
4. Improvements of the regulatory framework as a precondition for rapid introduction and adoption of (global) technological developments in other branches of industry and technology.
5. So called “demonstrators”, “real life application” of products (based on specifications developed within the OCORA framework) to showcase usability and applicability in test environments.
6. Publications targeting the dissemination of OCORA results to the benefit of stakeholders in the European railway community.

As a first step, OCORA aims at providing a comprehensive and coherent set of specification (architecture and interfaces) for a modular CCS on-board environment. These specifications shall serve as a voluntary format for tender templates, supporting companies currently engaged in procurement activities or soon starting procurement programmes.

Additional, future deliverables include supporting material for IVV (Integration, Verification and Validation) and material helping to justify OCORA-based CCS on-board implementations (e.g. business case calculation templates).

2 OCORA business rationale

To keep up competition with modal competitors, investing heavily in digitalisation and automation, railways rapidly have to embed innovative technologies in their physical assets, planning systems and operations. Digitalisation and automation are the prerequisites for boosting productivity, controlling cost and risk levels, and improving performance. That is why OCORA deems the fast integration of the game changers in the CCS domain of imperative importance and intends to gradually extend the grade of automation of heavy rail to the domain of fully automatic, unmanned operation (since decades business as usual in light rail).

The European railway community has identified ATO over ETCS to be the preferred solution for implementing ATO in heavy rail environments. At the same time, it recognizes the drawbacks of the current ERTMS implementation process which encompass high development and investment costs for suppliers and customers, performance issues and considerable technical, operational and financial risks. This raises the question as to what needs to be accomplished to provide railway transportation a sound and future proof economic foundation and how this can be achieved.

In the October 15 to 17, 2019 ERA CCRCC Conference in Valenciennes, DG MOVE formulated its objectives as follows:

To compete, rail needs to fully embrace digitalization, building on ERTMS to improve interoperability, drive down costs, and deliver a better service for passengers and business;

The DG MOVE CCS framework vision targets one European, adaptable CCS system;

Its principles are to enhance interoperability, provide for a cheaper, secure and future-proof system, a managed evolution and preservation of investments while creating the prerequisites for fast deployment and development.

For RU's this will result in CCS life-cycle cost reduction, standardized components, easier maintenance and upgrades and software and hardware independence.

(Presentation of Mr. Fitch, Day 2 – Session V)

The benefits the OCORA initiative expects to harvest are:

- Reduction of CAPEX: amount of capital expenditure reduced for a CCS on-board solution. This includes also the non-recurring engineering costs for development, integration engineering, certification, and even baseline upgrades.
- Reduction of OPEX: amount of operating expenditure reduced for a CCS on-board solution. This includes operation, maintenance, updates, as well as the life-cycle exchanges at least over a full vehicle lifespan.
- Fast and flexible migration: capabilities supporting functional evolution and simplified integration in existing vehicle and infrastructure.
- Shorter time-to-market: amount of time reduced to introduce new or adapted CCS functionalities and/or technologies into a vehicle. The time to fix an issue is also relevant when it comes to adaptations related to error correction or security patching.
- Increase performance: for the CCS on-board solution, an increase in reliability is expected, the availability and the maintainability, while maintaining the current level of safety.

Figure 2 provides a brief overview of the business rationale OCORA has identified. It relates OCORA objectives (as stated earlier in chapter 1.5) to the design goals it seeks to apply in its system architecture design (see chapter 5).

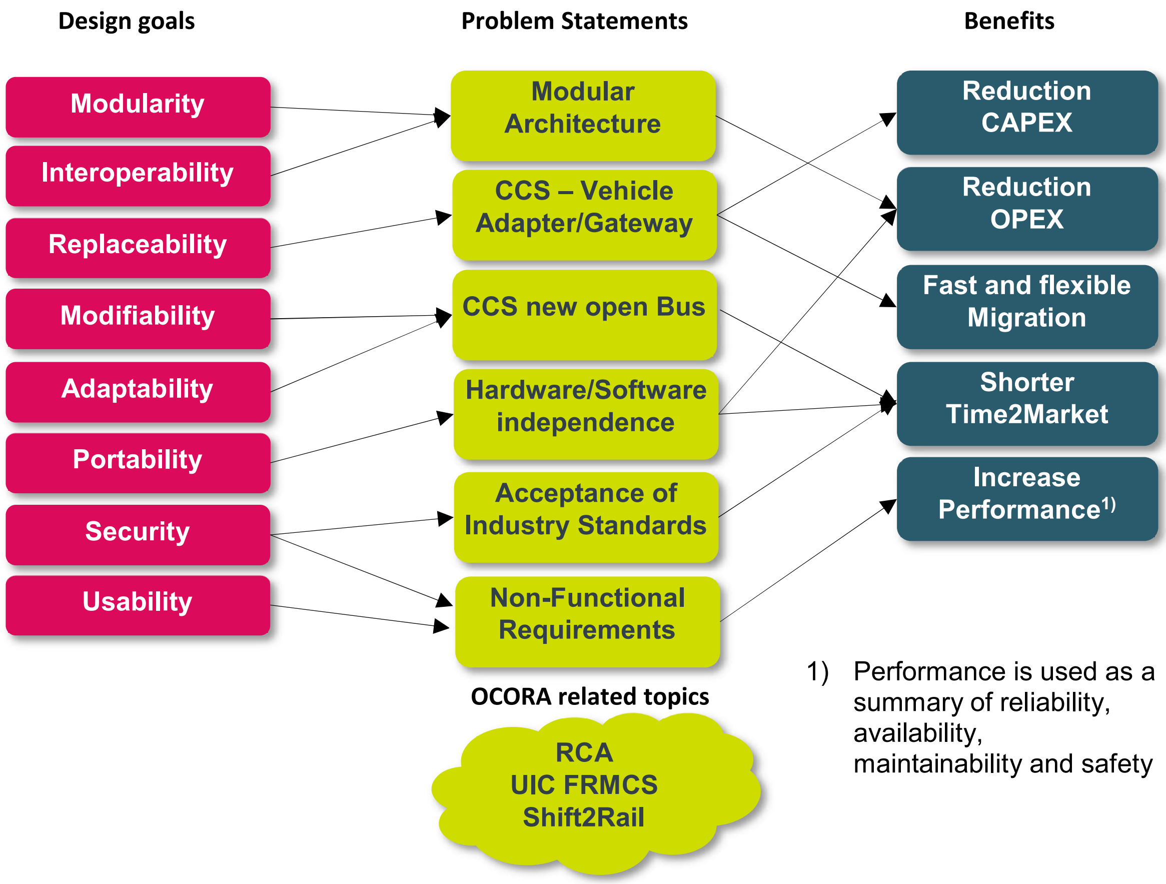

Figure 2 OCORA objectives and benefits

At a later stage, an economic evaluation will be presented. This will provide answers regarding the relations shown in Figure 2.

3 OCORA scope and collaboration with other groups

OCORA is an open CCS reference architecture for an on-board software and hardware platform, providing hardware abstraction interfaces and services primarily to CCS on-board applications and eventually to other on-board applications. OCORA covers only the train borne part of the overall control-command and signalling infrastructure needed for safe and automatic railway operation (Automatic Train Protection and Automatic Train Operation). A good integration in the overall CCS environment is therefore essential and requests a good collaboration and liaison with related activities, in particular with the following:

- RCA (Reference CCS Architecture): ERMTS Users Group and EULYNX
- Localization: EUG working group "Localization"
- FRMCS: UIC working group “Telecom On-Board Architecture”
- ERA CCS architecture group through CER CCS SG
- Shift2Rail: ATO working group, Linx4rail

Prior to this OCORA Alpha release, alignment with RCA, FRMCS and EUG have been discussed. As a result, it can be said that a common view is shared, and the identified Problem Statements are aligned. Collaborative meetings and joint alignment groups are in preparation to reach a pragmatic an efficient cooperation.

4 OCORA design goals

The OCORA initiative decided to use the product quality characteristics defined by ISO 25010 to identify the goals of the architecture.

The following figure shows an overview of the currently identified design goals, supporting the OCORA objectives for Openness, Modularity, Evolvability, Simplification, and Independence.

1. Modularity	• degree to which a system or computer program is composed of discrete components such that a change to one component has minimal impact on other components.
2. Interoperability	• degree to which two or more systems, products or components can exchange information and use the information that has been exchanged
3. Replaceability	• degree to which a product can replace another specified software product for the same purpose in the same environment. • Another word for replaceability in the OCORA context is **interchangeabilty**.
4. Modifiability	• degree to which a product or system can be effectively and efficiently modified without introducing defects or degrading existing product quality. • Another word for modifiability in the OCORA context is **upgradeability**.
5. Adaptability	• degree to which a product or system can effectively and efficiently be adapted for different or evolving hardware, software or other operational or usage environments. • Another word for adaptability in the OCORA context is upgradeability and/or **flexibility**.
6. Portability	• degree of effectiveness and efficiency with which a system, product or component can be transferred from one hardware, software or other operational or usage environment to another. • Another word for portability in the OCORA context is **hw/sw indepence**.
7. Security	• degree to which a product or system protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorization. • Another word for security in the OCORA context is **cybersecurity**.
8. Usability	• degree to which a product or system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. • Another word for usability in the OCORA context is **openness and/or simplification**.

Figure 3 OCORA design goals

These design principles are based on the most needed improvements for CCS on-board solutions. Apart from the technical goals the OCORA architecture shall also pave a way to reduce investment risks and preserve already made investments.

5 OCORA architecture

5.1 Introduction

The on-board CCS system is currently "only" ensuring the safe movement of the vehicle over the railway infrastructure. Except for the emergency brake intervention in case of supervised speed threshold overshoot, it is up to train staff, especially the driver, to manage all facets of train operation.

OCORA considers the TSI 2022 revision to be a first stage in the process of bringing new technology to the railways. In this stage, preparations are made for the integration of the game changers, notably FRMCS and ATO. The OCORA architecture aims for plug and play interchangeability within the CCS domain through isolation of specific functions in combination with the specification of a generic and open communication backbone, the Universal Vital Control and Command Bus. Furthermore, the integration of the control-command and signalling system in the vehicle is supported by a generic gateway interface specification.

Figure 4 depicts a simplified high-level view of the envisioned OCORA CCS on-board system architecture. Please note that the number of functions or devices is not limitative and includes e.g. train positioning, train integrity management, etc. These are not specifically made visible, since it is a matter of the detailed architectural design to allocate such functions to either the CCS on-board or train domain.

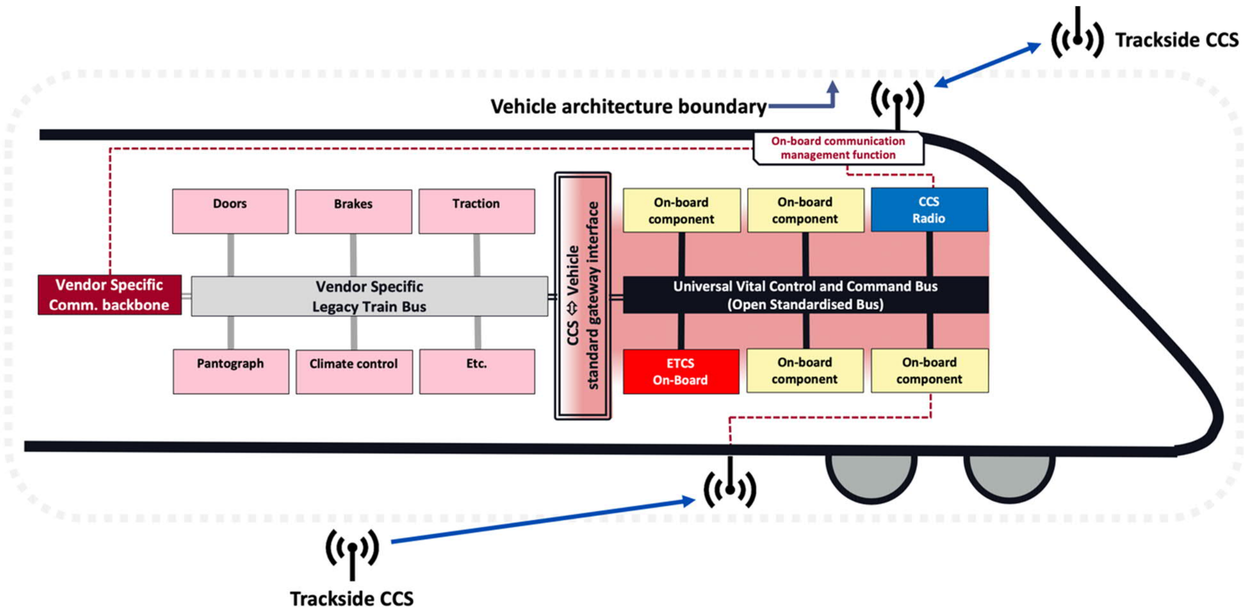

Figure 4 High-level simplified vision of post TSI 2022 revision vehicle architecture

OCORA aims to prepare an open reference architecture and standardized interface specifications for the ETCS on-board system, allowing interested parties to tender this system according to the relevant TSI version and the OCORA specifications. This is the reason for highlighting the ETCS On-Board in Figure 4 (red box).

CCS radio (highlighted in blue in Figure 4): the major game changer of ERTMS is the next generation radio, successor of GSM-R. The radio is paramount in the railway digitalization for the ETCS, ATO and ATC (also referred as TMS), but also for vehicle and infrastructure remote diagnostic and monitoring.

In the next chapters, this simplified representation of the OCORA architecture is brought in relation with the OCORA objectives. The OCORA design goals are distilled, the principles for isolating and combining functions are fixed and a first, tentative architecture is defined.

5.2 Design principles supporting the OCORA design goals

To support the OCORA design goals as outlined in chapter 4, the following design principles and measures are applied:

Design principles & measures	Design goals							
	replaceability	portability	modularity	modifiability	adaptability	interoperability	usability	security
1. The CCS on-board shall be decomposed according to the rules defined in chapter 5.3.	x	x	x	x	x			
2. Functions shall be realised in software (applications and services).	x	x	x	x	x			x
3. System design shall enable software to be updated, upgraded, removed, added or exchanged without the need for hardware changes or (re)certification of other than the software affected.	x	x	x	x	x			x
4. Core ETCS functionality shall be isolated from other on-board functions and the core ETCS functionality shall be decomposed according to the rules defined in chapter 5.3.	x	x	x	x	x			x
5. CCS on-board functionality foreseeable to become obsolete in the future shall be isolated to ensure easy decommissioning, once the respective functionality is not needed anymore.	x	x	x	x	x			x
6. Whenever no standardized TCMS/CCS bus is available, the CCS on board shall communicate with vehicle functions through a gateway.	x	x	x	x	x			x
7. Open standards are used wherever possible and reasonable.	x	x	x			x		
8. The re-use of software is maximized (same software for various deployments).		x		x				
9. A service-oriented architecture on application level shall avoid duplication of code. Therefore, common applications or application services will be identified.				x				
10. The architecture/design provides support for automated testing.	x	x		x	x			
11. The on-board CCS system is optimized in regard to the optimal number of building blocks						x	x	
12. Hardware is separated from software, allowing to handle the different life cycle profiles.	x	x	x	x	x			
13. The architecture considers that a competitive market for the different building blocks can develop.	x	x	x	x	x			

Table 1 Design principles and measures to support the design goals

5.3 System decomposition principles

The overall goals of the system decomposition are to enable:

1. Plug and play like replacement of CCS building blocks, i.e. (software) applications to be updated, upgraded, removed, added or exchanged without the need for hardware changes or (re)certification of other than the (software) application affected;
2. Fast, simple and – whenever feasible from a point of view of system performance, cyber security and operational effort – remote replacement, update or upgrade of software;
3. Simplified and – where possible – automated safety case development and certification; component oriented (modular) certification;
4. Compatibility alignment on application level between CCS on-board sub systems / constituents and between train borne and trackside.

To manage the complexity of designing, building, and testing the OCORA control-command and signalling system, the decomposition in single building blocks needs to be achieved according to a set of decomposition rules and principles that follow from the design principles listed in chapter 5.2. A building block is defined as a piece of hardware and/or software, providing one or more functions/capabilities (tasks to be performed to achieve a predefined result). The software that realises the task defined for a function is called ‘application’ or 'service'. Top level requirements for decomposing the on-board CCS are:

1. The level of modular decomposition will be at the minimum viable functional set (building blocks), i.e. system architecture shall be based on the lowest reasonable granularity to enable the maximum level of exchangeability between single building blocks. Building blocks shall have narrow interfaces (low coupling) and must allow for regression free testing.
2. Since the function requiring the highest safety integrity level defines the safety integrity level required of all other functions in the same application or service, mixing of functions requiring different safety integrity levels in one application or service shall be prevented;
3. CCS on-board functions not needed in the future (e.g. GSM-R), shall be isolated. This allows easy removal, once the functionality is not needed anymore.
4. Single building blocks are strictly isolated and connected by testable FFFIS.
5. Physical distribution of building blocks over a train must be possible (e.g. maximum cable length requirements, antenna positioning, etc.)
6. Functionality not needed in all CCS on-board implementations are isolated in separate applications or services, allowing to deploy functionality on an as needed basis.
7. Strategy for product selection (e.g. off the shelf products, make or buy, RU's IT strategy, procurement strategy, different or multiple suppliers, etc.) is considered.

The main criteria applied for the decomposition of the CCS on-board system are:

1. Coherence and consistency of life-cycle management on a single module level.
2. Module life-cycle management is isolated / independent from other modules.
3. Module life-cycle management has no impact on CCS architecture.

5.4 Architectural views

A common practice in systems and software engineering is to use different architectural views. For designing the CCS on-board system architecture, the following views are currently used:

- Logical view
- Technical / physical view
- Technical / deployment view

In this document version (alpha), only high-level views are used. In subsequent versions (beta, gamma, etc.), the system's architecture will be developed further, and additional (e.g. Non-Functional view, communication view, etc.) and more detailed views will be provided.

The non-functional view requires a systemic approach. In particular, response time requirements, will be elaborated in cooperation with other stakeholders. The problem statement [2] on non-functional requirements addresses this aspect.

The following chapters show the current state of the CCS on-board architecture, using the different views.

Throughout this chapter, the following notation is used:

- White boxes: external systems or functions
- Blue boxes: system logical blocks
- Yellow boxes: OCORA system hardware
- Red boxes: OCORA relevant interfaces

5.5 Logical architecture

For the alpha version of the OCORA architecture, a high-level tentative decomposition of the CCS on-board functionality is available (see Figure 5). The graphic shows the current concept for the 1st level of logical decomposition of the CCS on-board. It is aligned with the RCA Architecture (refer to [3]) and lists the interfaces already identified by RCA, using the RCA defined IDs.

The logical view is structured in well-defined building blocks. This allows implementing changes regression free in individual components. Furthermore, it will increase the re-use of software and expand the supplier market for implementing CCS functionality.

A hardware abstraction layer ensures that all external systems and functions are represented the same way towards the services and applications, independent from the train type and configuration.

The logical architecture consists of the following layers:

- Software Abstraction: this layer contains services, providing common functionality used by multiple applications or an "input-output" conversion from and to other applications in coherence with the data model. The services showing an interface (red box), are aligned with what is defined in the RCA Architecture Overview [3]. Track-train interfaces will be further developed in close cooperation with the RCA initiative. For pure on-board interfaces (e.g. interfaces to actors and sensors, vehicle interfaces, etc.), OCORA plans to lead the efforts. A more detailed and complete logical decomposition and a functional view will be made available in later versions of this document.
- CCS On-board applications: currently identified CCS on-board applications are listed. The applications showing an interface (red box) are aligned with what is defined in the RCA Architecture Overview [3]. A more detailed and complete decomposition of CCS on-board applications will be made available in later versions of this document.
- Other applications: no applications are currently foreseen. However, the OCORA platform shall allow to deploy non-CCS related on-board applications.

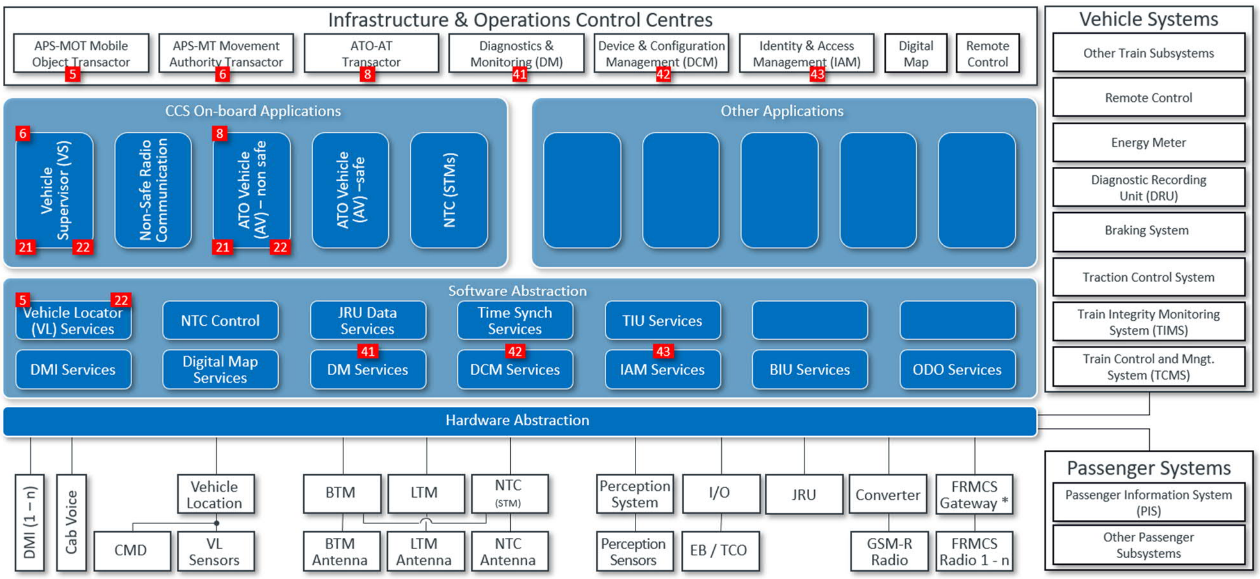

Figure 5 Logical architecture

* FRMCS Gateway may not be a dedicated piece of hardware.

For the next version of the OCORA architecture, the logical view will be decomposed in more detail and a functional decomposition will be developed. During that process currently identified applications and services may be renamed or changed. Tight alignment with the RCA functional architecture is continued to be ensured.

5.6 Technical / physical architecture

The OCORA platform (hardware and middleware) is at the centre of the CCS on-board system and consists of a universal vital control and command bus (open standardised bus), 1 to n CCS computing units (CCUs) and the middleware (see chapter 5.7).

The number of CCUs can differ for the various implementations, depending on the RU's need. Also, the functional behaviour of the different CCUs can be different in the various implementations. The latter is a result of deploying the software on the different CCU nodes. For migration reasons, multiple CCUs may be needed for certain implementations. Furthermore, the CCUs can also be used to increase availability and reliability by defining one or multiple CCU nodes as fail over or standby units.

In order to allow multiple CCUs architecture, each CCU shall contain a virtual bus. Each application communicates with its peered applications through either the physical or the virtual bus (refer also to chapter 5.7).

The number of CCUs and interfaces have direct effects on non-functional requirements (e.g. response time) and IVV. The optimal number of CCU, functional blocks and interfaces shall be found in order to conserve the simplicity of the on-board subsystem.

The CCS domain is connected via a gateway to the "vehicle systems" (vehicle / wagon domain) and, if required, to the "passenger systems". The gateway provides a means of integrating the CCS system with various vehicle technologies. The gateway provides a means for migrating existing fleets.

The radio communication module (Radio COM), connected to the gateway, provides (cyber-)safe connectivity to the data centres for all 3 domains: CCS, vehicle/wagon and passengers.

The following figure depicts the current conceptional view of OCORA regarding the hardware architecture. Please note that systems on the figure are examples.

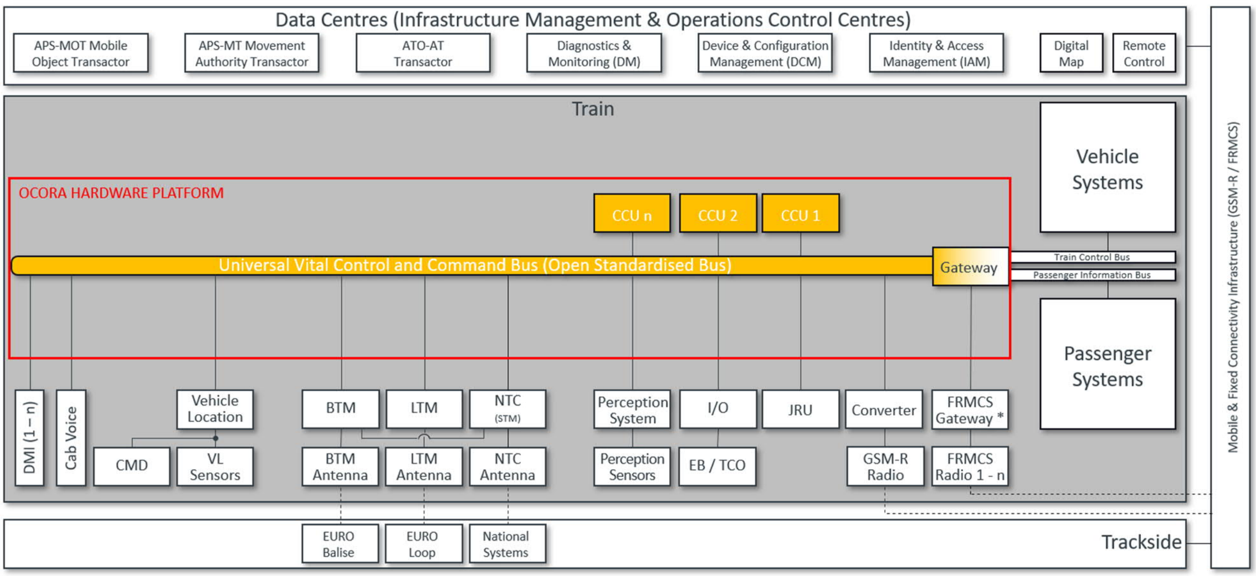

Figure 6 Technical / physical architecture

* FRMCS Gateway may not be a dedicated piece of hardware.

Comment: not all (wire) connections between external systems (e.g. between "EB / TCO" and the "Vehicle System") are shown. The TIMS is currently assumed to be an integral part of the "Vehicle Systems". However, for certain situations (e.g. freight trains), the TIMS could be a building block connected directly to the UVCCB.

5.7 Technical / deployment architecture

The technical / deployment architecture aims to show a possible deployment of logical blocks on the hardware, and the concepts of hardware and software abstraction/separation.

OCORA acknowledges that a separation of hardware and software in a “one-size-fits-all” approach, i.e. with one common level of platform harmonization for all applications, may not be reasonable. Instead, it could be necessary to define multiple levels of open interfaces (as shown in the Figure 7), such that

- applications which have very specific needs and are highly cross optimized between SW and, e.g., operating system, could utilize their own dedicated runtime environment (e.g., running on a virtual machine), but would operate on the same, standardized hardware abstraction approach (Interface H2);
- all other applications and services should be designed to utilize a common run-time environment incl. a common OS (Interface H1).

Applications in need of common functionality can access respective application level services through "Interface S".

OCORA plans to define the abstraction interfaces and to make the specifications publicly available.

The following picture shows a possible deployment of logical blocks (blue) on 2 CCU hardware nodes (yellow) and identifies the possible “abstraction interfaces” as mentioned above.

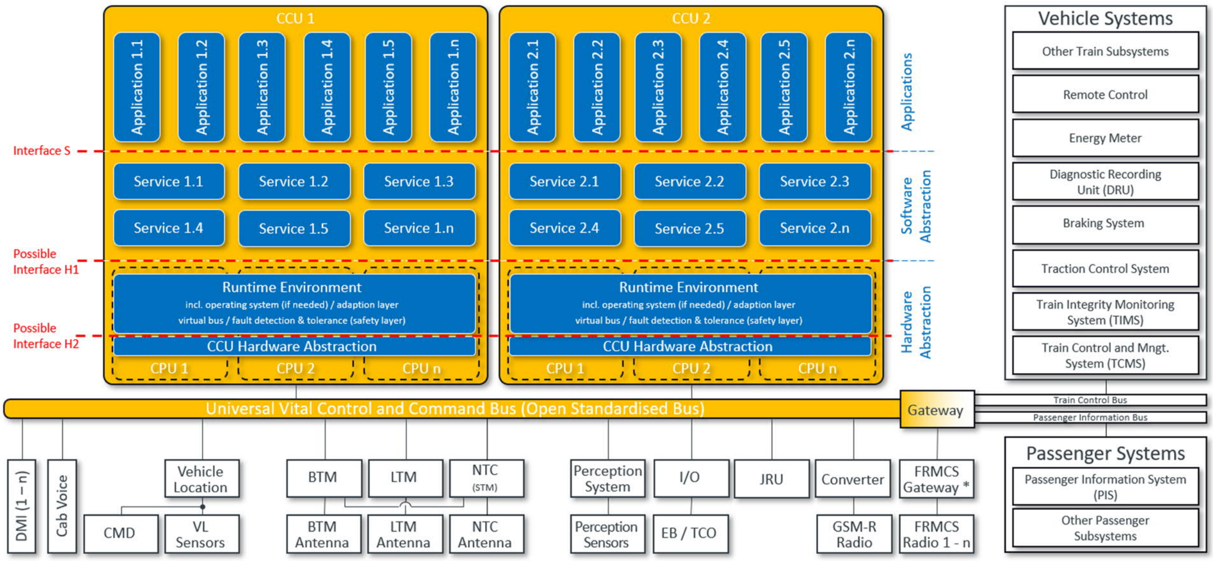

Figure 7 Technical / deployment architecture

* FRMCS Gateway may not be a dedicated piece of hardware.

In the next version of the OCORA architecture, this view will be analysed in more detail, this especially in regard to the hardware abstraction.