OCORA

Open CCS On-board Reference Architecture

Introduction to OCORA

Document ID: OCORA-BWS03-010

Version: 6.40

Date: 31.01.2025

Management Summary

OCORA, the “**Open CCS On-board Reference Architecture**” initiative, whose signatory founding Members are **NS, SNCF, DB, SBB and ÖBB**, has reached a next important milestone with this next Release of the specifications of the OCORA architecture.

OCORA aims to **reduce life-cycle costs** and **facilitate** the introduction of **innovation and digital technologies** beyond the current proprietary interfaces, by establishing a **modular, upgradeable, reliable and secure CCS on-board architecture**.

The **OCORA Release** descripts **CCS On-board** and includes sector feedback. It is **feeding the TSI development** and **Europe’s Rail Joint Undertaking** with **qualified technical and business input**.

OCORA deliverables are published under the **European Union Public License (EUPL)** and are consequently available for all stakeholders.

OCORA plans publishing in a **half year cycle**, **a Release in July** and one in **December**.

This document serves as an **introduction to OCORA** by answering the basic questions **Who, What, Why, How around the OCORA collaboration**.

Revision history

Version	Change Description	Initial	Date of change
0.01	▪ Initial release	JH	10-06-2020
0.02	▪ First complete draft	JBS	21-06-2020
1.00	▪ DRAFT release for review	RM	23-06-2020
1.01	▪ Final draft (formatting, solving SBB + DB comments, clarification following SNCF comments)	JBS	24-06-2020
1.10	Official version for OCORA Beta Release	RM	29-06-2020
2.01	▪ Gamma release revision	JH	16-11-2020
2.02	▪ Review RM	RM	17-11-2020
2.02	▪ Review JBS	JBS	23-11-2020
2.03	▪ Integration of SNCF and SBB reviews	JH	23-11-2020
3.00	Official version for OCORA Gamma Release	RM	04-12-2020
3.01	▪ Initial version for Delta	JH	19-05-2021
3.10	▪ Template, editorial changes and mgmt summary	RM	25-05-2021
3.11	▪ Last comments JBS integrated and refined	JH	28-05-2021
4.00	Official version for OCORA Delta Release	JH	25-06-2021
4.99	▪ Final Draft for OCORA Release R1	PV	12-11-2021
5.00	Official version for OCORA Release R1	PV	29-11-2021
5.01	▪ Final Draft for OCORA Release R2	PV	10-06-2022
5.10	▪ Review RM	RM	20-06-2022
6.00	Decoupled document from a specific OCORA release	PV	22-06-2022
6.10	Official version for OCORA Release R3	PV	01-12-2022
6.20	Update based on brush up and editorial work	RM	19-05-2023
6.30	Update based on brush up and editorial work for R5	PV	13-11-2023
6.40	Update based on brush up and editorial work for R6	LDL	24-01-2025

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Reader's note: please be aware that the numbers in square brackets, e.g. [1], as per the list of referenced documents below, is used throughout this document to indicate the references to external documents. Wherever a reference to a TSI-CCS SUBSET is used, the SUBSET is referenced directly (e.g. SUBSET-026). OCORA always reference to the latest available official version of the SUBSET, unless indicated differently.

[1] OCORA-BWS01-010 – Release Notes

[2] OCORA-BWS01-020 – Glossary

[3] OCORA-BWS01-030 – Question and Answers

[4] OCORA-BWS01-040 – Feedback Form

[5] OCORA-BWS03-020 – Guiding Principles

[6] OCORA-BWS04-010 – Problem Statements

[7] OCORA-BWS05-010 – Road Map

[8] OCORA-BWS06-010 – Economic Model – Introduction & Overview

[9] OCORA-BWS07-010 – Alliances

[10] OCORA-TWS05-020 – Stakeholder Requirements

[11] OCORA-TWS05-021 – Program Requirements

[12] Chéron, Christophe, et.al., Rail Strategic Research & Innovation Agenda – SRIA, ERRAC, December 2020, www.errac.org.

[13] European Commission, Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions: Sustainable and Smart Mobility Strategy – putting European transport on track for the future - SWD(2020) 331 final, COM(2020) 789 final, Brussels, 9 December 2020.

[14] European Commission, Directorate-General for Mobility and Transport, Decision: Authorising the use of unit contributions to support ERTMS deployment under the Connecting Europe Facility (CEF) - Transport sector, Brussels, 19 February 2019, https://ec.europa.eu/inea/sites/inea/files/ertms_decision-annex_i_unitcontributions.pdf

1 Introduction

1.1 Purpose of the document

This document aims to introduce the reader into OCORA through 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 to reduce total cost of ownership, increase productivity and customer value, and control investment and operational risks.

This document is addressed to experts in the CCS domain and any other person interested in the OCORA concepts for CCS on-board. The reader is invited to provide feedback to the OCORA collaboration and can, therefore, engage in shaping OCORA. Feedback on this document and any other OCORA documentation can be given using the feedback form [4].

If you are a railway undertaking, you may find useful information to compile tenders for OCORA-inspired CCS building blocks, complete on-board CCS system, or on-board CCS replacements for functional upgrades or life-cycle reasons.

If you are an organisation interested in developing on-board CCS building blocks according to the OCORA design principles, information provided in this document can be used as input for your development.

1.2 Applicability of the document

The present document is considered informative and applies to the full OCORA Release. Subsequent releases of this document will be developed based on a modular and iterative approach, evolving within the progress of the OCORA collaboration.

1.3 Context of the document

This document is published as part of the OCORA Release, together with the documents listed in the Release Notes [1]. Before reading this document, it is recommended to read them. If you are interested in the context and the motivation that drives OCORA we recommend reading the Problem Statements [6]. The reader should also be aware of the Glossary [2] and the Question and Answers [3].

1.4 OCORA naming conventions

The terminology used by OCORA has been developed to free the development architecture team of the normative, traditional way of architecture development that is used in the TSI's e.g., Subset 026 for the on-board. Precis definitions of terms like "building blocks" or "Interface" are key for any architecture framework, therefor a comprehensive Glossary [2] has been developed and established over time.

2 Why OCORA in general?

Automation and digitalization of rail operations are widely considered to be the appropriate strategy to keep the competitive edge rail transportation currently has over its modal competitors. A pivotal element in rail transportation competitiveness is its ‘green’ reputation, since it provides a more sustainable mode of transportation than its competition. Other qualifications are the level of safety and the ability of fast downtown to downtown transportation (passengers) and large volume capability (freight). Consequently, ‘Europe’ has advocated rail transportation as the predestined backbone of the European transport network and made it the centrepiece of its transportation policy.

To achieve its political objectives, Europe invests in the development of a Single European Rail Area (SERA) to substantiate its policy. These investments pertain the research, development and innovation necessary to allow the railway community keeps its competitive edge (via Europe’s Rail). The subventions supporting the technological evolution towards SERA (e.g., via the “Horizon” program) contribute to the implementation of ERTMS as basis for automation and digitalization steps inrail operation like ATO or Moving Block.

Where differences in gauge and power supply ceased to be barriers for interoperability, national technical rules, network specific operational rules and, specifically, the persistence of legacy control, command and signalling (CCS) systems (often also a mixture of those) are still barriers for an optimised and unified railway system in Europe. The first objectives of ‘Europe’, therefore, are eliminating country or network specific solutions for either of those three issues.

The objective of OCORA is to provide an architectural framework for the on-board that supports such European solutions, taking into account that the migration starts with a legacy to be managed (e.g., existing ERTMS infrastructures and onboard ETCS installations).

2.1 CCS Risk profile

Despite the investments in the implementation of ERTMS, the program has not been sufficiently successful. The rollout stagnates, seriously jeopardising EU transportation policies but also the resilience and viability of the European signalling industry. The main reasons for this development are:

1. the volatility of the CCS system for the railway community at large because of issues such as frequent updates of the specification and technological developments. The variability of user specifications is also a reason, resulting in an average life cycle expectancy for CCS systems of 5 to 10 years with an assumed average of 6 years. With a life expectancy of +30 years for the rolling stock, the net result of this development is that older rolling stocks have to be retrofitted several times during their remaining lifecycle, while new rolling stocks fitted with ERTMS would need at least four consecutive retrofits during their lifecycle. The CCS market will, therefore, be dominated by the need for retrofits and not by newly built equipment;
2. the persistence of fleet size as a main cost factor since every retrofit requires an intricate cocktail of surveying, documenting, engineering, prototyping, approving, testing and commissioning. It leads to CCS equipment becoming an integral part of the larger entity: the rolling stock;
3. the market deficiencies, forcing suppliers to separately allocate scarce resources to develop and manufacture an ever-evolving range of CCS systems that should be, as a matter of principle, highly standardised. The evolution of the CCS products should be centrally managed to ensure diachronic coherence and consistency of system performance;
4. consequently, the high lifecycle cost of such systems that jeopardise the economic foundations of users. The target initially indicated at start of development of ERTMS in the early nineties of the last century, namely that ERTMS would be more cost effective than legacy systems, has been thoroughly falsified;
5. the prolonged duration of implementation projects and programs which is an outcome of various issues such as technical complexities (from an RU point of view specifically safe integration of ETCS in the vehicle), financial considerations or regulatory complications. It results in long lasting retrofit project with duration multiple years, including costly downtime for desperately needed vehicles;
6. the inherent obsolescence problem invoked by a relative short life cycle of ERTMS equipment and a relative long implementation cycle, urging railways to reconsider investments in the wake of potential developments that will restrict the pay-back period of those investments. The most notorious at the moment is the expected implementation of FRMCS, since it is expected that this integration of a new connectivity technology will trigger a baseline upgrade of ETCS with required re-certification;
7. the ensuing reluctance of railways to invest more in the implementation of ERTMS than necessary, even if those investments can partly be redeemed from European subventions;
8. the depleting market volumes for CCS suppliers, compromising their ability to deliver quality products and to perform the necessary R&D and innovations to keep their (global) competitiveness;
9. the modal competition catching on rapidly with developments in operationalising e.g., platooning, autonomous road transportation and electrically propelled planes.

These developments are swiftly becoming existential risks for the entire railway community.

1. RUs to lose the modal competition and become a declining niche in the transportation market, their function to be overtaken by automated road transportation.
2. IMs to gradually lose their legitimacy, resulting in declining budgets for maintenance and extension projects.
3. Suppliers to become ever more dependent on single projects (and low market volumes) to cover expenditure on innovation and R&D, making them increasingly vulnerable to global competitors.
4. The EU, in not being able to achieve policy objectives and, in the end, rail budgets being diverted to other, new priorities.

2.2 Intended role of the OCORA collaboration

ERTMS today is widely deployed throughout Europe, targeting 15,000 km of tracks to be equipped by 2023 and 51,000 km by 2030. As explained in the previous section, ERTMS still has to achieve its main goals: cross border (or rather: cross deployment) interoperability, controllable cost, and satisfying performance levels. At the same time, ERTMS is an important enabler for the automation and digitalisation of an interoperable railway in Europe. The constraints to be eliminated to allow the European rail sector to fully benefit from ERTMS are:

1. current CCS OB solutions in Europe are driving significant investment and maintenance costs as well as complexity and uncertainty for fleet interoperability;
2. solutions do not consider the differences in life cycles between ERTMS 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 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).

The detailed OCORA Problem Statement [6] is part of this release.

Recognizing that a coherent, modular, upgradeable, interchangeable, reliable and secure system architecture is paramount to overcome these challenges for the overall CCS 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 CCS subsystem. The OCORA architecture is intended to provide an effective approach to mitigate the risks indicated above, without claiming that it alone can solve all the issues that were listed. On the contrary, OCORA relies on close cooperation with the other stakeholders to jointly address the issue of reviving and speeding up the automation and digitalisation of the European railways.

3 What is OCORA?

OCORA is first and foremost a platform for cooperation to the benefit of the European Railway sector. Guiding Principles [5], 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 CCS OB systems that supports the mutually agreed OCORA objectives (Chapter 6). Collaboration takes place in workstreams. Each working group is responsible for specific tasks, topics or issues. Workstreams 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 founding 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 RU or train keeper willing to accept the MoU and CoC. Ideally, all members are having delegates that actively support one or several working groups.

4 OCORA objectives

It is OCORA priority in general to develop a single generic concept for the CCS OB to facilitate the:

- introduction of innovative technologies that satisfy the user needs and requirements of railway companies, while providing a solid and resilient economic foundation for the European signalling industry;
- implementation of fully operational interoperability[1] (or ‘seamless transportation’) on the European rail network, indicating that any vehicle equipped with ETCS, will ultimately be able to seamlessly operate any ERTMS equipped infrastructure.

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

1. to define an Open CCS OB reference architecture by e.g.:
    - having an open standardisation of the ETCS/ATP, ATO train interfaces, functions and other on-board building blocks;
    - establishing the principles and necessary requirements of the OCORA initiative;
    - aligning the initiatives and ideas already started and finding synergies to align scarce resources;
    - streamlining the industrialisation processes, in particular the certification.
2. to validate the viability and relevance of the OCORA approach by using e.g.:
    - proof of concepts;
    - demonstrators;
    - or prototypes.
3. to promote the use of OCORA for the CCS OB solutions in Europe 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, AERRL), and in close

[1] Please note that this word that is also used in another sense: in ISO 25010 terminology as an indicator the 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.

cooperation with joint undertakings, already in charge of defining certain aspects of the ERTMS (e.g., EU-Rail, EuG, EULYNX, UNISIG, JPCR, UIC, RCA);

- 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 (and 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).

4. to support Europe's Rail Joint Undertaking (EU-Rail) with an active participation in System-Pillar domains and Innovation-Pillar work packages related to CCS-OB.

Achieving these objectives requires 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 long period. However, future fundamental changes ask for swift and decisive action now: continuing the existing paradigm for ERTMS realisation will stifle future developments. Therefore, OCORA has already developed and communicated public Problem Statements [6] that point out issues that have to be addressed in future TSI Revision as a preparation for more fundamental changes in the near future. OCORA has prepared detailed proposals for enhancement of the TSI CCS that are being processed through the designated channels.

OCORA primarily has a logical, functional and technical perspective and includes the optimization of the on-board to wayside interface. Obviously, costs and benefits are not in all cases evenly distributed between IM's and RU's and trade-offs are necessary to achieve the most cost-effective solutions on a sector level. This could require arrangements for financial compensation to ensure the enduring cooperation of stakeholders. Although the OCORA collaboration recognizes the importance of establishing such arrangements, these will not be a topic for OCORA work packages and the issue will, consequently, not be addressed in OCORA documentation. It will be pushed forward in other sector interest groups (e.g., CER) as foreseen in OCORA Alliance document [9]. OCORA considers a close collaboration with institutional and industrial stakeholders on a sector scale as an essential enabler for fast progress.

5 What are (the?) 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. a set of harmonized tender artefacts to allow RUs requesting for CCS OB, both integration into existing rolling stock as well as new build vehicles;
3. an economic evaluation supporting the OCORA architecture and approach;
4. robust interface specifications allowing for smooth evolution and migration;
5. an improvement of the regulatory framework as a tool for rapid introduction and adoption of (global) technological developments in other branches of industry and technology;
6. Demonstrators i.e., real life application of products (based on specifications developed within the OCORA framework) to showcase usability and applicability in test environments;
7. 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 user specifications (architecture and interfaces) for a modular CCS OB environment that will be published in consecutive OCORA releases. These user specifications shall serve as a voluntary format for tender templates, supporting companies currently engaged in procurement activities or soon starting procurement programmes.

5.1 Demonstrators

The TSIs contain ambiguities, gaps and errors, resulting in vendor specific interpretations of what should be functionally completely identical CCS applications. Suppliers spend scarce R&D resources on the upkeep of routine products while hampering open competition. To break out of this deadlock, the current deficiencies of the specifications must be eliminated.

Moreover, CCS equipment are today customized for specific vehicle classes, sometimes even retrofit project wise. The absence of a harmonized bus system and interfaces makes it impossible to achieve standardisation of CCS components. Indeed, these can be installed or removed without specific developments or adaptations of the integral CCS OB integrated into various classes of vehicles. Consequently, effective life cycle management, including management of migration and innovation, is prevented because any change will evenly affect building blocks of the CCS system as integrated part of the rail vehicle. Issues concerning short life cycle products (like application software) might in the end have the potential of necessitating renewed approval and certification of the entire fleet. Therefore, both suppliers and their customers avoid change because it will incur major investment, and performance and operational risks. Users only very reluctantly venture into new contracts, leading to lower market volumes. OCORA intends to develop the demonstrators to show that this predicament can be solved by applications of its approach in a real time environment.

The OCORA demonstrators are looking at disentangling existing dependencies between building blocks of different life expectancy, between CCS modules, as well as finding a pragmatic path for the design, demonstration and industrialisation of an OCORA compliant on-board CCS. The OCORA preferential approach would be to execute the demonstrators jointly with stakeholders within the EU-Rail framework.

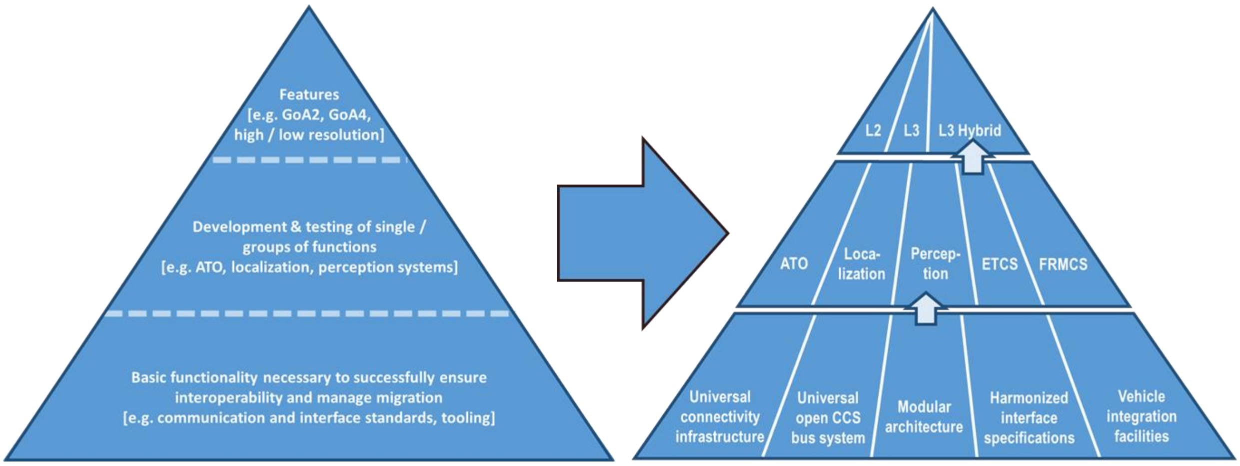

Figure 1 OCORA demonstrator strategy

5.2 Road Map

OCORA aim is to deliver quick value through recommendations that can be used in newly built rolling stock, retrofit and CCS design projects. This is accomplished by providing a framework concept for migration, based on a comprehensive and scalable reference architecture for the on-board (Figure 2).

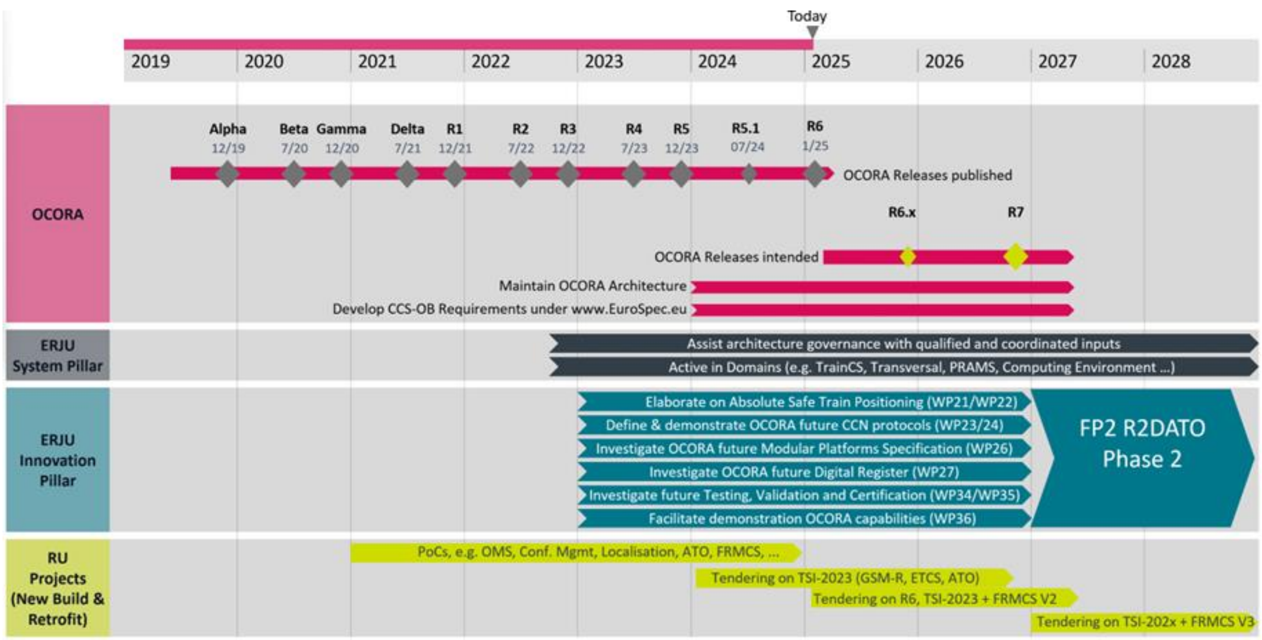

Figure 2 OCORA migration strategy Road Map [7]

OCORA intends to initiate and foster a collaborative platform that supports successive technological migrations within existing community arrangements, e.g., LinX4Rail and EU-Rail. Moreover, OCORA will keep on infusing an independent user perspective in these collaboration platforms to liaise and balance frequently between European policy, industry ambitions and empirically perceived fleet owner needs and requirements. OCORA thinks it is well positioned to execute such a complex task.

Through OCORA releases and capitalising on industry partnerships, the set of OCORA user recommendations will expand and ultimately be transformed into a solid foundation for the definition of tender templates for modular and serviceable CCS products. These will only serve stakeholders when they are well tested, hence validated and verified in real time demonstrators. OCORA is making the demonstrator development and testing sequence part of EU Rail program, Innovation-Pillar and for topics not foreseen in related work programs under the OCORA collaboration.

6 OCORA business rationale

To keep up competing with other modes of transport investing heavily in digitalisation and automation, railways rapidly need 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 paramount 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 metro operation).

The European railway community has chosen 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. EC and ERA already acknowledge that a modular architecture is one of the prime prerequisites to boost the roll out of ERTMS over the European rail network. The rapid expansion of ERTMS equipped infrastructure will improve market dynamics, but also lead to a substantial increase in market volumes as indicated in the EC report published recently by Mr. Ruete (see below). This, again, is expected to improve the economic foundation of the supply industry.

DG MOVE in its end of May, 2020 version 'CCS framework: governance and arrangements at EU level':

The current typical CCeeS on-board configuration includes multiple proprietary and Class B driven interfaces between the main train on-board building blocks. This induces low on-board upgradeability and dependency on the initial suppliers (CCS and rolling stock) when on-board upgrades are necessary and, consequently, increased cost and complexity.

[…]

This situation significantly increases CCS complexity and reduces the opportunity for more open and competitive markets across Europe. It also creates a system that is not conducive to harmonised evolution and innovation.

Hence it has been agreed in the CCS Framework vision that there should be: one European CCS system: There should be a genuine integrated European CCS system, beyond the current specifications in the CCS TSI, with much greater standardisation and much less variation than at present. This integrated CCS system shall on the one hand deliver unrestricted movement of trains, on the other hand, it shall create a larger market for components.

[…]

As a key enabler of the Single European Railway Area, technical interoperability needs to be ensured in the sense that:

- *A vehicle fitted with a compatible ERTMS on-board unit can safely operate anywhere on the European network with acceptable performance.*
- *The implementation and consistent application of CCS is made sustainable for users by allowing for cost effective implementation, updating, upgrading and replacement of CCS systems and single parts thereof.*

Considering the intrinsic nature of rail as on integrated complex system, a harmonised functional and technical CCS architecture on a systems level is a prerequisite to master complexity and ensure enduring coherence. Managing the complexity requires a common harmonised functional CCS approach between the different CCS components, with a clear separation of safety-related and non-safety-related layers with non-safety functions.

The role of customer in defining services, requirements and specifications supplier in designing and developing the technologically and operational enablers of the functional system architecture is recognized.

The benefits the OCORA initiative expects to harvest are:

- Reduction of CAPEX i.e., in this context the 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. But this also includes reducing the risk for operators to avail of rolling stock beyond operational requirements because of prolonged stand still of vehicles because of recurrent retrofits.
- Reduction of OPEX i.e., in this context the amount of operating expenditure reduced for a CCS on-board solution. This includes operation, maintenance, updates, upgrades, as well as the life-cycle exchanges at least over a full vehicle lifespan.
- Fast and flexible migration, i.e., capabilities supporting functional evolution and simplified integration in existing vehicle and infrastructure. This will require decoupling CCS building blocks with different life cycles.
- Shorter time-to-market, i.e., reduced amount of time 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.
- Increased performance, i.e., for the CCS on-board solution, an increased reliability, availability and maintainability is expected while maintaining the current level of safety.

In this release, OCORA provides a quantitative and qualitative economic evaluation where first, critical aspects of OCORA's member corporate and business objectives, design goals and architecture design will be analysed and modelled.

6.1 Market dynamics

An important general notion underpinning the necessity of the OCORA collaboration is the expected growth of market demand in relation to the financial burden for the treasury of the European Communion. The Work Plan 2020 of the European Coordinator for ERTMS provides an estimated number of newly built and existing vehicles to be equipped with ERTMS up to 2030 in a "low bound" and a "high bound" scenario. These scenarios appear to be based on the assumption that trains need to be equipped with ERTMS only once during their lifetime, and that demand is distributed evenly and balanced over the period under consideration. However, experience teaches that the ERTMS on-board has to be replaced or upgraded once every 5 to 10 years, with an average of 6 years at the moment (OCORA assessment). Moreover, it is quite conceivable that shockwave changes like the introduction of FRMCS and the decommissioning of GSM-R will result in peak demand in relatively short time windows.

Taking account of the fact that approximately 3600 vehicles have been retrofitted already with an estimated average residual life expectancy of 15 years, and an average conservative replacement rate of 7 years, the annual demand for on-board CCS installations up to 2030 would be as depicted in the right-side graph of the figure below.

Mr Ruete Draft Workplan 2020 (§ 3.3, p. 27) low bound 2019 – 2030 demand estimate:

Mr Ruete Draft Workplan low bound 2019 – 2030 demand estimate inclusive of pre and post 2019 ERTMS fleet retrofit requirements:

Figure 3 Market volume trends and OCORA assessment of ensuing retrofit volumes

As can be seen from this graph, the demand (and expenditure) for fitting and retrofitting capacity will increase considerably in the next decade, resulting in a continuous high demand that will stretch the supply industry production capabilities. The demand for retrofit capacity is and will remain to be the dominant factor in the CCS market. Since any retrofit currently involves adapting a specific vehicle type or series to a vendor specific ERTMS solution, an intricate cocktail of surveying, documenting, engineering, prototyping, approval, testing and commissioning is necessary to prepare serial installation.

If the assumptions used by the ERTMS coordinator Work Plan are extrapolated to 2040, taking account of an average ERTMS on board replacement (or at least fundamental upgrade) rate of 6 years and one to one replacement of rolling stock decommissioned at end-of-life cycle, Figure 3 again demonstrates that retrofitting will be the dominant factor in the implementation of ERTMS. From reference, it is crystal clear that controlling the cost and performance, and planning risks of retrofits need to become manageable for users to satisfy Europe's deployment ambitions. Since modularisation based on the principle of exchangeability will enable migration needs to be confined to the affected part of the CCS only, achieving modularity based on an agreed reference architecture is imperative for the entire rail sector. On the upside, user acceptance of ERTMS will inevitably be improved, which will drive demand and, therefore, market volumes.

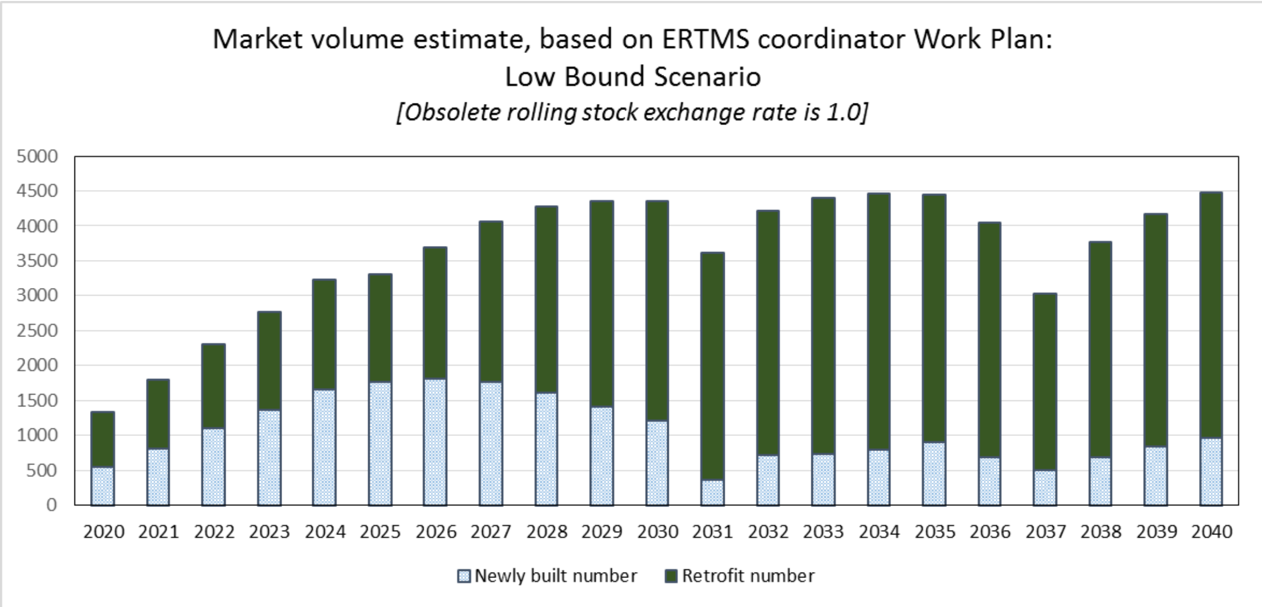

Figure 4 Extended market volume trends 2020 - 2040

A major liability is the number of prototypes (or, installations) that are necessary. OCORA calculations, based on the Ruete figures, point to the necessity of over 3,500 retrofit projects, and as much prototyping, in the period up to 2050 in the low bound scenario. At a cost of approximately €10 million per retrofit (and sometimes more), this will require staggering investments which cannot be borne by either the railways or subsidised by Europe. So, it is not questionable that the first step towards a controllable migration through modularisation is all about decoupling the CCS system from the rail vehicle. OCORA estimates suggest that a reduction of up to 25% on retrofit investment costs may be possible; further details in Economic Model – Introduction & Overview [8].

For discussing, the financial impact of implementation of OCORA Guiding Principles [5] is suitable for reference purposes. This is an abstract from the European Commission (EC) publication 'Decision Authorising the Use of Unit Contributions to Support ERTMS Deployment under the Connecting Europe Facility – Transport Sector' [14]. It defines the actual reimbursements for the retrofit of rail vehicles and the level to which RUs receive compensation for their investments.

Activities	Cost category		Scenario	Sub-scenario		Amount identified in report (K€)	Unit contribution after application of the differentiated co-financing rate (K€)	Co-financing rate applied (%)
On-board ERTMS B3 equipped vehicle	Retrofitting	Prototype	International	/	/	2.509	900	36%
			National	/	/	1.352	450	33%
		Serial	International	/	/	255	110	43%
			National	/	/	273	80	29%
	Upgrade	Prototype	International	/	/	1.683	600	36%
			National	/	/	907	350	39%
		Serial	International	Software	/	41	18	44%
			National	Software	/	44	15	34%
			International	Software	Hardware	130	55	42%
			National	Software	Hardware	139	55	40%
	Fitment					100	25	25%

Table 1 EC CEF Unit contribution overview

The recent experiences demonstrate that the actual expenditure is significantly higher than anticipated by EC, even at the rates indicated in the **Table 1**: bills for prototyping are typically approximately €10 million and the retrofit cost of train sets is in specific cases nearing €1 million per vehicle. From a financial point of view, the structural compensation of RUs will amount to hundreds of millions of Euros annually in the most optimistic scenario. Moreover, the expenditure for the RUs themselves, paying the majority of the investments needed, will rise beyond what is economically viable. The advent of the game changers which drive CCS OB system complexity threatens to increase cost levels even further.

At the same time, developments give a glimpse on the opportunities for the railway community. Market volume is on the rise, even in a conservative scenario. In the hazardous scenario now unfolding, releasing the market potential by ensuring the availability of cost-effective solutions for the on-board CCS will trigger a vast and swift transformation of railway networks. The current fragmented railways will transform into a fully interoperable European Network because it is affordable and offers a value proposition that it currently doesn't have.

It is the prime objective of OCORA to provide the preconditions that allow to effectively accelerate development towards an affordable on-board. It will drive market expansion while ensuring a positive business case for RUs. This has to be done in close collaboration with authorities, institutions and especially the supply industry. Expanding market volume while harnessing cost and performance levels need to be actively and jointly managed from both the demand and supply sides.

7 OCORA collaboration with other groups

OCORA covers only the train borne part of the overall CCS infrastructure needed for safe and automatic railway operation (ATP and ATO). A continuous exchange in the overall CCS environment is therefore essential and requests a collaboration and liaison with related activities, in particular with the following:

- EUG (ERMTS Users Group)
- Localization: EUG working group "Localization"
- FRMCS: UIC working group “Telecom On-Board Architecture”, TOBA
- ERA: Topical Working Group train architecture through Community of European Railway, CER CCS SG
- S2R (Shift2Rail): LinX4Rail, LinX4Rail
- EuroSpec
- EU-Rail: System-Pillar and Innovation-Pillar

However, it is clear that there is ample room for improvement of the collaboration between the railways and their suppliers on the issue of CCS in general and ERTMS in specific. Especially the relations between RUs and the industry beyond the boundaries of regular, commercial interactions need to be intensified to ensure a successful roll out of ERTMS and the upcoming game changers.

EC actively drives mutual cooperation forward jointly with ERA, and ERJU. It recently formulated its intentions in a number of papers on the future framework for CCS development, intentions that come very close to those of the OCORA collaboration.

> *DG MOVE in its end of May, 2020 version ‘CCS framework: governance and arrangements at EU level’:*
>
> *The business needs of customers and suppliers are not necessarily aligned at the “design phase”. Customers do not believe that suppliers have the appetite to move to a different model – away from tied-in national solutions. Indeed, through initiatives such as RCA EULYNX and OCORA, significant resources have already been invested by many IMs and RUs to develop an architectural view on rail system level. Suppliers do not believe that customers have the discipline to move towards a “single uniform architecture”, with the danger that the evolution would end up being as fractured and diverse as today.*
>
> *In order for the European Union to effectively manage and direct funding for rail research and innovation activities within the S2R JU and its successor, coherence at European level to make best use of financial and human resources and obtain the best result is required. This will bring a clear return on taxpayer money, i.e. improved services for passengers and shippers, i.e. maximising the logistic value chain.*

On one hand, the OCORA partners believe that the European railways cannot operate without a viable and, therefore, profitable supply industry. On the other hand, the same applies to the supply industry that cannot do without a viable and therefore financially sustainable rail transportation sector. The equilibrium between these two beliefs will be a healthy and profitable demand from the European railways for the supply industry’s products. Resources and expertise are scarce in the railway domain, especially with respect to CCS, and a productive cooperation between RUs and Industry is vital to safeguard the future for both parties. One of the prime preconditions to achieve such equilibrium, is that the supply industry provides for a cost effective and innovative range of products and services that meets user requirements, ref. [10], [11]. On the other side, railways can accommodate the industry by improving the predictability and stability of demand, especially for rationalizing the number of specialties.

For OCORA the current state of affairs, which is discussed in previous chapters, needs to be improved and balanced to satisfy both RU and supplier interests. OCORA perception is that adaptation of market conditions to changing environmental, societal and economic requirements can only be achieved through close collaboration. This should happen in what could be called ‘safe isles of collaboration’ such as LinX4Rail. According to OCORA, the responsibility for the development and maintenance of generic interoperability developments that drive automation and digitalisation of Europe’s rail network, e.g., train bus systems and interface specifications, should be a shared one. This solves the issue of fragmented, vendor specific R&D for generic interoperability constituents, eating away rail sector financial and human resources, and guarantees joint and therefore managed CCS migration. The involved parties decide together on the next steps which allows for a natural awareness of the interests of all stakeholders.

Of course, OCORA also firmly acknowledges stakeholder concerns. Perhaps the most important of those is the volatility of customer requirement specifications, forcing the industry to invest in ever new variant of proven company standard solutions. OCORA intends to mitigate this situation by developing harmonized RU CCS procurement specifications. Another concern is the less than generous volumes put in the market by RUs. This is partly a consequence of gradual but inevitable disintegration of larger fleets in ever smaller series over the rolling stock life cycle. Nevertheless, OCORA intends to solve the issue by harmonizing the interface between vehicle and CCS, allowing plug-and-play exchangeability of the CCS system into an otherwise unchanging vehicle.

Another worry often encountered is how to deal with legacy. The railway sector has to gradually migrate to successfully implement the solutions for automation and digitalisation it envisages. Sector partners have to manoeuvre in brownfield situations where stakeholders have vested interests. That is why OCORA has identified the need to closely collaborate with its stakeholders to identify and define those diverse interests, and develop a common and shared roadmap that allows a managed migration. In any case, OCORA reaches out to its stakeholders to discuss concerns with the specific intent to find solutions that are acceptable to all; driven by the conviction that this is the only way to a successful future for the entire industry.

OCORA believes that a productive collaboration with its industry partners would accelerate the evolution of the CCS system and provide for the universal and open CCS configuration it is looking for. That would boost RU’s confidence in the ability of the industry to deliver according to OCORA requirements and, ultimately, market volume. ‘Confidence’ being a pivotal theme, OCORA assumes that a frequent, well-structured, open and unbiased exchange of views and ideas with its suppliers is fundamental to initiate customer-oriented product and service development. OCORA believes that reasonable cost-to-benefit ratios would support the business requirements of both customers and suppliers.

8 Evolution of the OCORA architectural framework

The CCS OB system in the past was focused on 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 aspects of train operation. This will change with the advent of digitalisation and automation in train operation, supported by innovation in computing and telecommunications. Currently, ATO projects are being developed by several RUs that are for the moment targeting GoA 1 and 2 levels. GoA 3 and GoA 4 experiments are also being increasingly started with the express intention to begin operations as soon as possible e.g., for automatic shunting.

8.1 Requirements for an adaptive architecture

OCORA follows an evolutive, stepwise approach that targets test and approval of the core functions of an OCORA compliant CCS OB. The main characteristics are exchangeability within the CCS domain through isolation of specific functions, in combination with the specification of a generic and open communication backbone: the CCS Network. Furthermore, the integration of the CCS system in the vehicle is supported by a generic gateway interface specification.

To accommodate the gradual evolution of OCORA, a number of development steps are identified that allow the OCORA members to consecutively address actual topics.

8.1.1 Preparing imminent retrofit projects

In this step, the interface between the proprietary CCS system and the fully integrated proprietary vehicle environment is isolated. It enables exchange of the CCS environment without affecting the vehicle and vice versa, hence simplifying obsolescence issues. The importance of this step is already indicated above (chapter 6.1).

OCORA members are already engaged in retrofit projects that are, or will be, well under way. It is not realistic to expect all OCORA requirements to be fulfilled in these implementations hence an evolvable approach is needed. In this phase, the objective is to establish exchangeability and modularity on a CCS system level. It enables end of lifecycle replacement without any residual artefacts having an impact on the selection of suppliers for successors or the implementation of the OCORA CCS platform.

OCORA is developing a correct, complete and comprehensive ETCS and ATO to TCMS interface specification, based on the SS-119 and SS-139.

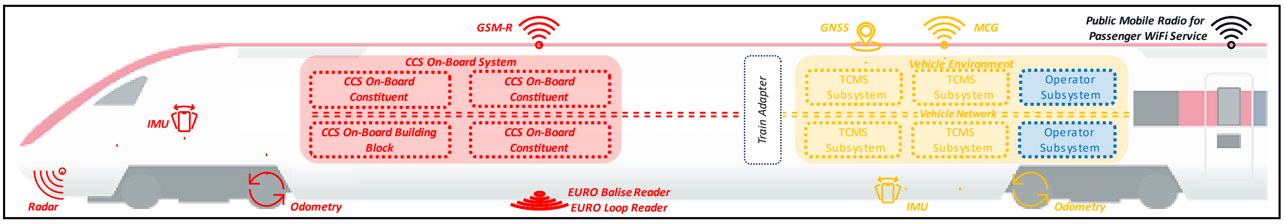

Figure 5 Decoupling of the CCS on-board and the vehicle

8.1.2 Modularisation of the CCS on-board

In this step, the CCS OB will be decomposed into individual building blocks connected by open interfaces and an open bus system. This will allow exchangeability between the building blocks without affecting either the vehicle or other CCS constituents. Obsolescence management and migration issues can be simplified, and approval and certification can be confined within the boundaries of the building blocks instead of the CCS OB or the whole vehicle. This step implies developing the specifications for the CCS network (sometimes called “one common bus”) and the interfaces between the single building blocks. This development has started as SS-147 but needs to be developed further until the OSI layers 1-6 are defined.

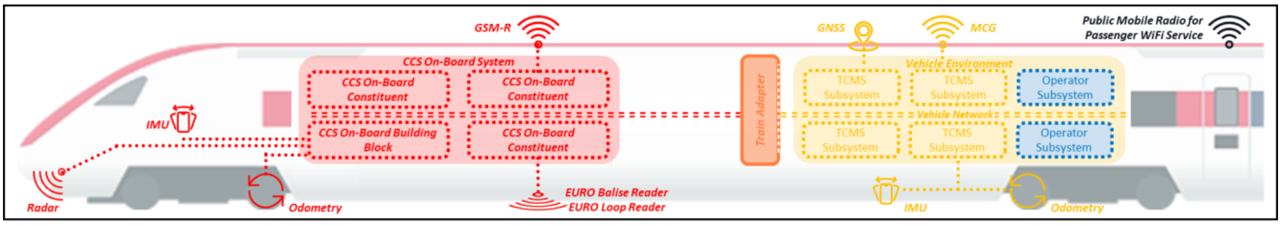

Figure 6 Modularization of the CCS on-board proper - CCS network introduction

OCORA intends, with the output from this modularisation exercise, to challenge the TSI CCS Revision of 2023 in order to prepare the path for the long-term CCS evolutions. The definition of building blocks should help to shape an adequate level of granularity for TSI options, which will facilitate both standardisation of product supply and migration from existing to future CCS building blocks.

8.1.3 OCORA CCS platform

In this step, the core CCS functions will be organised on a generic platform that enables adding, removing or changing functional applications. It will not affect the computing platform or runtime environment on which they are installed, or the state of approval of non-affected parts of the system. This will facilitate fast and easy software updates and upgrades of only those applications for which that is necessary, e.g., when requirements demand frequent updates of security software. Authorisation issues can be further simplified and contained.

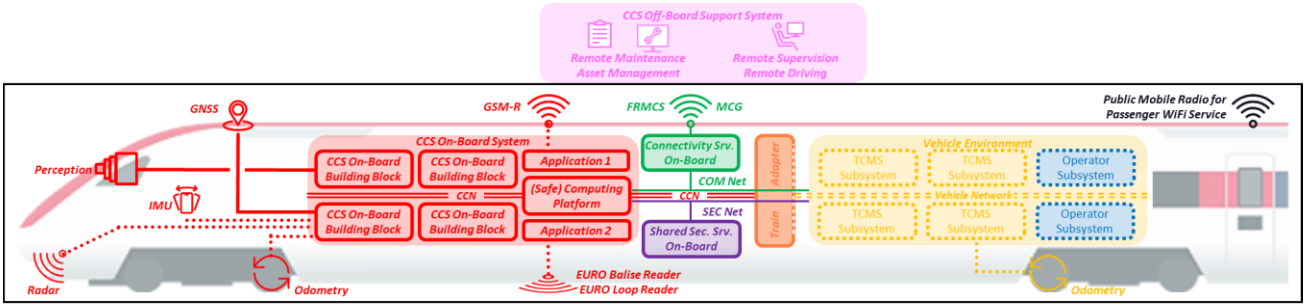

Figure 7 CCS platform with full plug and play capabilities for applications, hardware and peripherals

On the longer run is the convergence of vehicle networks, consisting of one or multiple bus systems that integrate the CCS and vehicle bus systems. This is already under scrutiny of OCORA and Shift2Rail Conecta.

Developments like GoA3 and GoA4 will require remote access and automated control of an increasing number of CCS and vehicle functions. Moreover, the evolution of the CCS domain and the vehicle will become inevitable at some point in the future. Such development will have a considerable impact on vehicle design, performance and cost structure. It will give a strong impetus to improved management of cost, risk and performance for both users as well as suppliers. Train interfaces allowing to connect to legacy bus systems may disappear but standardised secured communication interfaces to either physical or virtual building blocks, must be anticipated to facilitate decoupling. This would ease safety approval, non-regression, cyber security and maintenance management, while allowing for innovation and fair competition. Existing technical standards should be improved or developed, the certification, c.f. approval process, should be revised and new business models should be developed for both fleet owners, users and the supply industry.

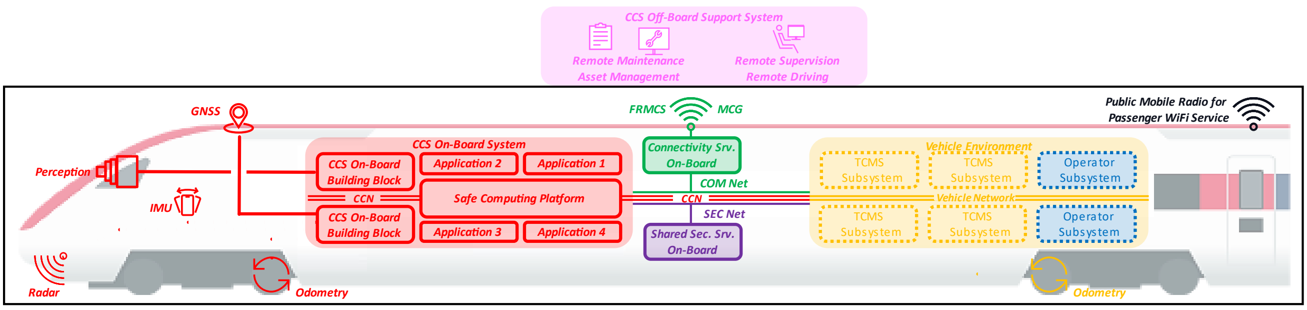

Figure 8 Future view: CCS building block integration supported by vehicle standardisation