OCORA

Open CCS On-board Reference Architecture

Introduction to OCORA

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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 the Release R1 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 based on the Gamma Release. It is **feeding TSI-2022** 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 to publish the next **Release 2.0** by **mid of 2022**.

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

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References

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-BWS05-020 – Minimal Viable Product

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

[10] OCORA-BWS07-010 – Alliances

[11] OCORA-BWS07-020 – CCS On-board for Europe's Rail Joint Undertaking

[12] OCORA-TWS05-020 – Stakeholder Requirements

[13] OCORA-TWS05-021 – Program Requirements

[14] RCA.Doc. 2, Beta.1, RCA Architecture Overview

[15] TSI CCS: 02016R0919 - EN - 16.06.2019 - 001.001 - 1: COMMISSION REGULATION (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union, amended by Commission Implementing Regulation (EU) 2019/776 of 16 May 2019 L 139I

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

[17] 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.

1 Introduction

1.1 Purpose of the document

This document aims to provide the reader with 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 aim of this document is to introduce the reader into OCORA. While the document has been published already several times, the OCORA Guiding Principles have been carved out and made available separately, see ref. [5].

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

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

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

1.2 Applicability of the document

The document is considered informative and applies to the full OCORA Release R1. 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 R1, together with the documents listed in the release notes [1]. Before reading this document, it is recommended to read the Release Notes [1]. If you are interested in the context and the motivation that drives OCORA we recommend to read 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

OCORA has adopted much of the terminology developed by RCA. This new terminology has been developed to free the development architecture team of the normative, traditional way of architecture development that is used in e.g. the TSI's, for the on-board specifically e.g. Subset 026 of [15].

Many traditional architectures, like the ones mentioned, approach logical, functional and technical system decomposition and structuring in a seemingly free format, intermingling them without apparent guidelines or design principles. The RCA approach forces both the architect and the engineer to duly consider from what ontological perspective and at what level of decomposition the CCS system is defined, enabling a more precise breakdown taking account of its environment.

In OCORA too, this approach has proven its value, sparkling discussion on how to unambiguously define and model core CCS functions. Nevertheless, it is inevitable to answer the question on how the RCA and OCORA architectures relate to the traditional approaches. The fact that in OCORA discussions the divide between the traditional and the RCA / OCORA approach had to be frequently bridged, will be reflected in the OCORA Gamma release documentation and help the reader to understand the OCORA approach, Moreover, the OCORA team did its utmost to provide useful and comprehensive information on the RCA / OCORA terminology in the Glossary [2]. In case of doubt, the reader is therefore referred to the Glossary for better understanding.

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 uncontested 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, so called, Single European Rail Area' (SERA) to substantiate its policy. These investments pertain the research, development and innovation necessary to allow the railway community keeping its competitive edge (via Shift2Rail and its successor, Europe's Rail), and subventions that support the technological evolution towards SERA (via e.g. the 'Horizon' program), i.e. in the implementation of ERTMS and the game changers (e.g. ATO, FRMCS). But SERA has not been achieved, yet.

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.

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

2.1 CCS Risk profile

Despite the investments in the implementation of ERTMS, the program has not been sufficiently successful. And 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 e.g. frequent updates of the specification and technological developments, but also the variability of user specifications, resulting in an average life cycle expectancy for CCS systems of 5 to 10 years with an average of, currently, about 6 years. The net result of this development is, that rolling stock has to be retrofitted several times during its (residual) lifecycle. For new rolling stock fitted with ERTMS and with a life expectancy of +30 years, this would mean at least 4 consecutive retrofits. The CCS market will, therefore, be dominated by the need for retrofits and not by newly built requirements.
2. The persistence of leet size as a main cost driver since every retrofit requires an intricate cocktail of surveying, documenting, engineering, prototyping, approval, testing and commissioning, which in the end leads to CCS equipment becoming an integral part of the larger entity: the rail vehicle.
3. 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, and the evolution of which should be centrally managed to ensure diachronical coherence and consistency of system performance.
4. Consequently, the high life cycle 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 e.g. technical complexities (from an RU point of view specifically safe integration of ETCS in the vehicle), financial considerations or regulatory complications, resulting in a mean retrofit project duration of between 8 and 10 years, often more.
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 in most cases a baseline upgrade of ETCS with required re-certification.
7. The ensuing reluctance of railways to invest more in the implementation of ERTMS than absolutely 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. RU's to lose the modal competition and become a declining niche in the transportation market, their function to be overtaken by automated road transportation.
2. IM's 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 full benefit from ERTMS, are:

1. Current control-command and signalling on-board 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 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, etc.).

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 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. 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 on-board command-control and signalling systems that supports the mutually agreed OCORA objectives (Chapter 6). 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 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 railway undertaking 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 on-board to facilitate the:

- Introduction of innovative technologies (starting with the so called 'game changers' like ATO and FRMCS) 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 full 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 on-board reference architecture by e.g.:
    - Open standardisation of the ETCS/ATP and ATO train interfaces and functions and other on-board building blocks 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 using results and experiences from 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

[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.

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 developments. Therefore, OCORA has already developed and communicated problem statements that point out issues that have to be addressed in the TSI CCS Revision of 2022 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. OCORA closely cooperates with RCA and other stakeholders to ensure that this interface is optimized with the express intention to optimised results with a railway transportation ecosystem focus. 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. These will be pushed forward in other sector interest groups (e.g. CER) as foreseen in OCORA Alliance document [10]. OCORA considers a close collaboration with institutional and industrial stakeholders on a sector scale is an essential enabler for fast progress.

5 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. Improvement of the regulatory framework as a tool 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. One of those demonstrators will be developed as part of the ‘Minimum Viable Product’ or MVP, the condensed version providing the core functionality of the OCORA platform for both validation and verification as well as authorization purposes.
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 user specifications (architecture and interfaces) for a modular CCS on-board 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.

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). This will be done by developing prototypes for testing and demonstration purposes. These ultimately have to be industrialised for serial production.

5.1 Minimum Viable Product MVP

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. The intention is to develop, maintain and update a model of the core functions of the CCS system – only those functions absolutely necessary to safely move a train over a rail network – using formal logic. This formal model should be tested in a laboratory environment and empirically in a prototype that performs the basic functions necessary for train operation.

Moreover, CCS equipment are today customized for specific vehicle classes, sometimes even retrofit project wise. The absence of a harmonized bus system and interfaces, make it impossible to achieve standardisation of CCS components to the extent that these can be installed or removed without specific developments in, or adaptations of the integral CCS on-board (in its turn integrated into) those 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. Both suppliers and their customers, therefore, avoid change because any change will incur major investment, performance and operational risks. Users only very reluctantly venture into new contracts, leading to contracting market volumes. OCORA intends to develop the MVP to demonstrate that this predicament can be solved by applications of its approach in a real time environment.

The OCORA MVP is looking at disentangling existing dependencies between building blocks of different life expectancy at the one hand and between CCS modules on the other, 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 MVP development jointly with stakeholders, e.g. within the S2R2 framework. Alternatively, a development venture has to be set up by the OCORA members and other participants to execute the MVP development.

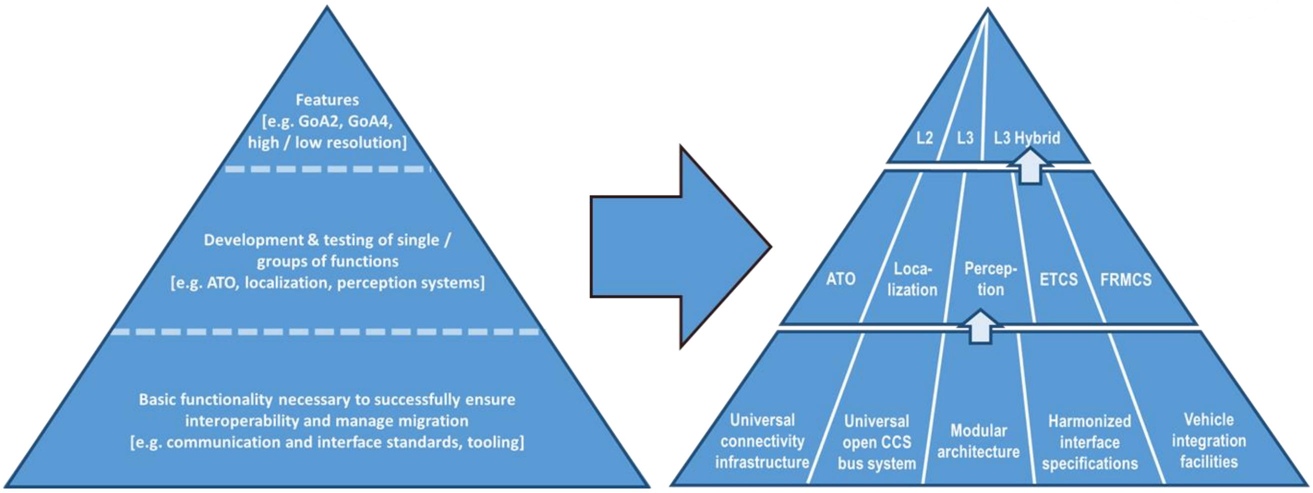

Figure 1 OCORA MVP strategy

5.2 Roadmap

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

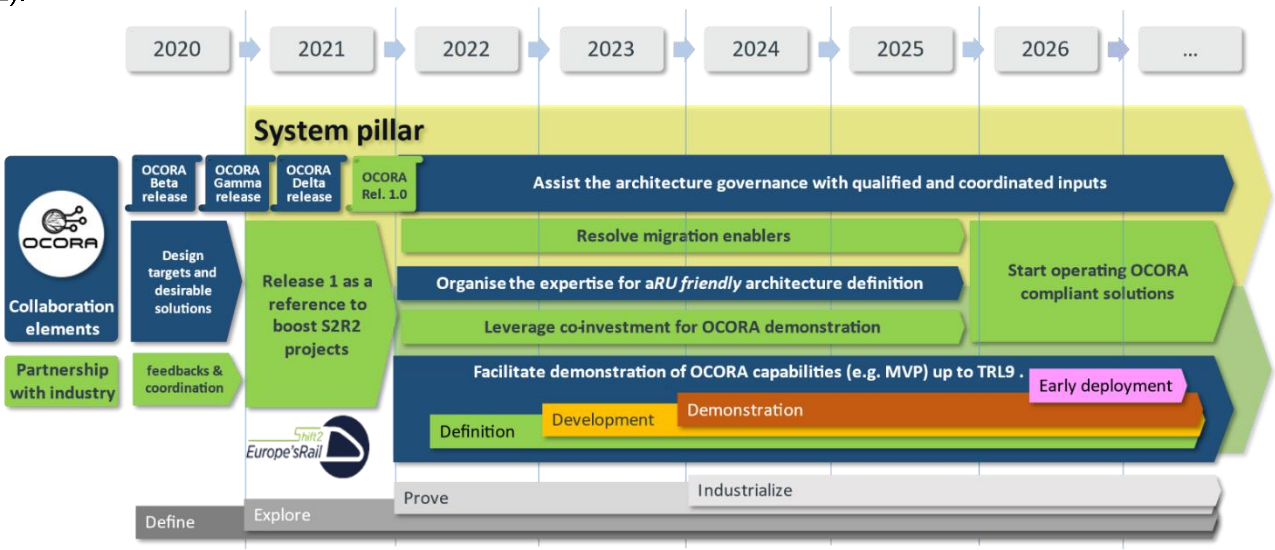

Figure 2 OCORA migration strategy Road-Map,

OCORA intends to initiate and foster a collaborative platform that supports successive technological migrations within existing community arrangements, e.g. LinX4Rail and ERJU. Moreover, OCORA will keep on infusing an independent user perspective in these collaboration platforms in order to liaise and balance frequently between European policy and 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. Obviously, these will only serve stakeholders when they are well tested, hence, validated and verified in real time demonstrators. With 'demonstrator', OCORA not just means mock ups showing certain features in operation, but full service, approved, certified and ready for immediate industrialization prototypes, enveloping the minimum set of vital functions to prove the operational readiness of the OCORA approach and philosophy. This development is termed the OCORA Minimum Viable Product or MVP.

OCORA intends to make the MVP development and testing sequence part of Europe's Rail JU program. The envisaged global planning and roadmap are represented in **Figure 3** and **Figure 4**.

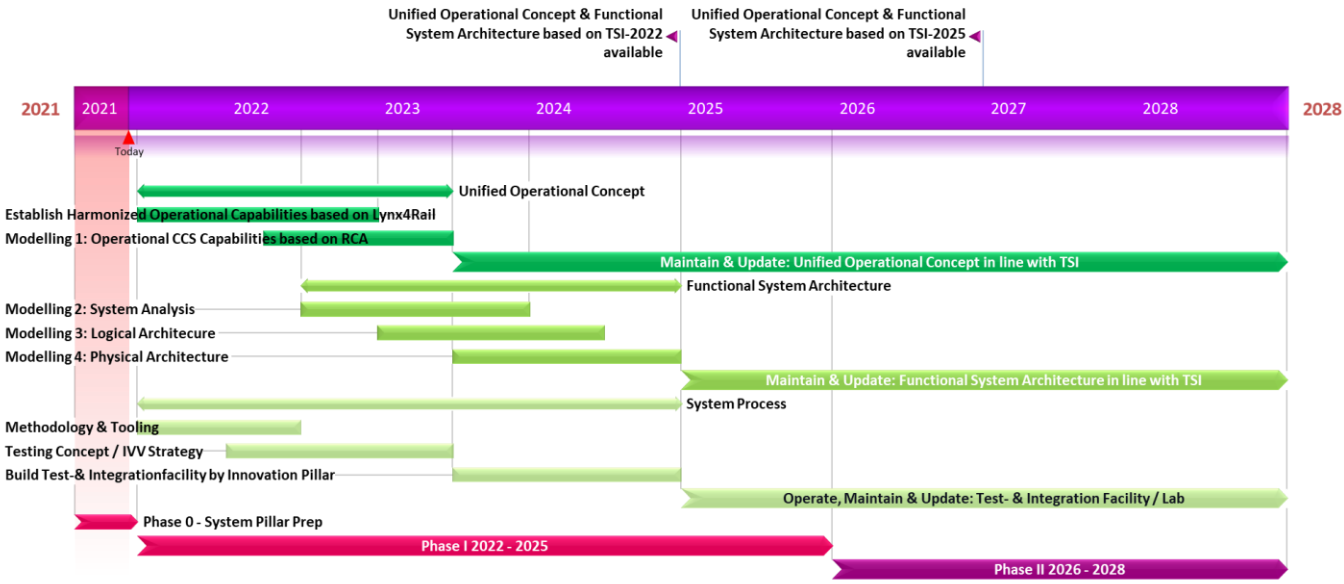

Figure 3 OCORA collaborative product development ER JU System Pillar

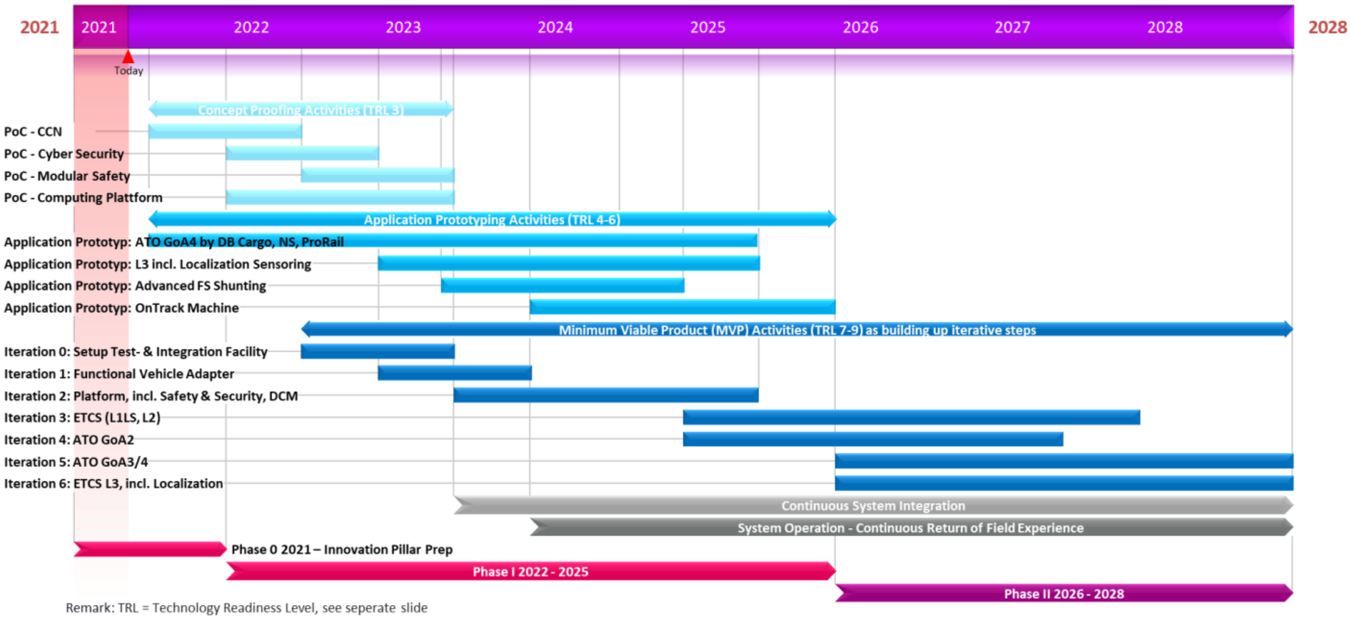

Figure 4 OCORA collaborative product development ER JU Innovation Pillar

6 OCORA business rationale

To keep up competition with modal competitors, 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 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. 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 and successful adoption of the game changers, 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: 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 as a consequence of recurrent retrofits.
- 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. This will require decoupling CCS building blocks with different life cycles in order to consistently manage performance aspects (cost, compatibility performance and migration relevant) by isolating and capitalising on solutions for core safety and interoperability aspects.
- 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.
- Increased 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.
- Correction of market distortion caused by the necessity of heavy investments for CCS in aged rolling stock, causing inverse capital, depreciation and cost structures for rolling stock owners, especially leasing companies and ROSCO's.

OCORA provides a quantitative and qualitative economic evaluation in this release where first, critical aspects of OCORA member corporate objectives, 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 estimate of the 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. Experience teaches, however, that the ERTMS on-board has to be replaced once every 5 to 10 years, on average 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 (retro)fitted already with an estimated average residual life expectancy of 15 years, and a (conservative) average 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 in 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 5 Market volume trends and OCORA assessment of ensuing retrofit volumes)

As can be seen from this graph, the demand (and expenditure) for fitting and retrofit 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 Ruete assumptions 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 'retrofit' will be the dominant factor in the implementation of ERTMS and the game changers. From reference, it is crystal clear that controlling the cost, 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 plug and play 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.

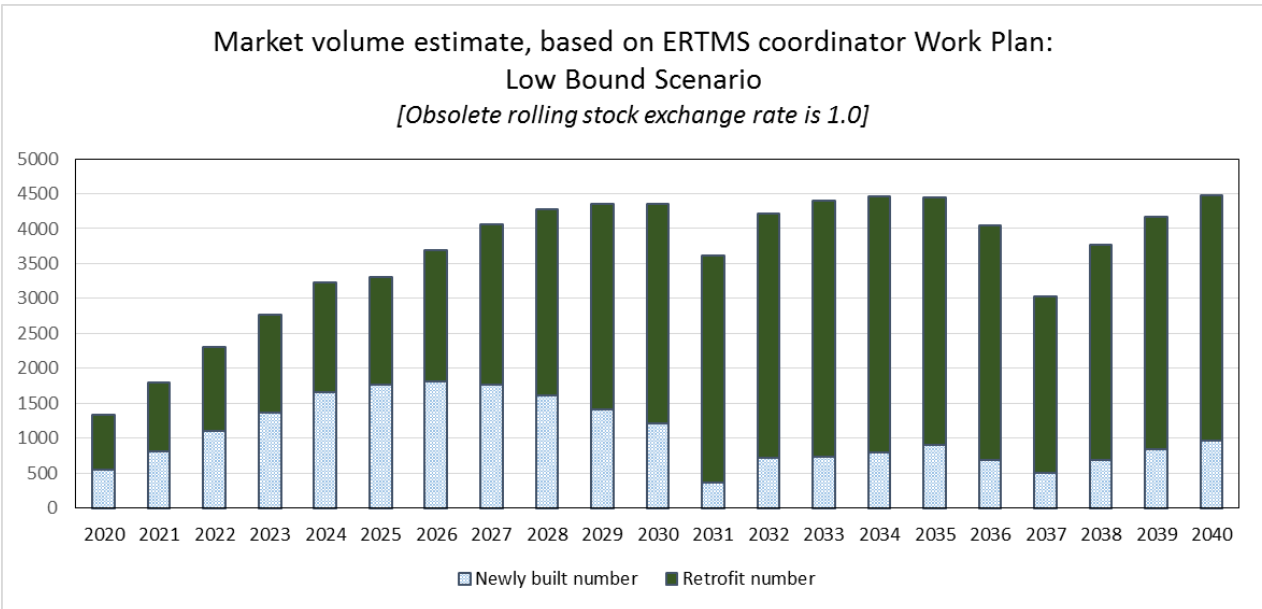

Figure 6 Extended market volume trends 2020 - 2040

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, i.e. 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 born by either the railways or subsidised by Europe.

So it is unquestionable, 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.

For discussing the financial impact of implementation of OCORA design guideline [5], is suitable for reference purposes. This is an abstract from the EC publication 'Decision Authorising the Use of Unit Contributions to Support ERTMS Deployment under the Connecting Europe Facility – Transport Sector[2]. It defines the actual reimbursements for the retrofit of rail vehicles and the level to which EC compensates RU's 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

Although recent experiences demonstrate that the actual expenditure is significantly higher than anticipated by EC (bills for prototyping are typically approximately € 10 million and the retrofit cost of train sets is in specific cases nearing € 1 million per vehicle), even at the rates indicated in the Table, the structural compensation of RU's will amount to hundreds of millions of Euro's annually in the – from the financial point of view –most optimistic scenario. And the expenditure for the RU's themselves, paying the majority of the investments needed, will rise beyond what is economically viable. The advent of the game changers which drive CCS On-board system complexity, threatens to increase cost levels even further.

At the same time, developments give a glimpse on the opportunities that offer themselves to the railway community. Market volume is on the rise, even in a conservative scenario. In the do-or-die scenario that is 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 from the current, fragmented railways to a fully interoperable European Network. Because it's 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 that drives market expansion while ensuring a positive business case for RU's at the same time. This has to be done in close collaboration with authorities, institutions and especially the supply industry. Expanding market volume, while at the same time harnessing cost and performance levels need to be actively and jointly managed from both the demand and supply sides.

[2] https://ec.europa.eu/inea/sites/inea/files/ertms_decision-annex_i_unitcontributions.pdf

7 OCORA collaboration with other groups

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), involving 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 (Connecta, Linx4rail) and its successor, Europe’s Rail.

OCORA is aiming at close and efficient liaison with other stakeholders in order to help consistency and complementarity between sector initiatives affecting the definition of CCS on-board subsystem. 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 RU’s 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 S2R. 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.*

The OCORA partners believe that the European railways cannot do without a viable and, therefore, profitable supply industry, just as much as the supply industry cannot do without a viable and therefore financially sustainable rail transportation sector that provides for a healthy and profitable demand for their products. Resources and expertise are scarce in the railway domain, especially with respect to CCS, and a productive cooperation between RU’s 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. [12], [13]. On the other side, railways can accommodate the industry by improving the predictability and stability of demand, especially rationalizing the number of specialties.

For OCORA it’s clear, that the current state of affairs, which is discussed in previous chapters, needs to be improved 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 in, what could be called, ‘safe isles of collaboration’, e.g. 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 not only solves the issue of fragmented, vendor specific R&D for generic interoperability constituents, eating away rail sector financial and human resources, but also guarantees joint and therefore managed CCS migration. The involved parties together decide 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 variants of proven company standard solutions. OCORA intends to mitigate this situation by developing harmonized RU CCS procurement specifications, Another concern are the less than generous volumes put in the market by RU's. This is partly a consequence of gradual but inevitable disintegration of larger fleets in ever smaller series over the 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. And expects this first step in its incremental approach as a huge step towards larger market volumes.

Another worry often encountered, is how to deal with legacy. OCORA is well aware of the fact that the 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's is why OCORA has identified the need to closely collaborate with its stakeholders to identify, and define those diverse interests and develop a common, 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 the RU 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 and open, unbiased exchange of views and ideas with its suppliers is fundamental to initiate customer-oriented product and service development. OCORA believes that as a rule of thumb, it should target reasonable cost to benefit ratio's that support the business requirements of both customer and supplier.

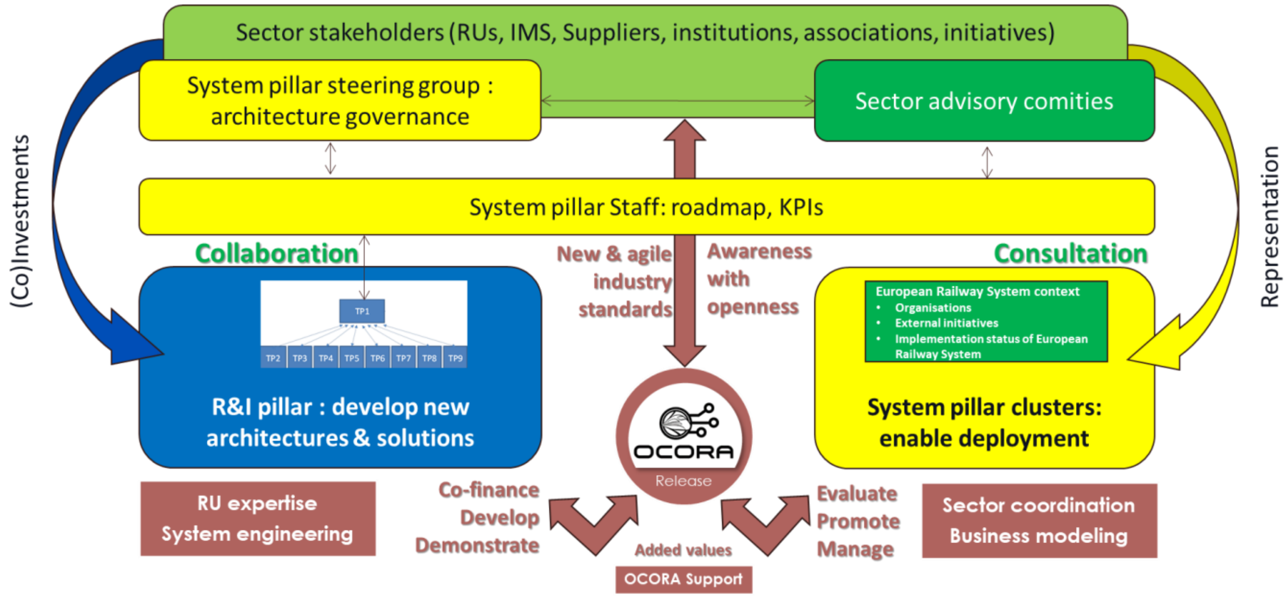

Figure 7 OCORA role perception *viz*. Shitf2Rail2.

The question of sector cooperation has gathered momentum with the preparations that are made to start Europe's Rail JU (ERJU In Europe's Rail, OCORA has the ambition to:

1. Assume the role of specifying on behalf of RU's user requirements where train borne CCS is concerned;
2. Provide expertise;
3. Contribute to and support (e.g. through coordination and analysis of outputs) research and development efforts that result in achieving the OCORA platform to the level of industrialization, starting with the OCORA MVP.
4. Participate in advising and managing the ER JU organization.

OCORA intends to assume these tasks with a firm conviction that intensive collaboration between institutions, railways and supply industry is paramount to succeeding in establishing SERA.

8 Evolution of the OCORA architectural framework

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. 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 RU’s, for the moment targeting GoA 1 and 2 levels. But increasingly also GoA 3 and GoA 4 experiments are started with the express intention to start 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 testing and approval of the core functions of an OCORA compliant on-board prototype, the so called ‘Minimum Viable Product’ as a first stage. The main characteristics of the MVP are 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 5 depicts a simplified high-level view of the envisioned stage one OCORA CCS on-board system architecture as presented in earlier releases. 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.

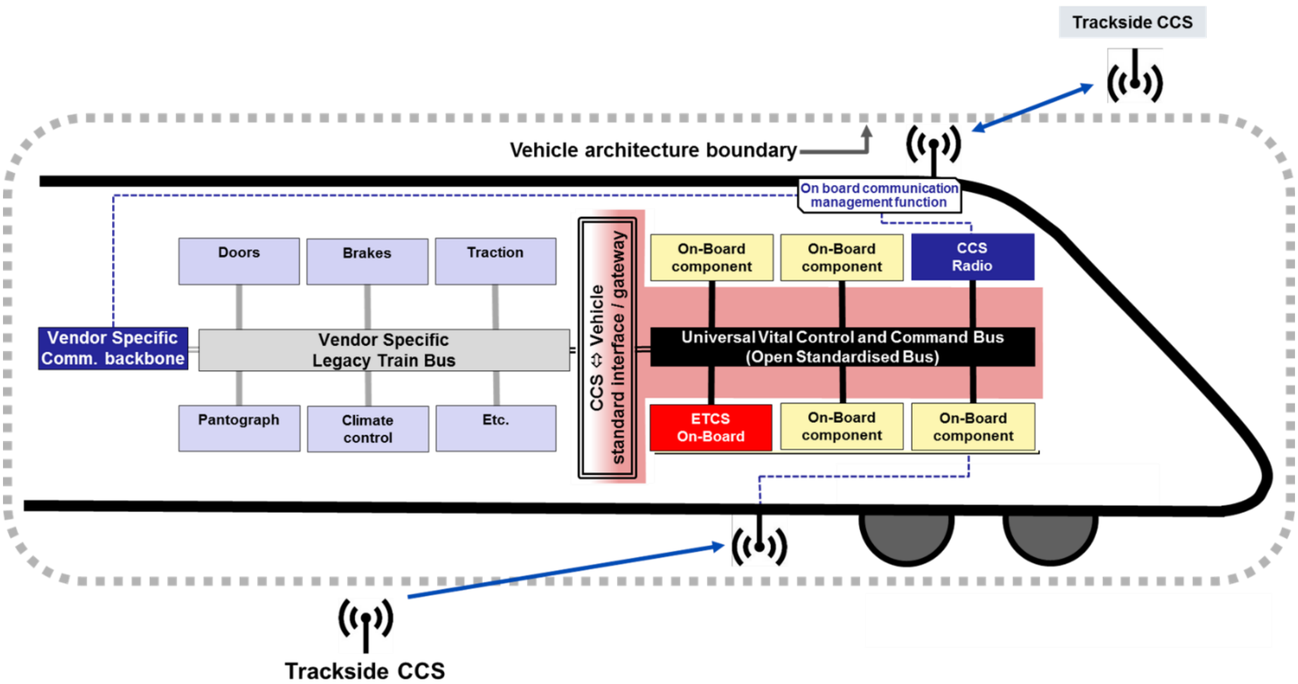

Figure 8 High-level simplified vision of OCORA stage one vehicle architecture

Obviously, this architecture retains several drawbacks of current vehicle design and stops short of the complete modularisation of the vehicle inclusive of the CCS system that will be required for commercial operation under GoA 3 and GoA 4. Therefore OCORA foresees that further development on the overall vehicle architecture will be necessary in order to ensure technology convergence and standardisation for buses on the vehicle side. Indeed, OCORA probing the options with industry partners in the frame of S2R-LinX4Rail discussions on CONNECTA.

With the advent of automated train operation in heavy rail, notably through GoA 3 and 4, the option of unmanned rail traffic – for decades already “business as usual” in light rail – becomes feasible. The expected introduction of ATO and FRMCS in TSI 2022, supported by improvements of e.g. braking curve calculation, are a first step in that direction. The imperative of cost reduction and productivity improvement allowing rail transportation to keep up with modal competition, will inevitably drive the development of further automation and digitalization.

The on-board CCS domain is now defined by the need of safe movement of the individual (combination of) rail vehicle(s) over the railway infrastructure. It essentially requires an ATP system (ETCS core) and supporting functions to feed the ETCS core with the necessary data. 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.

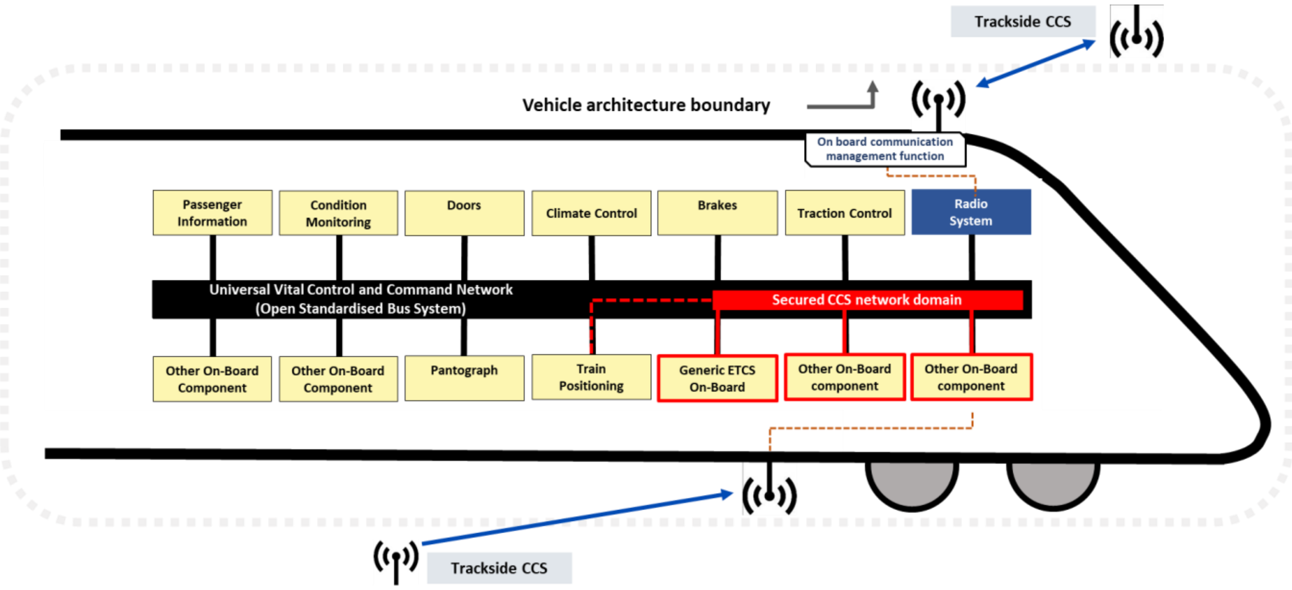

Figure 9 High-level simplified vision of OCORA long term vision on vehicle architecture

The reduction of the human element in train operation requires that an increasing number of vehicle systems be effectively controlled by technical system. Traction, doors, climate, etc., have to be automatically controlled when human control is absent. On the long term, OCORA envisages unmanned train operation on, at least selected, sections of heavy rail networks, especially high traffic density lines, or for specific transportation functions like shunting. Obviously, this requires a progressive adaptation of the railway system architecture, infrastructure and rolling stock, along the definition of the CCS architecture as depicted in Figure 6: a train network shall allow to connect adaptable train borne components and manage their functional distribution in an agile, plug and play, way.

8.2 OCORA architecture development stages

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

8.2.1 Preparing imminent retrofit projects

In this step, the interface between the proprietary CCS system and the fully integrated proprietary vehicle environment is isolated, enabling 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. In this phase, the first objective is to establish exchangeability and modularity on a CCS system level, enabling replacement at end of life cycle without any residual artefacts having an impact on the selection of suppliers for successors or the implementation of the OCORA CCS platform. The first objective is, therefore, to specify an unambiguous and open interface between the CCS system and the vehicle, including ATO functionality. OCORA aims at eliminating ambiguities from the existing subsets 119 and 139 and closing the gaps in these specifications.

OCORA is developing a correct, complete and comprehensive ETCS to TCMS interface specification, based on the UNISIG SS119 version 1.0.15 [15]**Error! Reference source not found.** and a gap analysis of the

OCORA ETCS - TCMS interface specification and UNISIG Subset 119, version 1.0.15 [15]**Error! Reference source not found.**. OCORA engages with ERA to further investigate the findings. OCORA strongly advocates the necessity of aligning both specifications and agreeing upon a mature, coherent and complete SS119 before considering inclusion in the TSI revision of 2022. The aim is to have a generic and open interface between vehicle and ETCS system as depicted in Figure 7 for future and existing fleet.

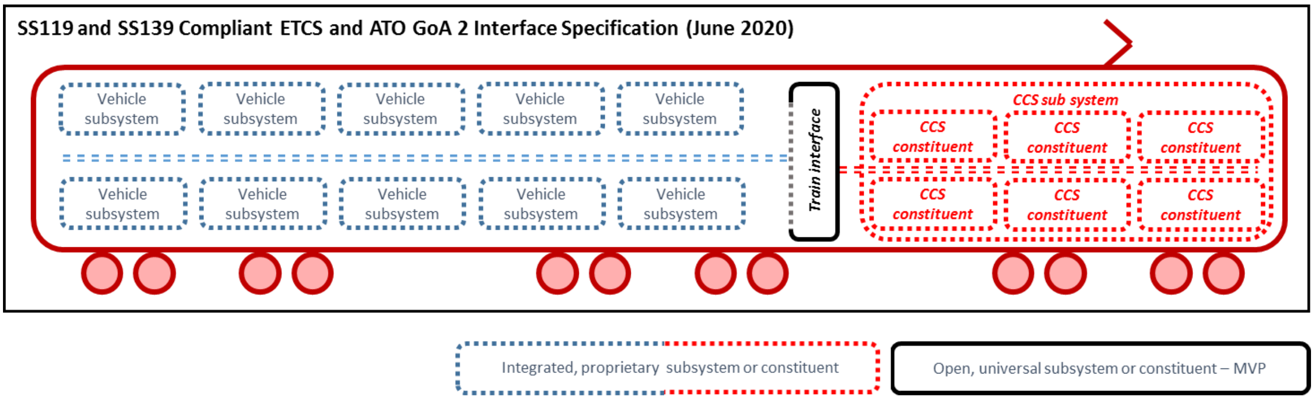

Figure 10 Decoupling of the CCS on-board and the vehicle

OCORA intends the output from its subset 119 and 139 development work to be integrated in the TSI Revision of 2022 to complete and enhance the existing specification.

8.2.2 Modularisation of the CCS on-board

In this step, the CCS on-board will be decomposed into individual building blocks, connected by open interfaces and an open bus system allowing exchangeability between the building blocks without affecting either the vehicle or other CCS constituents. Obsolescence management and migration issues can be simplified; approval and certification can be confined within the boundaries of the building blocks instead of the CCS on-board or the whole vehicle. This step implies development of the specifications for the Universal Vital Control and Command Bus and the interfaces between the single building blocks. Based on this development, software will be generated, a test environment established which will eventually result in a prototype that can be empirically tested in an operational environment. The objectives include the approval of the prototype as a first step in industrialisation.

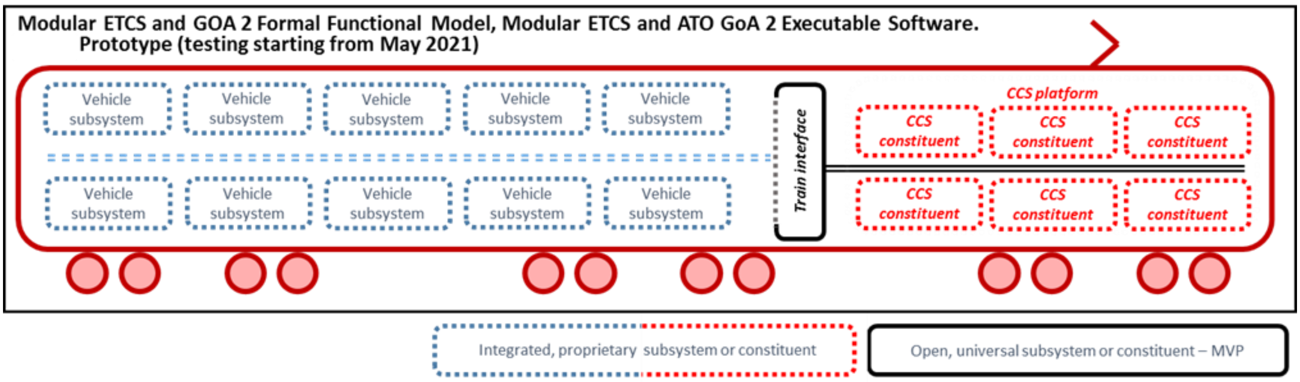

Figure 11 Modularization of the CCS on-board proper - UVCCB introduction

OCORA intends, with the output from this modularisation exercise, to challenge the TSI CCS Revision of 2022 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 smoothen the migration from existing and future CCS building blocks.

8.2.3 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 without affecting 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.

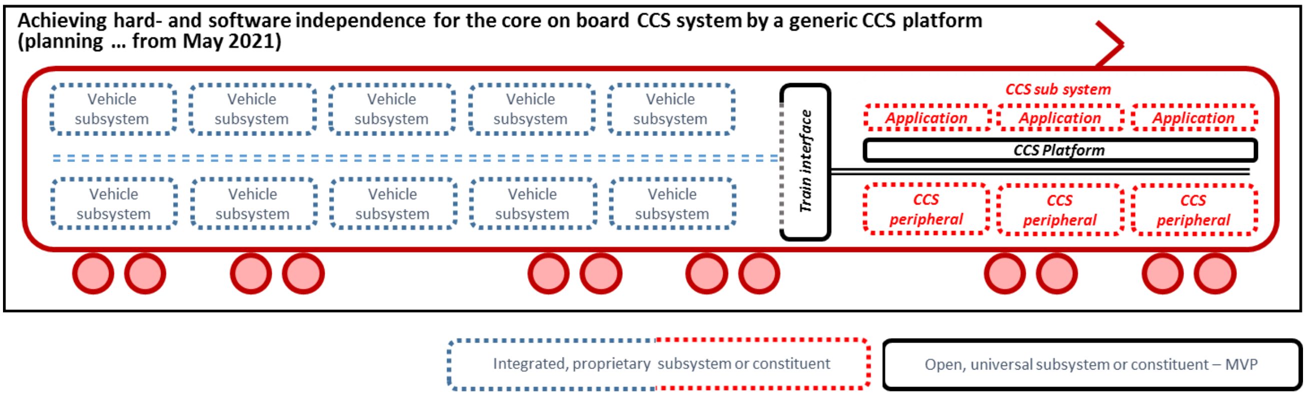

Figure 12 CCS platform with full plug and play capabilities for applications, hardware and peripherals

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

Developments like GoA3 and GoA4 will require remote access and automated control of an increasing number of CCS and vehicle functions. 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 and 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 in order to facilitate decoupling. This would ease safety approval, non-regression, cyber security and maintenance management, while allowing for innovation and fair competition. Obviously, 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.

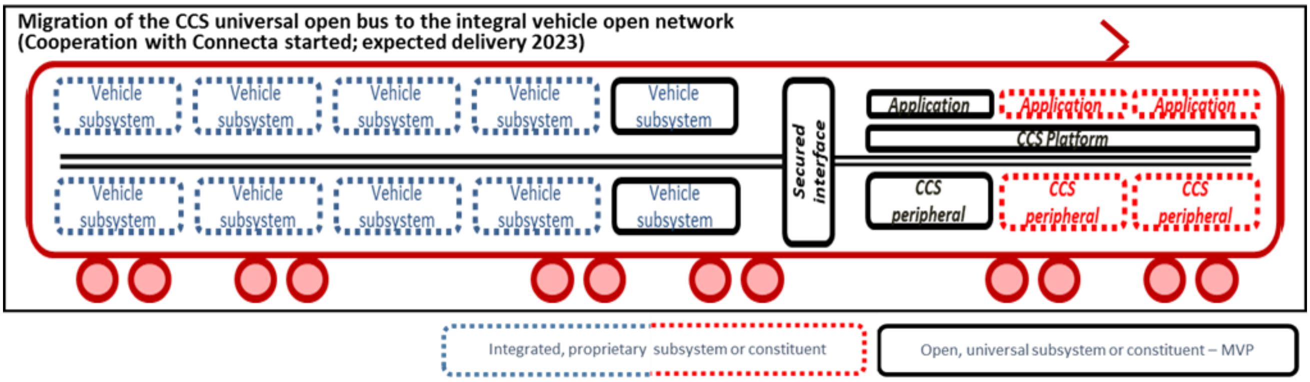

Figure 13 Future view: CCS building block integration supported by vehicle standardisation