OCORA

Open CCS On-board Reference Architecture

CCS On-board for Europe's Rail Joint Undertaking

OCORA Proposal for a constructive and collaboration oriented setup of Europe's Rail JU, discussion paper

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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.

[1]   OCORA-20-001-Gamma_Executive-Summary-Slide-Deck

[2]   OCORA-30-001-Gamma_Introduction

[3]   OCORA-30-002-Gamma_Problem-Statements

[4]   OCORA-40-001-Gamma_System-Architecture

[5]   OCORA-40-003-Gamma_UVCC-Bus_Evaluation

[6]   OCORA-40-004-Gamma_Computing-Platform-Whitepaper

[7]   OCORA-40-005-Gamma_Functional-Vehicle-Adapter_Introduction-and-Overview

[8]   OCORA-40-009-Gamma_(Cyber)-Security-Overview

[9]   OCORA-40-012-Gamma_Modular-Safety

[10]   European Commission, Proposal for a COUNCIL REGULATION establishing the Joint Undertakings under Horizon Europe, Brussels, 23.2.2021, COM(2021) 87 final, 2021/0048 (NLE) [Single Basic Act]

[11]   DG MOVE, ERTMS Stakeholders Platform, CCS Framework 2020

All OCORA references, including this document are available on the OCORA public repository[1].

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[1] https://github.com/OCORA-Public

1   Introduction

The purpose of this document is to **outline OCORA's proposal for a constructive and collaboration-oriented setup of Europe's Rail JU's System-, Research and Innovation Pillars**. It is addressed to railway decision makers, sector representatives, railway experts and any other person, interested in the mission of OCORA in relation to that of Europe's Rail JU. OCORA intends to align the position presented in this discussion paper with CER, RCA and EuG to prepare a joint proposal. Therefore, this paper must be interpreted as input for upcoming discussions. OCORA specifically also targets a constructive dialogue with the supply industry to identify and initiate potential collaboration projects that could be carried out within the framework of the future Innovation Pillar.

The reader will gain insight in the ideas and concepts OCORA would like to propose concerning ER JU organizational and design and development processes, innovation priorities and research and innovation initiatives. OCORA preferences are derived from the OCORA perspective on the preferential development of the future digital European railway environment,

OCORA started in 2019 as collaboration of Railway Undertakings with the specific intent to render the on-board control, command and signalling (or: CCS) system, a user requirement compliant, thus cost effective and high performance support for automation of rail operations across the European network. OCORA strongly believes, that this can only be achieved if all stakeholders in the European railway community benefit from its approach: the railways themselves but also the supply industry and institutional partners.

OCORA has an extensive library of information products – including an Executive Slide Deck [1] and comprehensive Introduction [2] - that can be accessed through our network site: https://github.com/OCORA-Public/Publication.

2 Existing pre-work – OCORA input for ER JU

The OCORA collaboration has published a wide range of deliverables pertaining to the CCS On-board. Based on the coherent, joint user perspective of its members, technical work streams have delivered conceptual descriptions of CCS architecture building blocks such as an open Ethernet based bus system, generic applications for plug and play integration of CCS systems in rolling stock ('functional vehicle adapter'), modular safety and (cyber-) security. In addition, business perspectives (e.g. development of an economic model) and implementation issues (e.g., testing strategy and an approach for applied prototyping) have been developed, based on the cumulative know how and empirical field experience of the involved railways.

OCORA's vision is to develop a CCS environment where European rail stakeholders (manufacturers, railway undertakings, infrastructure managers), supported by their associations (CER, EIM, EUG, UIC, UNIFE…) and institutions (EC, ERA, Shift2Rail, EURail, Member States…) improve the CCS system (specifications) and the related processes (from research to recycling through design, systematic analysis and evaluation) in order to enable a faster, more cost effective and interoperable automation of train control and command throughout Europe.

OCORA expects that ER JU will provide major opportunities to establish, together with other stakeholders in the railway domain, an integrated and effective engineering community to collaboratively find solutions for the challenges the railway community is facing. Being an open innovation community, OCORA has evolved into a well-established and open collaboration that brings together qualified railway engineering resources. Therefore, OCORA can contribute to building - through Europe's Rail JU - a joint design community through its bundled competences and experience. Focussing on an open architecture for the on-board, OCORA envisages a symbiotic interaction with the European industry ecosystem involved in the JU to share the benefits of its approach.

OCORA proposes the following approach for streamlining and aligning ER JU innovation processes, including those regarding the CCS on-board domain, by establishing:

- **A community of experts that contributes to and monitors System Pillar developments in order to ensure that it fulfils fleet owners needs and requirements. It is expected that the System Pillar will resolve functional harmonization challenges but also contribute to common approaches for engineering methods and processes.**

- **A fleet owner community, ready for supporting and executing collaborative testing and industrialization of innovative solutions that are compliant with OCORA, in close collaboration with its stakeholders, especially the supply industry. It is expected that the Innovation Pillar will accommodate co-investment schemes for prototyping, demonstrations and real time operational implementations. OCORA thus aims to demonstrate, jointly with the supply industry, the feasibility and viability of its main capabilities (through an OCORA Minimum Viable Product), the industrialization of solutions for OCORA building blocks up to TRL9, and, moreover, the development of new integration and validation approaches and tools.**

The following sections of this document are identifying key development activities that could be addressed in a collaborative way in Europe's Rail JU structure and projects. OCORA is keen to open collaboration with new members, operators and manufacturers' partners through ER JU.

The last section of this document suggests principles and criteria for organising gateway and development processes for accelerating the innovation deployment and increasing R&D productivity and speed. The objective is to provide feedback loops to align identification, guided management and execution of the ER JU innovation calendar. OCORA believes this an indispensable prerequisite for accelerating Europe's rail transformation.

3 General approach for development within ER JU

3.1 General approach proposed for the development

ER JU will host a System Pillar in charge of developing and maintaining a reference system with its architecture and associated development processes whereas the Innovation Pillar will develop and demonstrate the generic products. OCORA understands that the two pillars will have to continuously cross-fertilize each other to generate solid results, as indicated in the picture below. OCORA is ready to support this process to push new products that respond to breakthrough concepts, developed in the System Pillar and Innovation Pillar. OCORA also commits to support a workable migration from the current to future configurations of rolling stock and the industry ecosystem.

Figure 1 below provides a first insight of the main aspects that should be considered when framing Europe's rail processes and objectives. It explains why and how topics treated in this document can be effectively delivered.
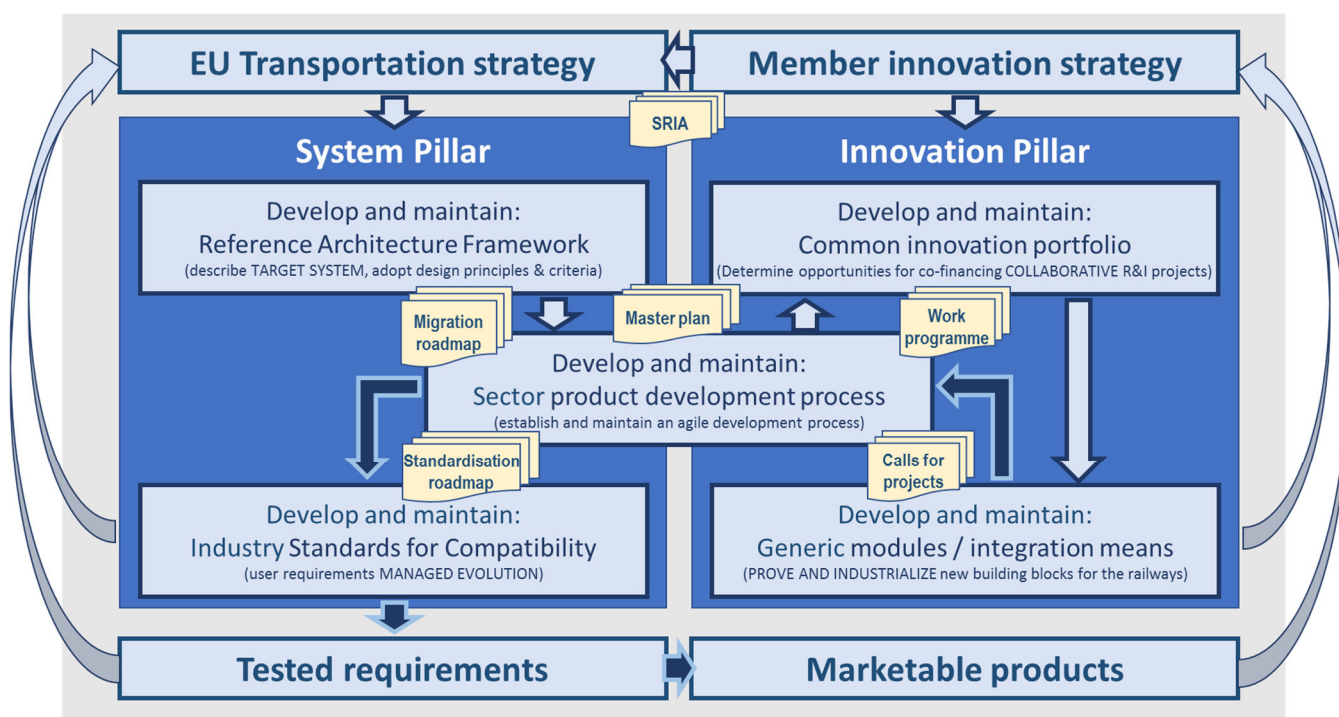

Figure 1 – System- and Innovation Pillar interaction

As stated above, OCORA intends to develop a prototype of the OCORA platform as Minimum Viable Product (MVP) in order to demonstrate the validity of its design principles, both from a technological and economical perspective.

In the next paragraphs, OCORA will present a comprehensive overview of its innovation and development priorities and their relation to the System and Innovation Pillars of the ER JU.

The objective of the OCORA MVP should be:

- **To increase technical readiness of OCORA building blocks (bus system, train interface FVA, applications, peripherals, etc.);**
- **To support prototyping of new rail system functionalities;**
- **To develop an open access laboratory facility for testing OCORA compliant modules.**

3.2 OCORA development priorities

OCORA has one prime objective for its involvement in ER JU: to foster the transformation of the OCORA CCS on-board concept into a concrete, mature, tested and certified prototype ready for operational testing and industrialisation. By doing so, OCORA seeks to:

1. Bolster close cooperation between the different parties in the railway community;

2. Find new ways to drive both the speed and the productivity of innovation in ER JU through e.g. adoption of disruptive development approaches already used in other branches of industry;

3. Initiate a collaborative development framework with other partners, specifically also the supply industry, to co-invest in the development of the future CCS system for SERA, and beyond that, a cost effective modular industry approach towards asset design and management (e.g. rolling stock design and manufacturing), to the benefit of all those involved;

4. Drive modernisation of the rail market in Europe with the specific intent to considerably increase market volumes, enable affordable and high performance automation solutions and provide the European railways a competitive edge in both modal (IM's, RU's) and global (supply industry) terms to satisfy European transportation strategy objectives (EC, ERA).

This prime objective translates into specific proposals for the System and Innovation Pillars.

3.2.1 System Pillar

OCORA perceives the System Pillar as the organizational fabric for framing railway sector ambitions and priorities as guiding principles for attracting investments in concrete innovation projects. These ambitions and priorities are formulated in the Single Basic Act [10] and CCS Framework [11]. Innovation projects, then, can be delivered by the Innovation Pillar. Innovation Pillar output will, in its turn, find a way back into the System Pillar to feed the regulatory standardisation and Europe's rail industry framework and, hence, will be commercialised as generic products and services. The System Pillar, consequently, will need to evolve into a coordination hub for concepts and ideas (intellectual property) on the one hand while on the other to become designer and steward of a coherent railway architecture to manage and control hub traffic.

3.2.1.1 OCORA perception of System Pillar objectives

According to OCORA, the prime task of the System Pillar is to:

1. Accommodate unhampered infusion of innovative ideas and concepts into the ER JU process without being constrained (too much) by existing regulations and norms;

2. Provide a platform for collaboration to align member business interests;

3. Design, implement and maintain a gateway process to enable value assessment for the standardisation of innovation proposals;

4. Design and maintain a consistently accepted, unified operational concept and functional system architecture for an integrated European rail network. These will generate principle criteria for value assessment of research and innovation proposals;

5. Contribute to the definition of a strategic technological research and innovation agenda to streamline priorities for projects to be organised in the Innovation Pillar;

6. Define engineering requirements, KPIs and quality criteria, enabling Innovation Pillar output to be integrated into the regulatory, standardisation and Europe's rail industry framework processes.

The critical precondition is that the System Pillar has to execute its role in an ever changing environment to satisfy evolving user requirements. This implies that the System Pillar set up should anticipate the need for a permanent process as far as the rail transport management function is concerned, and be sufficiently agile to adapt to changing conditions.

3.2.1.2 OCORA perception of the System Pillar task package

In order to achieve the objectives listed in the previous chapter, OCORA believes the following tasks need to be defined and performed:

- Establish an organizational framework for continuous reception and processing of sector input (e.g. assessment, acceptance, transfer to IP, communication with IP, exception handling, progress reporting) and hosting the development, maintenance and upgrading of the reference railway functional architecture (including physical interfaces, performance criteria and data format) and unified operational concept.

- Develop a gateway process to support and guide activities in the Innovation Pillar.

- Define **methodologies** and **templates** for system design, system deployment, modular integration, testing, verification and validation to support the development of the unified operational concept and functional system architecture.

3.2.1.3 Proposed OCORA contribution to the System Pillar

OCORA offers to support the System Pillar process by providing consolidated user know how, experience and expertise with respect to the development of:

- The reference architecture and a unified operational concept from both an on-board and a system perspective to enable consecutive system migration cycles and guide future evolutions. OCORA input will be based on e.g. Shift2Rail innovations (e.g. S2R IP1 and 2, LinX4Rail) and RCA/OCORA results (e.g. System-Architecture [4], UVCC-Bus Evaluation [5], Computing Platform [6], Functional Vehicle Adapter (FVA) [7], Modular Safety [8], and (Cyber-) Security [9]),

- Processes that support system design, deployment, integration, validation, safety and cyber-security adapted to the OCORA modular approach. This includes defining activities, scope of works, methods and associated tools, standard specifications and templates.

- A supportive and adaptive Model Based System Engineering (MBSE) approach that enables and feeds successive updates of TSI's with proposals that are tested in network operations.

3.2.2 Innovation Pillar

OCORA understands the Innovation Pillar as the entity that will support co-investment in railway innovation projects with a key objective to support the establishment of SERA. Output of the Innovation Pillar are not only concrete results but also input for updating and enhancing the TSI's, standards and industry practice, based on tested product development results.

3.2.2.1 OCORA perception of Innovation Pillar objectives

In general, OCORA assumes that ER JU intends to deliver a framework that will support collaboration, to develop new knowledge for the EU society and to sustain a competitive rail industry. Productivity, return on investment, sector acceptance and speed of execution of research and innovation projects are important issues to be addressed by ER JU to surpass S2R. Based on that assumption, OCORA identifies the following targets pertaining to (OCORA compliant) product design and development:

- Remove barriers and create a safe environment for rapid product development;

- Increase user cf. customer orientation, including institutional partners and stakeholders;

- Broker between demand and supply for investments;

- Accelerate preparation, planning and execution of projects;

- Restrict bureaucratic and administrative burdens;

- Foster, accelerate and iterate successful developments and swiftly discard with unsuccessful ones.

3.2.2.2 OCORA perception of the Innovation Pillar task package

OCORA focusses on the on-board aspects of the automation and digitalization of rail operation as integral part of the European rail architecture developed by the System Pillar. As such, OCORA envisages a sector approach, a validated system design and a deployment framework supporting advanced train automation and a fully digitalized and connected infrastructure. Mockups, models, prototypes and full scale demonstration should allow to boost the maturity of modules, supporting automatization and connectivity. Collaborative activities are needed to specify, develop, integrate and test those building blocks. OCORA, therefore, proposes the following multilevel approach:

1. Enable **proof of concept (PoC)** of innovation proposals: realization of the most innovative concepts to demonstrate their feasibility;

2. Enable **application prototyping**: field testing of prototypes to gain early field experience;

3. Develop **Minimum Viable Products (MVP's)**: build up product development in iterative steps to enable quick wins on the short term and maturity on the long run.

OCORA believes that there should be sufficient room for a systematic, structured trial-and-error approach to test the feasibility of as much promising innovations as possible ('safe isles of innovation') in compliance with Innovation Pillar budget and competences restraints.

3.2.2.3 Proposed OCORA contribution to the Innovation Pillar

OCORA intends to incrementally and consistently develop the CCS on-board over successive technology generations and taking account of evolving user requirements and Europe's transportation strategy. It is adamant in its conviction that this should be accomplished in close collaboration with its business and institutional partners in the railway community, specifically other RU's, IM's, the European supply industry and ERA and EC. OCORA perceives the Innovation Pillar as the ideal platform to accelerate concept and product demonstration activities.

OCORA targets to exploit innovation opportunities to perform proof of concepts (PoC) for **overall CCS on-board and system integration,** using platforms with multiple modules and related functions for testing CCS on-board systems (e.g. localization, speed control, ATO, connectivity) in its close (e.g. CCS trackside systems like TMS) and wider environments (e.g. energy, telecom).

OCORA proposes proof of concept sequences by prototyping and testing of either **elementary modules or combinations according to availability or maturity in** dedicated test environments (test benches). Prime target is modularization of the CCS on board according to OCORA design and engineering principles, to be tested in a prototype of a minimal but functionally complete CCS on-board, the Minimum Viable Product (MVP). Such modules include:

- An open and generic universal vital control and command bus system (UVCCB), to be integrated in the development of a universal and open train bus or network, driving the development of a fully modular train architecture. OCORA already closely cooperates with the S2R Connecta project to achieve this goal;

- A functional vehicle gateway (in combination with UVCCB / train network interfaces);

- A generic approach towards a Computing Platform (and the different SW layers);

- On-board ATO functionality, starting with GoA2;

- Train localization, including GNSS, digital mapping, according to LOC interface definitions;

- Ground connectivity (e.g. FRMCS) in relation to train and UVCC bus networks.

The first development step should allow to have a systematic overview of the actual technical readiness of tested prototypes to assess the opportunities for industrialization of different OCORA building blocks and design concepts.

The MVP should allow to assess and prove:

- System functional and operational behavior;

- System performance;

- Modularity supporting capabilities of interfaces (between modules and subsystems including trackside and on-board);

- Interchangeability capabilities between components and modules (e.g. different suppliers, different technologies);

- Capability of the CCS on-board sub system to adapt to heterogeneous external interfaces (reduced impact, use of the functional vehicle gateway);

- Maturity of integration and validation as well as deployment and configuration processes (e.g. activities, roles, means and tools);

- Maturity of modular safety (demonstration, roles, means/tools) and cyber security processes and solutions (demonstration, roles, means and tools);

- Maintainability (including methods and tools);

- Scalability by including upgrades while prototyping (e.g. GoA and ERTMS level upgrades or the transition from GSM-r to FRMCS).

Test environments include rolling stock simulation, trackside systems simulation and all necessary simulators requested by the modules listed above and under evaluation. At the end of the first step, a comprehensive simulation environment is targeted, defining a functional reference for testing respectively the CCS on-board, CCS trackside and TMS modules.

OCORA targets to achieve a systematic monitoring of the technical readiness of OCORA modules (building block) and to start operational demonstration of OCORA MVP performance and capabilities in real network operation from 2025. The intended development planning, prototyping and testing of the OCORA MVP, including dependencies, is tentatively represented in **Figure 2**.
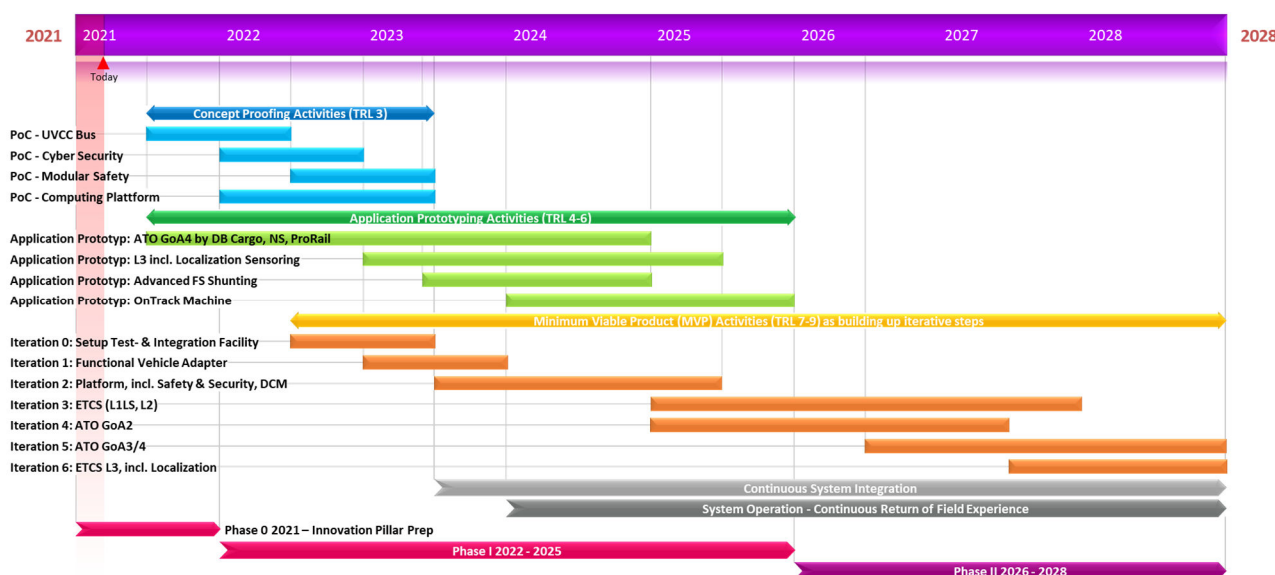

Figure 2 - OCORA proposed activities for Innovation Pillar (under construction)

OCORA furthermore offers to act as facilitator to identify opportunities for integrating new solutions in prototypes, and help identification of synergy between projects. OCORA aims to generally develop and steer the coherence and consistency of continuous prototyping and integration activities of the sector. As a result, a rapid and stepwise enhancement of both the performance and technical readiness of CCS on-board solutions and digital rail system solutions as a whole, will be enabled.

4 Cross-fertilizing ER JU System and Innovation Pillars

4.1 Business Rationale - Relevance of OCORA for ER JU and vice versa

For the last four decades, the railway community has attempted to forge the heterogeneous European rail network into one single and interoperable transportation system. Where power supply and gauge effectively ceased to be barriers for integration, CCS and operational rules remain persistent obstacles. These obstacles need to be rapidly removed to reinforce the competitive edge of the European railways and industry, and to establish a reliable, interoperable and sustainable European transportation system. That is why harmonisation of CCS and operational rules spearhead the innovation calendar of S2R and its successor, ER JU. OCORA specifically supports this drive regarding on-board CCS and therefore strongly supports the ER JU effort to look at a unified operational concept and functional architecture while at the same time demonstrating performance of new technological solutions.

ERTMS is identified as the IT backbone to drive automation and digitalisation of the European rail network. The implementation of game changing technologies like ATO and FRMCS depend on a successful roll out of ERTMS. OCORA, together with RCA, thoroughly share these objectives. Unfortunately, the approach and implementation processes to establish a truly interoperable and full size ERTMS deployment, do not yet adequately support the ambitions of the community. To drive forward the successful roll out of ERTMS and accommodate rapid railway innovation, OCORA proposes both a novel approach and a selection of key topics to break the current stalemate.

OCORA is convinced that migrating to a modular approach for (on-board) CCS equipment, based on the principle of plug and play exchangeability between modules, is vital for increasing market acceptance, cost efficiency, system performance and rapid adoption and implementation of innovations. OCORA intends to enable ERTMS roll out by formulating articulated, high grade user requirement specifications in successive releases. Each release envelops lessons learned and best practices from previous ones and their acceptance by the railway community, supporting a process of continuous improvement. As a result, OCORA can and will suggest priorities to be covered by the ER JU development agenda.

OCORA also acknowledges that successfully achieving its prime requirements and objective need careful balancing those with issues like handling of legacy, safeguarding a managed but agile evolution from one technology generation to the next, and legitimate business objectives and concerns of stakeholders. That is why OCORA also has developed an articulated collaborative strategy, focussed on coordinated migration via intense and constructive cooperation with the sector. From this perspective, this section will also provide ideas on how to constitute an effective ER JU organisational framework. The OCORA Problem Statement outlines in detail what the sector needs to overcome.

In a nutshell CCS On-board becomes the most important ERTMS rollout enabler once it is:

1. Cost efficient over the Lifecycle;
2. Easy to integrate and certify;
3. Upgradeable, and;
4. Modularity is given.

4.2 Achieving ER JU innovation objectives

OCORA understands an ER JU key guiding principle should be to support the establishment of SERA. European integration is impossible without (further) harmonization on an operational, technological and organizational level. ER JU is best placed to find solutions to today's lack of harmonization. A priority for the innovation agenda should be therefore, to resolve those harmonisation issues. As indeed is the case with operations and technology like CCS that has the potential to create green fields for new functionalities, therefore easy harmonisation paths.

Europe's Rail JU should allow that not the single partner perspective should prevail in the selection of innovation opportunities, but the wider, European perspective. This can be brought forward when developing and executing projects, concentrating on collaboration supporting the common business objective of achieving

SERA targets rather than answering to specific business needs of a single stakeholder.

OCORA believes that the fast achievement of interoperable CCS solutions requires the establishment of an open and agile development environment beyond the boundaries of normal market processes. The development process should be open and collaborative to support a communal search for promising innovations. The Single Basic Act already mentions different and interesting approaches, not only applying to railways but especially also those proposed for e.g. SESAR JU. New collaborative approaches are emerging, based on open innovation communities finding new paths to technology development. Examples can be found in e.g. the avionic, automotive or IT industries. **OCORA believes that ER JU is the one off opportunity for an environment allowing to explore new methodologies and tools for agile concept development, to prototype, test and align on new state of art rail approaches.**

4.3 Accelerating innovation within ER JU

Methods like reinforcement learning can bring swift results in the railway domain, provided innovation processes can be executed in an 'safe' environment, away from strict regulatory, legal, economic or competition constraints. OCORA therefore believes, that it could be worthwhile to decouple the product concept development process from the actual product development, as depicted in the picture below.
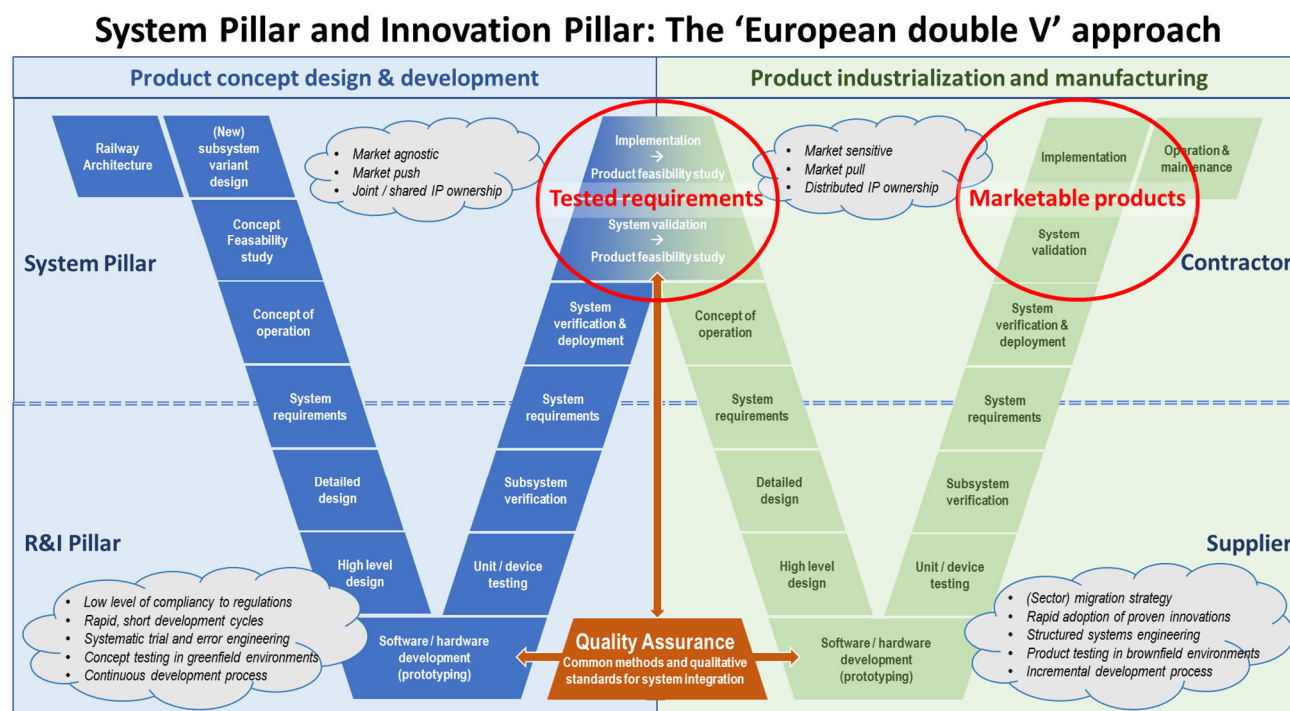

Figure 3 - OCORA suggestion for innovation acceleration and implementation

In an agile process of short cycle development of concepts, innovation concepts can be quickly analysed and processed. Unsuccessful concepts can be quickly discarded with, while proven innovations are developed into tested and approved prototypes that are ready for immediate industrialisation and manufacturing. The innovation process yields tested requirements which could instantaneously be embedded in the regulatory framework.

To ensure swift development, the concept development process has to be an open ecosystem where all stakeholders can take part and output is available for anybody. Since stakeholders are part of the innovation process, users can infuse their consolidated requirements where manufacturers can early detect potential market opportunities and start development of products while at the same time participating in the concerted and managed development of concepts. OCORA sees the interaction of stakeholders in the ER JU framework as an open development laboratory where demand and supply meet beyond the confines of market restraints and where products and services are developed in close collaboration.

OCORA proposes to explore and research such innovative approaches specifically in greenfield situations where there are no imminent commercial interests. Examples could be the harmonization of operational rules or the development of an ETCS 'Light' for yellow fleet, historical and vintage rolling stock, etc. When proven, the approach can be extended to other segments of the ER JU portfolio, specifically the CCS domain where the IT element is dominant, and a change of approach is necessary.

At the same time, OCORA has identified issues related to manage the evolution of products of harmonization like CCS. Currently, both regulations and technologies evolve rapidly but not necessarily in the same direction or at the same pace. Handling different subsequent technology generations simultaneously in an ever-changing regulatory landscape – specifically when compatibility between generations is required – and evolving customer requirements, substantially complicate migration management. OCORA thinks that the solution can be found in shared ownership of specifications and regulations, making migration a branch effort and not the interest of every single partner in that community.

4.4 Moving to Europe's rail digital industry

OCORA builds reference documentation in all openness. The objective should be to deliver qualified fleet owner requirements that favour good (off the shelf) products and services.

OCORA drives direct benefit (cost reduction for investment and maintenance). It is also an enabler for many improvements in the railway system (connectivity, digitalisation, automation, productivity). With a collaborative industry roadmap, supported by an executive sector governance for accelerating innovation, rail transformation can be the nominal path in Europe. This will require support from institutions, in particular ERA for setting a clear framework for system integration responsibilities. Today, with LinX4Rail, with ERA and in the future ER JU, OCORA proposes to develop the modularity framework driving migration agility. ER JU is expected to deliver a comprehensive toolbox that will support Europe's industry adapting to new technologies and new functions to the benefit of Europe's rail customers and industry.
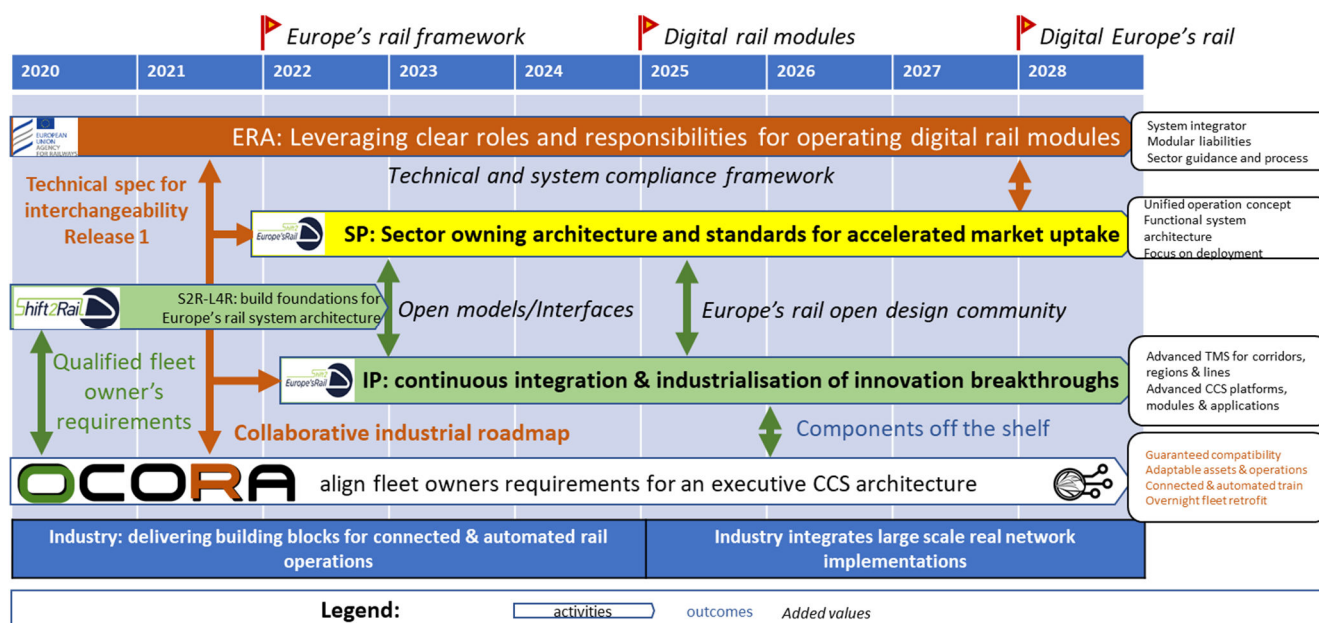

Figure 4 - Envisaged OCORA contribution to automation and digitalisation of Europe's rail network