OCORA

Open CCS On-board Reference Architecture

Methodology

Document ID: OCORA-BWS08-010

Version: 3.02

Date: 31.01.2025

Revision history

Version	Change Description	Initial	Date of change
1.00	▪ 1st Gamma version based on Beta incl. comments	RM	16-11-2020
1.10	▪ final for Gamma Release	RM	04-12-2020
1.20	▪ 1st Draft Delta version based on Gamma incl. comments	RM/TM	21-05-2021
1.30	▪ DRAFT version for Review	RM	17-06-2021
2.00	Official version for OCORA Delta Release	RM	25-06-2021
2.99	▪ DRAFT version for Review	RM	22-11-2021
3.00	Official version for OCORA Release R1	RM	26-11-2021
3.01	▪ Decoupled document from a specific OCORA release	TM	20-05-2022
3.02	▪ Editorial work in Introduction	LDL	24-01-2025

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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-BWS01-010 – Release Notes

[2] OCORA-BWS01-020 – Glossary

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

[4] OCORA-BWS01-040 – Feedback Form

[5] OCORA-BWS03-010 – Introduction to OCORA

[6] OCORA-BWS04-011 – Problem Statements

[7] OCORA-TWS05-010 – Requirements – Management Guideline

[8] OCORA-BWS08-020 – Tooling

Wherever a reference to a TSI-CCS SUBSET is used, the SUBSET is referenced directly (e.g. SUBSET-026). We always reference to the latest available official version of the SUBSET, unless indicated differently.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to provide the OCORA participants with an overview of the used methodology. It is and will remain a high-level document with the aim to ensure common approach and basis and also give the freedom of choice in all not defined areas to the workstream leaders to define appropriate processes, methodology and tools if required for the specific type of work foreseen.

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

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

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

1.2 Applicability of the document

This document is applicable for all OCORA workstreams. The OCORA Tooling [8] provides more insides on the toolchain used among the OCORA collaboration.

OCORA Methodology will be continuously revisited in order to serve the operating OCORA workstreams and proof sector compatibility with other ongoing sector initiatives (e.g. RCA, ER JU, LinX4Rail).

To serve the start of MBSE based modelling work, the interlinking between CENELEC, requirements engineering and MBSE modelling was investigated and defined.

1.3 Context of the document

This document is published as part of the OCORA release, together with the documents listed in the release notes [1]. It is the third release of this document which will be further developed in consecutive releases.

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 reading the Introduction to OCORA [5], and the Problem Statements [6]. The reader should also be aware of the Glossary [2] and the Question and Answers [3].

2 Best Practice

In the various workstreams, documents are created and compiled by geographically distributed teams. Each member of these teams has a different background and specific ideas and goals.

When developing a documentation in a topic specific workstream, the reviewing process must take place in parallel by the members of the workstream. This is to ensure that the document is developed in alignment with the ideas and goals of each team member.

While the workstream leader has the responsibility to compile the document (unless defined differently), the other workstream members provide input and constantly ensure that their respective organisation is in line with the major decisions taken by the team. This is to avoid major surprises during the final review process.

Documents that are submitted for final review shall be made available to the review team at least 2 weeks before the final review TELCO. The review comments are due at least 1 week prior to the final review TELCO. This allows enough time for the author to incorporate all review comments, using the change tracking mode and to forward a revised version to the review team. Review team members need to be in the possession of the revised document not later than 2 days prior to the final review TELCO.

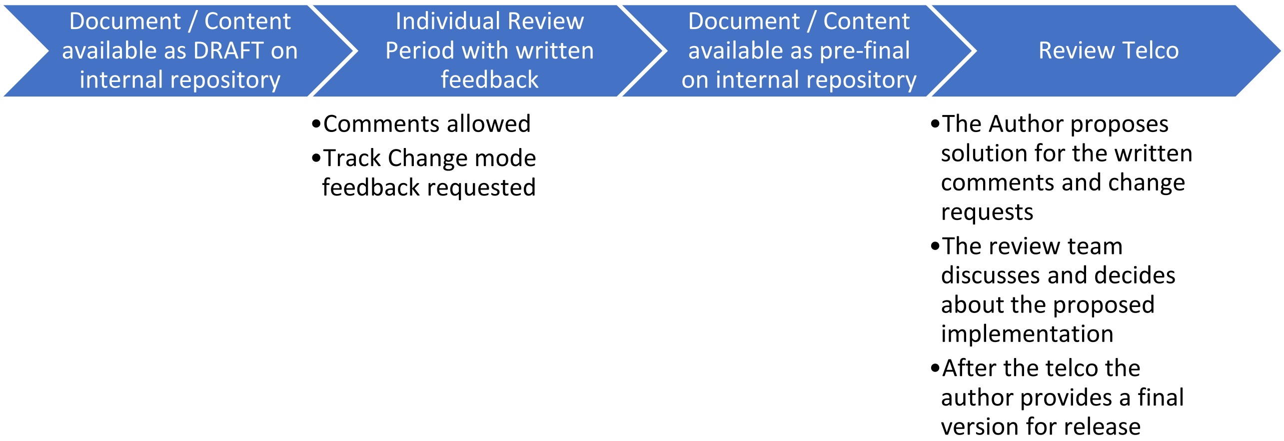

Figure 1 Best Practice Document Review

A final review cycle is very costly, especially in respect to the time needed. A minimum of 2 weeks is needed. Therefore, the workstream leader must make sure that documentation submitted for final review is in a perfect condition and workstream members have to ensure that their organisation's thinking is in line with the submitted documentation.

3 Polarion Review Process

OCORA has adopted Polarion as its Application Life-Cycle Management Tool covering quality assurance and requirements management. Polarion shall also be used to support the review process of Capella artefacts. See **Chapter 7** regarding Capella and Polarion integration.

The change management process is described in this chapter. On a high-level, Polarion artefacts - including Live-Docs - are reviewed following the below process:

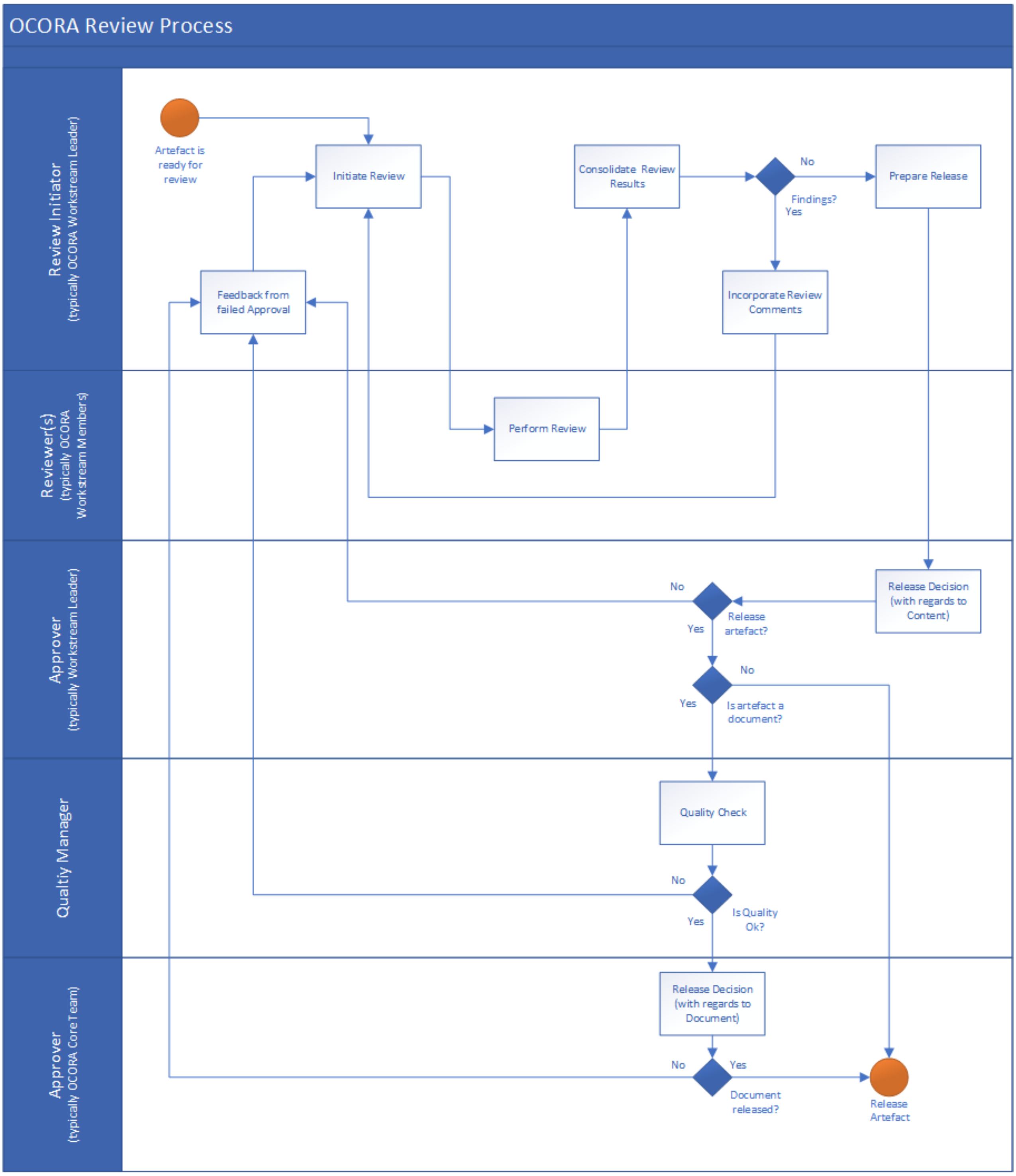

Figure 2 OCORA Review Process

3.1 Initiate Review

- The review initiator defines the persons that should participate in the review
- The review initiator ensures that all artefacts/Live-Docs have the needed quality to be reviewed.
- The review initiator ensures that all artefacts/Live-Docs to be reviewed have the state *In Review*"
- The review initiator provides all reviewers with the below information:
    - Artefacts/Live-Docs to be reviewed
    - Information regarding the role of the reviewer
    - If useful, the artefacts to be reviewed are split into logical groups and individual groups assigned to specific reviewers
    - Deadline for the review to be completed

3.2 Perform Review

- The reviewer reviews all assigned artefacts and provides its feedback in form of comprehensible comments on the specific artefacts/Live-Docs directly in Polarion.

3.3 Consolidate Review Results

- The review initiator checks at the end of the review period if enough reviewers have participated and if there are any findings.
- In case not enough reviewers have participated, he agrees with the reviewers if the review period should be extended.
- If there are no findings, the reviewer proceeds with *Prepare Release*, otherwise he continues with *Incorporate Review Comments*

3.4 Incorporate Review Comments

- The review initiator ensures that all artefacts that need updates based on review findings are moved back into state *Draft*
- The review initiator checks the findings and records necessary re-work as follows:
    - For every finding that requires an update, he replies to the corresponding comment indicating how the finding was addressed. Good practice is to start with "Done." followed by a short description.
    - For every finding that is not addressed, he replies to the corresponding comment indicating the reason why this finding was not addressed. Good practice is the start with "Ignored." followed by a short explanation.
    - For every finding that will be addressed at a later stage, he replies to the comment indicating that the finding will be considered at a later stage. Good practice is to start with "Postponed", followed by a short explanation on why addressing the finding was postponed.

3.5 Prepare Release

- The review initiator prepares the artefact/Live-Doc release (regarding content) and provides the necessary information to the Approver
- The review initiator ensures that the state of the artefacts/Live-Docs has been set appropriately e.g. *In Approval*
- The review initiator informs the Approver and ask for clearance of the respective artefacts/Live-Docs

3.6 Release Decision (regarding content)

- In case of a Live-Doc, the Approver checks the document following a document checklist. If the check is successful, the Approver forwards the document to the *Quality Check*
- In case of other artefacts, the Approver just changes the artefact state to *Approved*

3.7 Quality Check

- The quality manager checks that the document complies with the OCORA document requirements.
- If the document is compliant, it is forwarded for *Release Decision (regarding the document)*.
- If there are findings that need re-work, the findings are documented, and the document is sent back to *Feedback from Failed Approval*

3.8 Release Decision (regarding the document)

- The Approver performs a final check of the document, changes the document status to *Approved* and releases the document.
- If there is any issue with the document, the findings are documented, and the document is sent back to *Feedback from Failed Approval*

3.9 Feedback from Failed Approval

- The review initiator discusses the findings with the persons, that didn't approve the release. If necessary, the review initiator triggers the required re-work and changes the status of the artefact back to *Draft*.

3.10 Change Management Process

Change management occurs when an artifact has been released in an OCORA baseline and in a further one, has to be modified (e.g. connexion between "Release Artifact" and "Artifact ready for review) on **Figure 2**. There are two possibilities to request an official change:

1. Provide a comment on the dedicated artifact directly in Polarion (add a reference to the guide). This is mandatory for OCORA members who have access to Polarion,
2. Use the [4] OCORA-BWS01-040 – Feedback Form and then share it to GitHub (copy paste the content of the change process defined in [7] OCORA-TWS05-010 – Requirements – Management Guideline readme into the guideline) where each change can be identified through a unique ID.

4 OSI Model

OCORA decided to follow the OSI Layer protocol specification according the international standard ISO/IEC 7498-1:1994 and used within S2R X2R1 for Subset 143.

This protocol specification is divided into separate layers. Figure 3 shows the representation of the different layers according to the Open Systems Interconnection (OSI) model.

All OCORA developments shall be compliant to the end device interface characteristics as specified in Figure 3 OSI Layers in context of OCORA. This affects OSI Layer 1 – Layer 7.

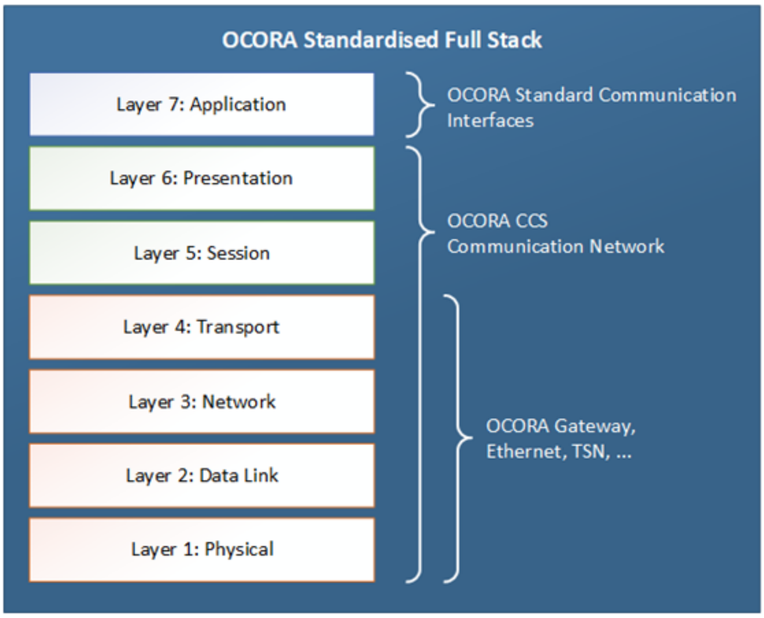

Figure 3 OSI Layers in context of OCORA

To achieve plug-and-play-like exchangeability of OCORA building blocks a fully standardised OCORA communication stack is essential. Standardised application interfaces are not enough - a harmonization of all layers is key.

5 Model Based System Engineering (MBSE)

Model-based systems engineering (MBSE), according to INCOSE, is the formalized application of modelling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases[1].

In contrast to most other engineering approaches, the MBSE methodology focuses on creating and evaluating domain models as primary means of information exchange.

To leverage nowadays system complexity in the CCS domain, OCORA as one of many others (e.g. EULYNX, RCA, S2R/LinX4Rail) decided to face this critical challenge in designing, managing, and optimizing by using Model Based System Engineering.

CCS on-board is a subsystem of the overall end-to-end railway command, control and signalling system; again, CCS on-board consists of many subsystems itself. This nested system of systems yields its own challenges when it comes to modelling parts within different railway initiatives.

[1] INCOSE: https://www.sebokwiki.org/wiki/Model-Based_Systems_Engineering_(MBSE)_(glossary)

The straightforward approach would be to model the entire end-to-end CCS system in one single model. However, following such an approach creates difficult dependencies between the different initiatives. In fact, proper subsystem modelling could only start once the team working on the overall end-to-end system had completed its Logical Architecture. Therefore, OCORA will deeply look into iterations, top-down and bottom-up approach and model separation in the upcoming Release 1.0

OCORA, in particular, with its focus on the overall onboard architecture aims to progress to a large extent independently of other initiatives whilst considering and synchronising with them at dedicated points in time.

The exact working model regarding MBSE is still under discussion. To a large extent this decision is driven by the collaboration model between LinX4Rail, RCA and OCORA and the transition of the initiatives into the System Pillar.

5.1 The Arcadia method

Ever-increasing expectations regarding functionality, safety, security, and performance of today's railway CCS systems, originating from different stakeholders, need to be managed and implemented in a structured and traceable way. The strength of any system is rooted in its architecture. The Arcadia method supports all required engineering activities that include analysing operational needs, structuring, and decomposing the system and considering constraints of existing standards and legislation as well as domain specific design objectives.

For the following reasons, OCORA has decided to use the Arcadia method for MBSE:

- Arcadia is a systems engineering method developed for safety critical subjects and therefore relevant in the context of OCORA
- The method is supported by a dedicated tool (Capella)
- Most founding members of OCORA are using the Arcadia method in their CCS projects already

Arcadia stipulates a viewpoint-driven approach (as described in ISO/IEC 42010) and emphasizes a clear separation of need and solution.

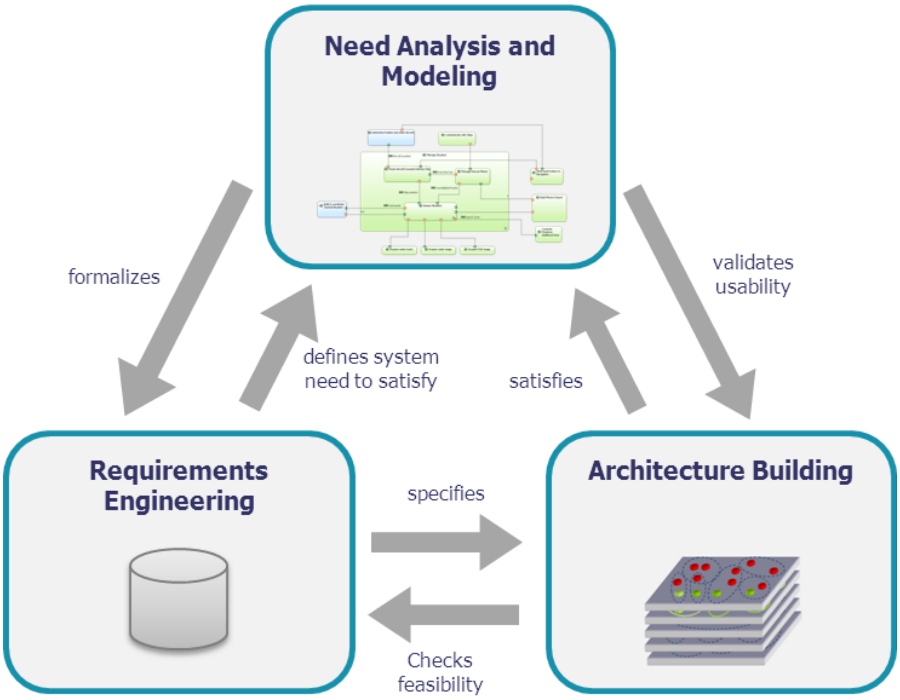

Figure 4 Viewpoint driven approach[1]

[1] Source : https://www.eclipse.org/capella/arcadia.html

Arcadia promotes four1 distinct perspectives:

- **Customer Operational Need Analysis** - definition of the Problem
  Focuses on analysing the customer needs and goals, expected missions and activities. It structures the need in terms of actors/users, their operational capabilities, and activities.
- **System Need Analysis** - formalization of system requirements
  Focuses on the System itself, to define how it will satisfy the compiled operational need - zeroing in on functions and its related exchanges, non-functional constraints (e.g. safety, security, etc.) as well as role sharing between system and actors.
- **Logical Architecture (Notional Solution)** - definition of solution architecture
  Aims at building a coarse-grained component breakdown of the system. This involves taking important engineering decisions which are unlikely to be challenged at a later stage. The system is decomposed into logical components, functions are allocated to components. This building process is where the majority of the OCORA design objectives and design rules will be considered.
- **Physical Architecture** - definition of solution architecture
  Makes the logical architecture vision evolve according to implementation, technical and technological constraints, and choices.

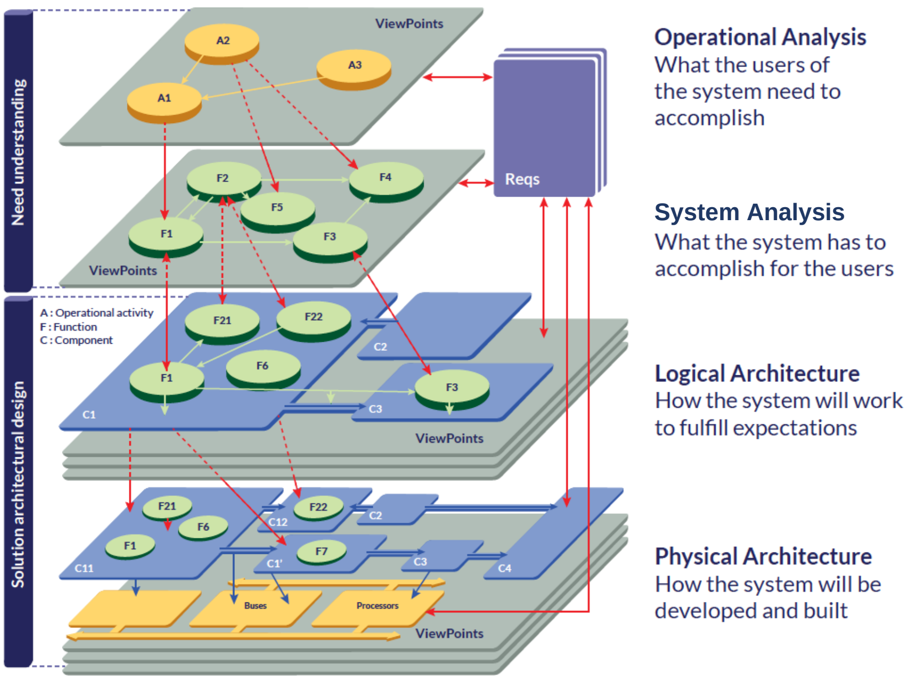

Figure 5 The four perspectives of Arcadia[2]

[1] Arcadia includes a fifth perspective regarding the Building Strategy. However, this perspective is currently considered to be out of scope of OCORA.
[2] Source : https://www.eclipse.org/capella/arcadia.html

6 OCORA in context of CENELEC

The main objectives of OCORA imply creating the preconditions for successful future product development – firmly based in prevailing EU regulations and notably the Technical Specifications for Interoperability or TSI's – that answer the needs and requirements of both the RU's[1] and the supply industry. In the relation to the supply industry, OCORA formulates the requirement specification that products and services on offer must comply with.

Requirements originate from:

- Prevailing Europe and national law and regulations, the development of which OCORA (notably the upcoming 2022 TSI CCS revision) intends to influence using the appropriate channels like ERA. These cover a wide array of functional and technical requirements.
- Business objectives of individual OCORA Members, translated into (mostly non-functional) harmonised requirements for procurement purposes.

With reference to standard systems engineering process modelling, OCORA aims at providing substantial generic artefacts to be used as input for specific CCS on-board projects. These artefacts include:

- The reference On-Board architecture including high-level CCS functions and their respective allocation to building blocks
- The apportioned non-functional requirements to the identified building blocks
- The detailed specifications of the required interfaces (on all OSI layers, ref. chapter 4)
- Applicable SRACs (Safety Related Application Conditions)

Individual building blocks are expected to become standardised, plug-and-play like exchangeable COTS products, offered by the supply industry.

Following that, any RU will be able to implement a OCORA compliant systems, based on the OCORA deliverables. The following figure shows the relation between the OCORA project (yellow area) and the future stakeholders involved in the implementation of such an OCORA compliant system.

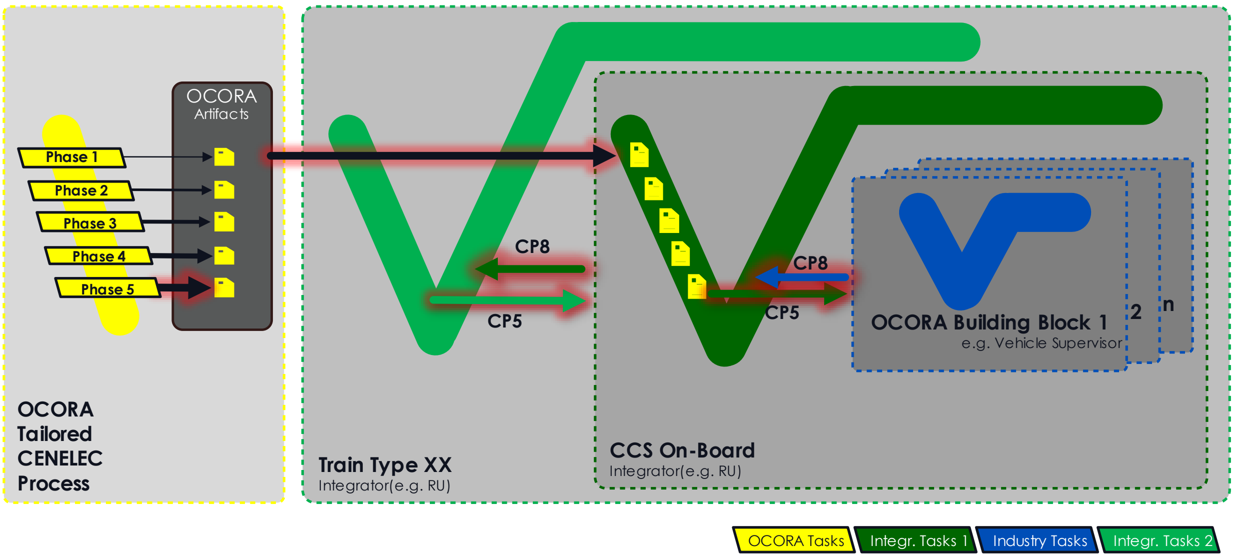

Figure 6 OCORA in context of the relevant projects

Figure 6 demonstrates the OCORA project (yellow area) with its deliverables (OCORA Artifacts) supporting a CCS On-board system integration project (dark green) with its artifacts.

The CCS On-board system consist of different subsystems and components (blue), which are integrated as part of the CCS On-board project (dark green). The CCS On-board is a subsystem of a train and needs to be integrated (dark green CP8 arrow) in another application (train level, light green).

[1] In relation to the vehicle authorization process the authors are aware that the term "RU" is inexactly applied.

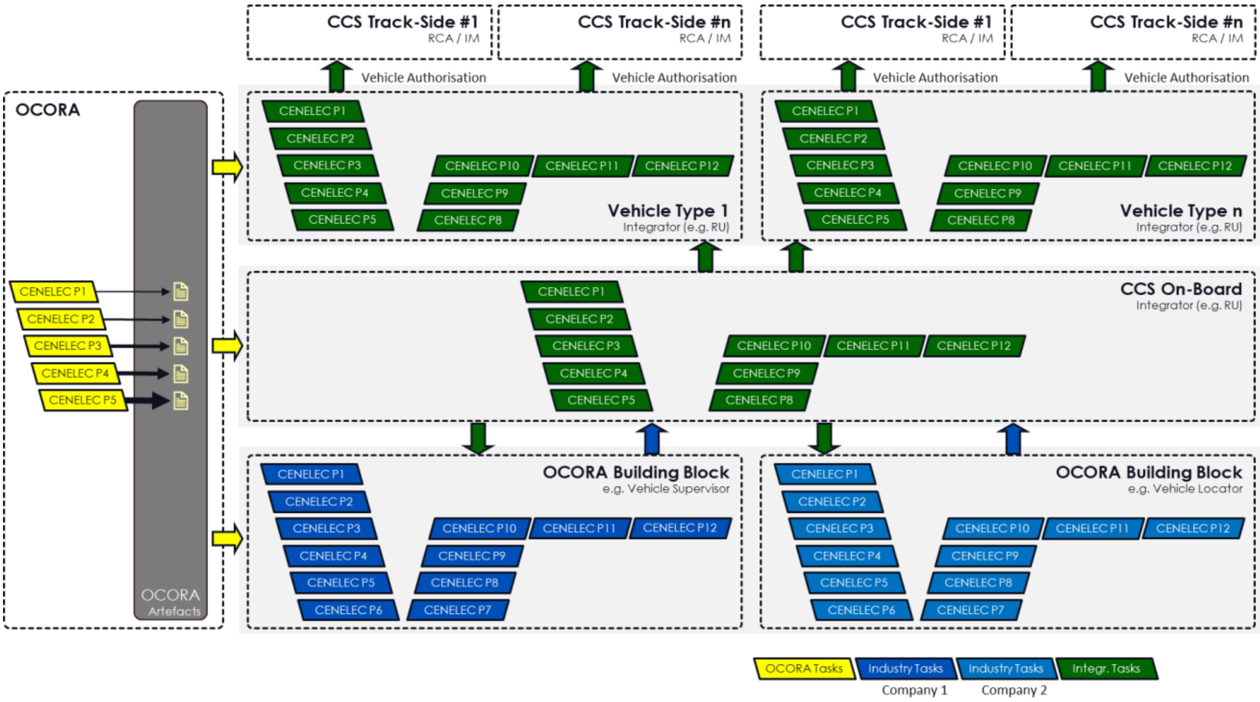

Figure 7 OCORA in context of the CENELEC V-cycles

For roles definition please take note of the Glossary [2].

The role of *OCORA* is to develop the reference CCS On-Board architecture. Using a structured CENELEC V-cycle approach (phases 1-5) warrants consistency, traceability and allows for reuse of certain artefacts in later CENELEC CCS On-Board implementation projects.

The role of the *Supply Industry* is to implement standardised OCORA compliant building blocks, configured according to the requirements provided by the integrators.

The role of the *Integrator* is to order and integrate all necessary building blocks to deliver a fully functional and certified OCORA-based CCS on-board system, using artefacts available from OCORA and complying with the specific *RU's* requirements.

Typically, the *Integrator* is also tasked:

- with the integration of the OCORA based CCS on-board solution into one or several vehicles and asked to achieve all mandatory certifications.
- to perform/support the mandatory vehicle authorizations, permitting operation of the vehicle(s) on specific rail networks / are of use.

The role of the *RU* is to task an *Integrator* to implement a certifiable OCORA-compliant CCS On-Board solution considering all *RU* specific requirements. Depending on the RU's capabilities and strategy it may take on certain integration and/or certification tasks.

7 Interlinking of Requirements Management and MBSE in context of CENELEC

OCORA prepares its deliverables to be compliant to the CENELEC process as defined within the international standard EN 50126. Ensuring CENELEC compliance throughout the full development process calls for definition of an organisation including e.g. quality, RAMSS, processes, etc, both on supplier and customer side. While Model Based System Engineering is foreseen as described in chapter 5.

As result of OCORA the gathered requirements among CCS On-board shall serve as input to tender templates for specific projects including return on experience form PoC’s, demonstrators, prototypes and later newbuild and retrofitting projects executed.

This chapter aims to define the interlinking of the methodologies used. In the following **Figure 8** the left hand side shows the OCORA foreseen CENELEC phases 1 to 5, including the requirements on levels A to D as defined in the Requirements Management Guideline, ref. [7]. The right-hand side shows the Arcadia / MBSE method including the layering Operational Analysis, System Analysis, Logical Architecture, Physical Architecture.

The following main interaction steps have been identified:

1. Based on A level “Stakeholder Requirements” the CENELEC Phase 1 “Concept” is developed
2. Based on CENELEC Phase 1 “Concept” and the Linx4Rail “System Need” definition the “Operational Analysis” and the “System Analysis” will be carried out from an end-to-end perspective lead by RCA supported from OCORAs CCS on-board subject matter experts
3. C level “System Requirements” are generated artefacts out of the two MBSE layers “Operational Analysis” and the “System Analysis” and are used as basis for the CENELEC Phase 2 “System Definition”
4. The subsequent CENELEC Phase 3 “Risk Analysis” and Phase 4 “System Requirements” are developed
5. Based on the two MBSE layers “Operational Analysis” and the “System Analysis” and the CENELEC Phase 4 “System Requirements” including all RAMSS aspects the “Logical Architecture” and the “Physical Architecture” are developed
6. D level “Building Block Requirements” are generated as artefacts out of the two lower MBSE layers “Logical Architecture” and “Physical Architecture”
7. Respecting the B level “Program Requirements”, the MBSE System Design output, the CENELEC Phase 5 “Architecture and Apportionment” collects the results
8. D level “Building Block Requirements” serve as input to tender templates for specific projects

Please note, the related tooling (Polarion, Capella) to perform these interaction steps can be found in the document Tooling, ref. [8].

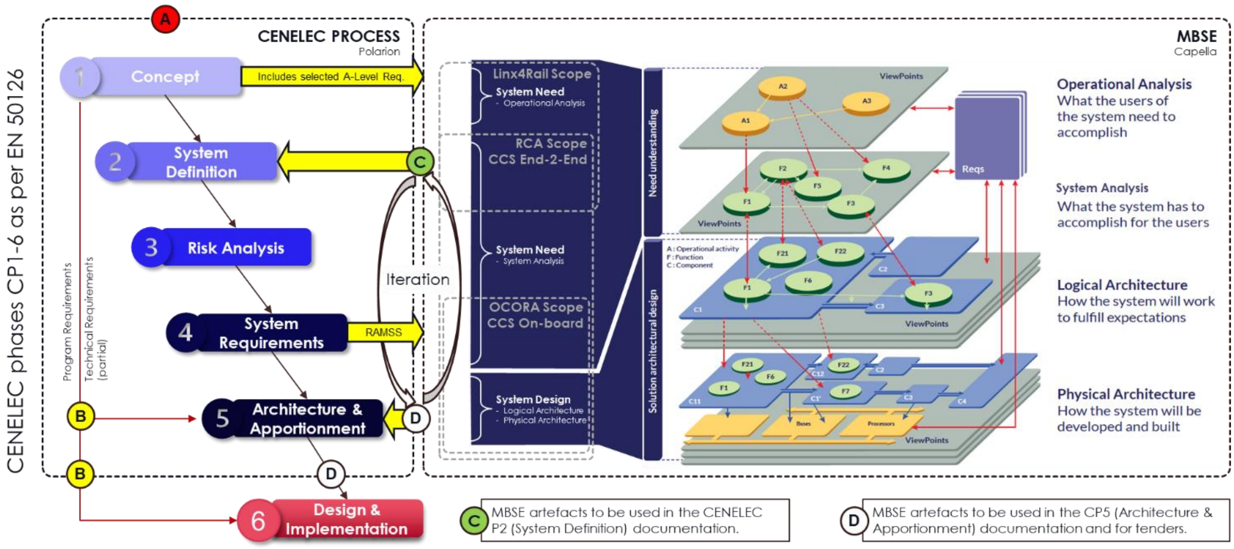

Figure 8 Interaction between CENELEC process and MBSE

The steps in **Figure 8** are shown as strict sequence, in reality the activities are foreseen as iterative parallel activities.

Appendix A OCORA Activities in CENELEC Phases 1-5

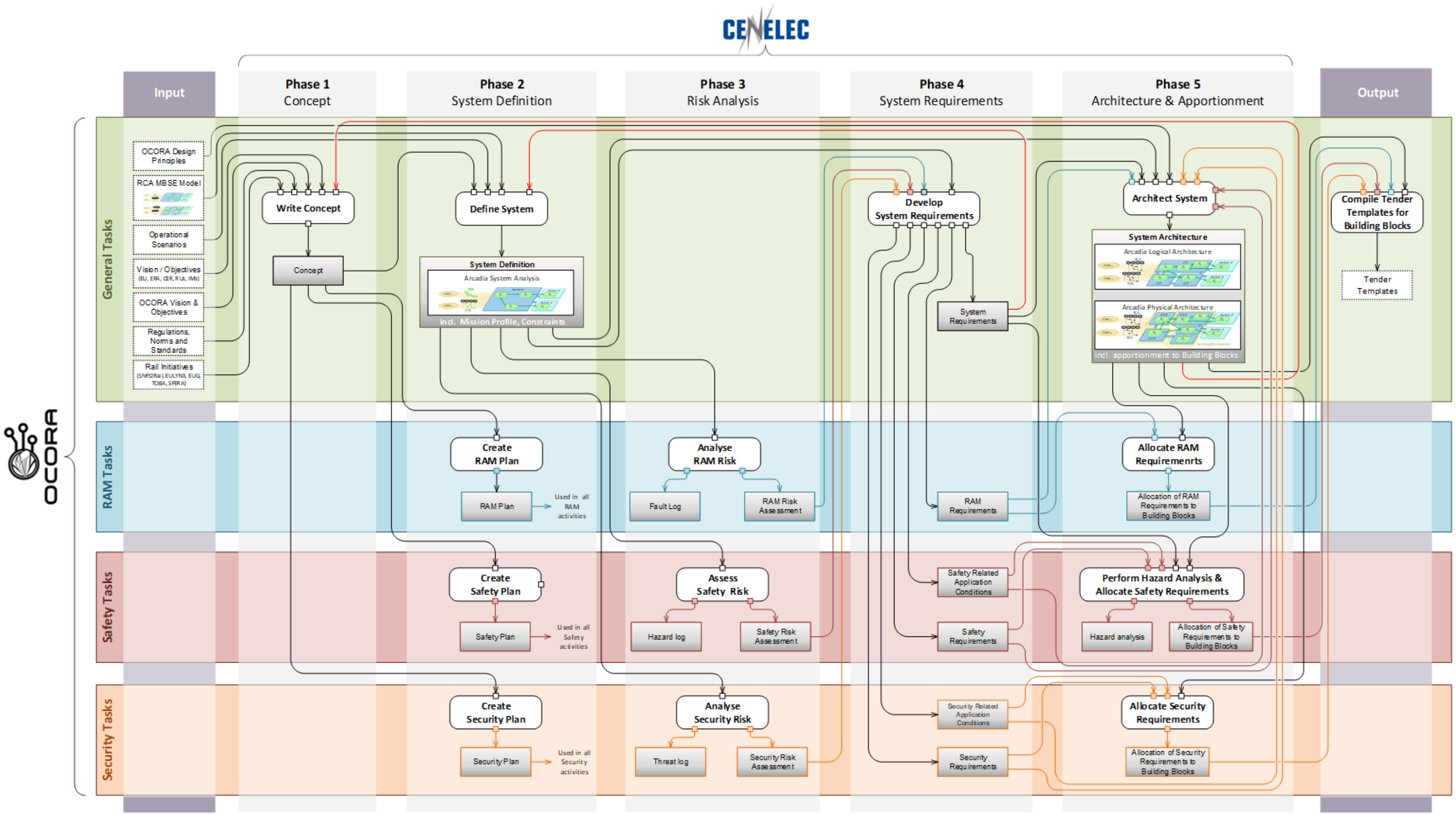

Figure 9 OCORA activities in CENELEC Phases 1-5

To define the open CCS on-board reference architecture, the OCORA initiative plans to follow the CENELEC process and run through the first five phases. This approach generates artefacts that shall ease and fast-track future CCS on-board system implementation projects. It shall also deliver interface specifications along with tender templates to facilitate sourcing of OCORA building blocks.

Throughout the execution of the 5 CENELEC phases OCORA will execute tasks in four major domains. In the above diagram, white boxes with round edges show activities, grey boxes depict artefacts being produced.

- **General tasks** including writing the system concept, using MBSE for the system definition, developing formal system requirements and using MBSE to specify the reference system architecture. Finally compile interface and building block specifications that can be used for tendering.
- **RAM tasks** including the creation of a RAM plan, performing the RAM Risk analysis and allocate the RAM requirements to the individual building blocks of the reference architecture.
- **Safety Tasks**, creating the safety plan, assessing the safety risks, performing a hazard analysis and allocate the safety requirements to individual building blocks of the reference architecture.
- **Security tasks**, compiling a security plan, analysing the security risks and allocate the security requirements to individual building blocks of the reference architecture.

Input to all OCORA activities originate on one hand from rail initiatives (Shift2Rail, EULYNX, EUG, TOBA, SFERA), from regulations, norms, and standards, from the RCA MBSE model as well as from operational scenarios.

On the other hand, OCORA Visions and Objectives along with Visions and Objectives of other stakeholders like EU, ERA, CER, etc. are considered and OCORA design principles applied when specifying the open CCS on-board reference architecture.