OCORA

Open CCS On-board Reference Architecture

Testing Strategy

Guideline for Modular Testing

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Management Summary

Considering integration & testing activities, this document synthetizes the high-level requirements and related guideline applying to "OCORA compliant" CCS development and deployment projects.

This guideline defines a structured approach mirroring the OCORA modular architecture where responsibilities are defined at each level of integration.

In short, the purpose of this guideline is to propose a high-level Testing strategy that addresses the top-level requirements of the OCORA architecture up to the acceptance to:

- From a quality assurance perspective, improve industrial and operational readiness.
- From a regulatory perspective, reduce the cost and delay of compliance assessment with the regulatory framework

This strategy shall cope with the different aspects / properties of OCORA (openness, modularity, exchangeability, migration readiness, evolvability, portability and safety).

This strategy shall foresee the future ecosystem of the different stakeholders (manufacturers of building blocks, integrator, railway undertakings, …): it should aim to shape the roles and responsibilities of the different stakeholders regarding integration and testing. In that context, it should define what would be the integration / validation / acceptance process to be applied to the different constituent parts (building blocks) of OCORA (provided by different suppliers). Focus will be done on the specific approach/items induced by OCORA in a further version.

Revision history

Version	Change Description	Initial	Date of change
1.01	Official version for OCORA Delta Release	SCA	30.06.2021
2.01	Official version for OCORA Release R1	JBO	03.12.2021
3.01	Official version for OCORA Release R2	AL	08.06.2022
4.00	First version for OCORA Release R3	AL	20.09.2022
4.01	Official version for OCORA Release R3	EC	16.11.2022

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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-BWS03-010 – Introduction to OCORA

[6] OCORA-BWS04-010 – Problem Statements

[7] OCORA-TWS01-030 – System Architecture

[8] OCORA-BWS08-020 – Tooling

[9] OCORA-TWS06-020 – (Cyber-) Security – Guideline

[10] OCORA-TWS07-010 – Modular Safety – Strategy

[11] OCORA-TWS07-020 – Evolutions Management

[12] OCORA-TWS04-010 – Functional Vehicle Adapter – Introduction

[13] OCORA-TWS04-011 – Functional Vehicle Adapter – Requirements

[14] OCORA-TWS04-012 – Functional Vehicle Adapter – Standard Communication Interface Specification

[15] OCORA-TWS04-013 – Functional Vehicle Adapter – Design Guideline

[16] OCORA-BWS08-010 – Methodology

[17] OCORA-TWS09-020 – Testing strategy requirements

[18] OCORA-TWS09-050 – Cybersecurity testing strategy

1 Introduction

1.1 Purpose of the document

This document is addressing the "testing strategy" as a whole (i.e. testing for integration, verification, validation and acceptance) for OCORA.

The purpose is to propose a high-level Testing strategy that addresses the top-level requirements of the OCORA architecture up to the acceptance in order to:

- From a quality assurance perspective, improve industrial and operational readiness.
- From a regulatory perspective, reduce the cost and duration of compliance assessment with the regulatory framework

This strategy shall cope with the different aspects / properties of OCORA (openness, modularity, exchangeability, migration readiness, evolvability, portability and safety).

This strategy shall foresee the future ecosystem of the different stakeholders (manufacturers of building blocks, integrator, railway undertakings, …). It should aim to shape the roles and responsibilities of the different stakeholders regarding integration and testing. In that context, it should define what would be the integration / validation / acceptance process to be applied to the different constituent parts (building blocks) of OCORA (provided by different suppliers). The focus will be on the specific approach/items induced by OCORA.

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 will gain insights regarding the topics listed in chapter 1.1, and 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 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 standard, information provided in this document can be used as input for your development.

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 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].

1.2 Applicability of the document

The document is currently considered informative but may become a standard at a later stage for OCORA compliant on-board CCS solutions.

1.3 Context of the document

This document is published as part of the OCORA Delta release, 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 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 High level integration and testing requirements

The following requirements are formalized in [17].

The reference for all requirements is Polarion tool and its extracted document for testing. In addition, in [17], the requirements are allocated to the testing and integration level that are defined in 3.2.

2.1 Scope and Capabilities of the Integration and Testing

The Integration & Testing Strategy shall allow to integrate, verify and validate the system under consideration of the OCORA collaboration which is CCS Onboard subsystem (CCS-OB), as well as its internal and external interfaces. The Testing Strategy shall particularly focus on the parts of the CCS-OB for which OCORA gives a high level of specification including for the functional requirements ("OCORA core" scope).

The Integration & Testing Strategy shall also consider the peripheral devices and connectivity devices which are part of the CCS-OB for which OCORA only provides interface specifications, high-level functional requirements, and non-functional requirements (basically, all requirements and specifications needed to ensure "plug & play"-like exchangeability).

The Integration & Testing Strategy shall also allow to integrate, verify and validate the part of the Train Adapter (TA, which is itself a part of the Physical Train Unit) for which OCORA aims at providing requirements, a standardized interface specification, and design guidelines. Currently, OCORA works on the specifications of the Functional Vehicle Adapter (FVA), which is a central part of the TA (refer to [12], [13], [14] and [15] for more details).

The Integration & Testing Strategy shall allow to verify and validate the modularity properties of the CCS-OB and the TA as defined in [7].

The Integration & Testing Strategy shall allow to verify and validate that the building blocks within CCS-OB and the TA support the whole functional scope of OCORA, for all grades of automation.

The Integration & Testing Strategy shall address cybersecurity issues: depending on the security category of the application, building block or subsystem, Testing activities may be needed to check that the cybersecurity requirements have been correctly fulfilled (refer to [9] and [17] for more details).

The Integration & Testing Strategy shall take into account that the configuration for a specific implementation is open and may include only a subset of the building blocks or components: Testing Strategy shall be able to address these different scopes of functionality, while remaining consistent and complete in regards with the building blocks and components implemented.

The Integration & Testing Strategy shall take into account that the functionality of some of the hardware components may vary.

Note: the number and the functional behavior of the CCUs can differ for the various implementations, depending on the RU's need. For migration reasons, multiple CCUs may be needed, or certain functions can be deployed on one node (e.g. safe functions) while others (e.g. non-safe) are deployed on a separate node. In some projects, additional CCUs may be used to increase availability and reliability by defining one or multiple CCU nodes as fail over or standby units.

The Integration & Testing Strategy shall define system tests that are composed of several test types that are used to verify different categories of requirements:

- Functional tests: these tests shall demonstrate that the test object fulfills the functional requirements and interface specifications assigned to this test object. These tests include ERTMS tests (e.g. Subset 76).
- Safety tests
- Non-functional tests: performance tests, Maintainability tests, Environmental (climate, EMC) tests, Load tests, Stress tests, Endurance tests
- User tests: testing by end users who perform specific tasks under real-life conditions
- Cybersecurity tests (refer to [17] for more details)

Note: the need for environmental (climate, EMC) system tests is induced by the fact that the integrated pieces of equipment are only individually validated in terms of environmental requirements.

The Integration & Testing Strategy shall consider degraded modes for each kind of test type defined above.

The Integration &Testing Strategy shall allow system tests to be classified into two categories, depending on where and how they can be performed:

- Factory Acceptance Tests
- Site Acceptance Tests

The Integration & Testing Strategy shall define the different levels of integration, verification and validation (like system test, sub-system test, component test…).

Beside other topics addressed by other workstreams (e.g. safety activities also requiring verification, cyber security requiring analysis and technical/architectural solutions…see [9] and [10]), the scope of the current "Testing strategy" document is to address integration and testing either in factory or on site as depicted on the sketch below.

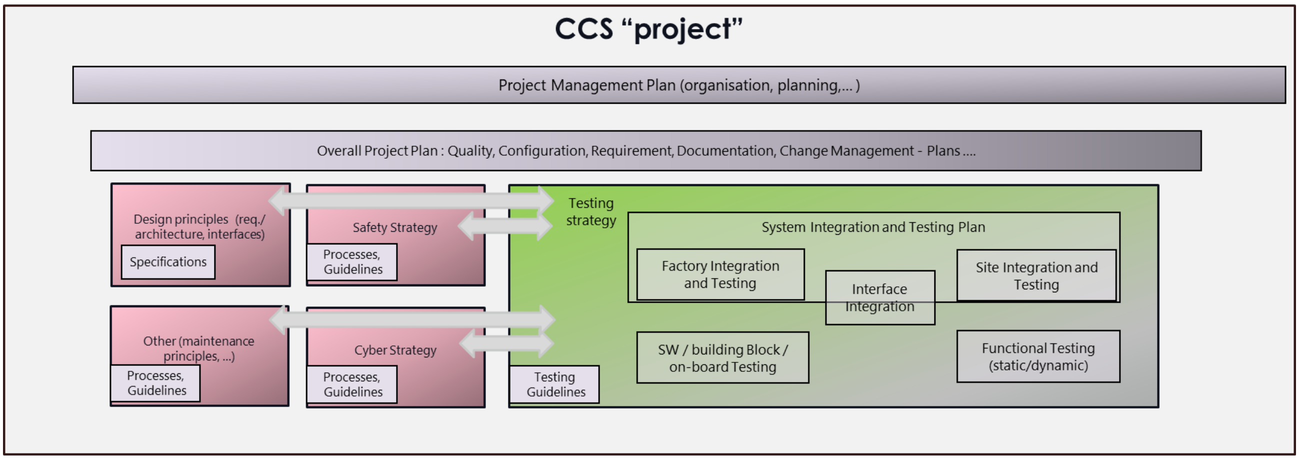

Figure 1: Scope of the Testing Strategy and interaction with other workstreams

2.2 Actors, Process and Methods

In this section of the present guideline, the aim is to clarify the "who", the "what" and the "how".

Therefore, a particular focus is proposed on the Actors ("who is in charge of what"), the process (which activities, in which sequence…) and the methods (how it shall be done). Specific requirements are proposed on these items:

- The Testing activity shall start as early as possible in the process.
- Early testing steps shall be proposed.
- The requirements shall be mastered (and their releases) during the whole cycle of development and validation.
- The Testing documentation shall be well structured down to test cases.
- The Interface Integration Plans for each interface shall be well structured (according to each interface) and mastered with clear steps (what/how/who…).
- The Interface Integration Plans shall be converged between all stakeholders involved.
- Each milestone of the Integration & Testing process shall be clearly defined.
- The Integration & Testing effort shall be adapted accordingly to the needs of each step.

- The risk of having many actors /many tools… shall be reduced by having a common environment (e.g. MBSE and its Testing) where specific tools are limited to stakeholders' specific activities.
- A system integrator (or system integrators but with an overall system integrator above) shall be designated.
- A clear process for bugs/anomaly tracing until corrections are made (among the different stakeholders) supported by ad hoc tools shall be proposed.
- When possible, safety demonstration shall also rely on additional and complementary methods, other than test and validation (use of formal method for instance).
- The Integration & Testing Strategy shall lead to a minimal effort in case of an update of a component:
    - Software update
    - Addition of a new CCS-OB – vehicle interface
    - Addition of a new building block (e.g. ATO-OB for ATO)
    - Replacement of a building block (e.g. replacement of LOC-OB due to a change of localization sensors – VLSs - or localization component - VL)
    - Replacement of an adapter (e.g. FVA replaced)
    - Addition of a new peripheral device (e.g. BTM, LTM…)
    - Hardware exchange (e.g. new processor)
    - Cybersecurity upgrade (refer to [17] for more details)
    - (…)
- The Integration & Testing Strategy shall be organized in well-defined successive and complementary steps.
  An example is given below:
    - Integration and testing of the HW (operating system test cases, bus communication test cases: load and performance tests)
    - Integration of the runtime environment (testing of the interfaces between OCORA runtime environment and vehicle apps by using vehicle app simulators)
    - Integration of CCS-OB building blocks (overall and operational use cases with trackside simulated), with simulated peripheral/connectivity devices and then real devices
    - Integration of a CCS-OB to a reference vehicle with trackside simulated, real balises and run basic ERTMS functions on a test track and a set of operational use cases
    - CCS-OB and Interoperability with Trackside in Lab
    - Test Reference Vehicle on Reference Track: interoperability on reference track with real trackside

  Note: the example given above has to be confirmed and defined later. The integration levels described may not always be performed sequentially. Parallel execution is allowed.
- The Integration & Testing Strategy shall define for every level of integration, verification and validation the appropriate verification and validation methods (e.g. review, inspection, black-box testing…) to be used.
- For each level of integration, verification and validation, a report containing the proofs that the required testing activities have been correctly carried out shall be provided by the actor in charge of this level.

2.3 Tools and Environment

In this section of the present guideline, the aim is to specify high level requirements on “tooling” and testing environment. Particular tools will be chosen within the corresponding Integration and Testing plans.

- The Testing Strategy shall rely on a test environment automized as far as possible.

  Note: especially in the first steps of integration (then manual testing may be needed in case of use of real peripheral devices).
- A powerful test environment allowing configuration testing, degraded modes…shall be available.
- A “reference” test environment shall be proposed and mastered.
- The Testing Strategy shall rely on a flexible line representation, where all particular and relevant configurations can be added.
- Early verification and validation using model-in-the-loop simulation shall be foreseen.
- The test environment shall support model-in-the-loop (1), software-in-the-loop and hardware-in-the-loop testing.

  (1) This also depends highly on the tools/methods used for system/subsystem definition (see [8]): the usage of formal or semi-formal language in specification and design phase shall help to reduce the overall test and safety demonstration effort.
- The test environment shall support easy re-use of test-cases between model-in-the-loop, software-in-the-loop, hardware-in-the-loop and vehicle testing.
- A common reusable set of scenarios shall be maintained with an incremental approach at each system release.

3 Integration and testing strategy guidelines

3.1 CCS Integration Verification Validation (IVV) activities

Each of the IVV activities contains technical and non-technical activities.

Technical activities of the IVV steps are the “Testing” activities: tests are needed during each of the IVV steps to prove that the system under test fulfils the objectives of this IVV step. On one hand, tests should confirm the correctness of the tested functions and properties, and on the other hand, possible errors should be detected. For this purpose, test cases are to be defined in such a way that as many errors as possible can be found and tests can be carried out as efficiently and automatically as possible. Nature and specification of these tests differ depending on the IVV step (Integration, Verification or Validation for a given life cycle phase) to which they are associated. Checks performed during the tests can be automatic or manual and are the checks associated to the “T” (Test), the “D” (Demonstration) and some of the “I” (Inspection: the ones that require a test scenario) of the IADT classification.

Non-technical activities are related to quality management, review of documentation, process compliance checking, safety activities, proof by analysis (“A” of the IADT classification) or inspection (“I” of the IADT classification that do not require any test scenario).

A full definition of the IVV activities can be found in the CENELEC documentation EN 50126-1 as well as in CCS TSI. Some basics are reminded hereunder. More details will be given in the OCORA Safety Plan (provided after the Delta release).

Verification tasks are included within each life cycle phase, whereas validation tasks are only undertaken in Phase 4 “Specification of system requirements” and Phase 9 “System validation”.

3.1.1 [Prerequisite] Traceability

A fundamental prerequisite for checks is the identifiability and traceability of relevant elements and units of all abstraction levels in all phases of the development process. This starts with the classification and identification of relevant elements and units as well as their change and configuration management. This leads to the mapping of classifiable relationships between relevant elements and entities. They exist in the context of application development and variants, in the context of versioning as well as in the context of generic developments. Without the implementation of identifiability and traceability in the development process, the application of checks in the sense of the standards is hardly possible.

3.1.2 Integration

The subsystems or components are specified or designed according to the top-down principle and integrated according to the bottom-up principle. During the integration activities, subsystems or components are assembled and installed to form an integrated system of higher level. Tested software components are to be combined step by step and systematically into larger units or with their target hardware and tested as a composite in each case. Finally, the embedded system is to be integrated into its target environment at common interfaces.

Integration activities shall demonstrate that these subsystems or components work correctly together as defined by the interfaces: they interact correctly as specified in the interface specifications to perform their intended function.

3.1.3 Verification

Verification activities provide inputs to the validation activities. They intend to demonstrate that the specified requirements have been correctly implemented and are fulfilled.

Verification determines the correctness of individual development steps. This involves assessing whether the task of the higher-level abstraction has been developed correctly and consistently. The evaluation of the results must be carried out phase by phase, up to the design of the software components. After implementation or code generation, the freedom from errors of the developed software must be demonstrated by testing the components, from step-by-step integrated software to the fully integrated system.

Verification means to answer the question **“have we built it correctly?”**

Depending on the required safety integrity level, the methods to be used are specified by the EN50657 resp. EN50128 standard. Different methods, tools and techniques may be used, including testing.

Testing activities are under the responsibility of the Testing team TWS09 whereas non-technical verification activities are under the responsibility of the CENELEC documentation team TWS01-WP09.

3.1.4 Validation

Validation activities intend to demonstrate that the system under consideration meets the needs of the customer and other identified stakeholders for the intended use or application.

First, the results of the verifications as well as the component tests and integration must be checked. The conformity of the development results with the requirements specification must be traced and evaluated. The focus is on functions and properties according to the assigned safety integrity level. This includes additional tests that include complex scenarios for stressing the system and reflect the actual requirements of the application in the target environment.

Validation means to answer the question **“have we built the correct thing?”**

Depending on the required safety integrity level, the methods to be used are specified by the EN50657 resp. EN50128 standard. Different methods, tools and techniques may be used, including testing.

Validation activities address functionalities related to safety and not related to safety.

Testing activities are under the responsibility of the Testing team TWS09 whereas non-technical validation activities are under the responsibility of the Modular Safety team TWS07.

3.2 CCS Integration and Testing activities sequencing

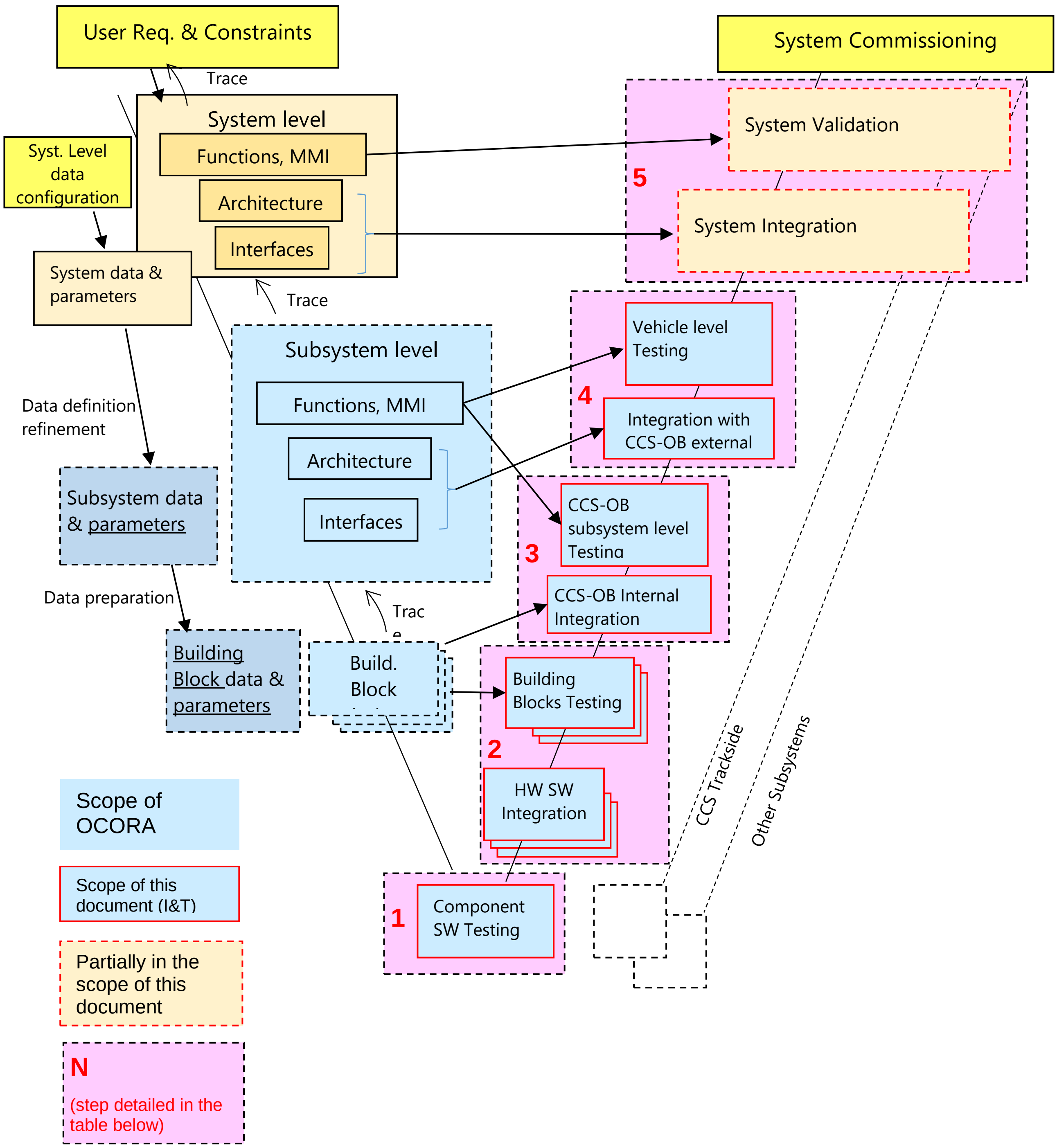

Figure 2: Integration and Testing activities sequencing

Integration, Verification and Validation steps for the Testing activities are detailed below:

Note: in following section, “Factory” is equivalent to “Laboratory”: factory tests are all the tests that are not performed on site.

Level	Activity	Scope	Documentation	Factory /Site	Responsible
0 - Platform Level	Qualification (HW/low SW level)	*Not further addressed in this document and not displayed on the figure above.*	Qualification plan	Factory	Platform Supplier (HW)
1 - Component Level	SW Testing	Component SW (configured applications) are tested individually (Verification and Validation).	Component SW Test Plan	Factory	Component Supplier (SW)
2 – OCORA Core Building Block level	Integration	SW of the n Component(s) that are part of one same OCORA Core Building Block are integrated together. Integration with one or several HW is also performed at this step.	OCORA Core Building Block Integration Plan	Factory	Component Supplier or On-board CCS Integrator (if n>1 and several Component Suppliers) NB: Component Supplier can be different from Platform

Level	Activity	Scope	Documentation	Factory /Site	Responsible
	Testing	OCORA Core Building Blocks (configured) are tested individually (Verification and Validation). **<u>Compliance with OCORA requirements:</u>** The tests performed shall at least cover the "Building Block Requirements" (D-Level requirements) specified by OCORA. These tests may be partially or totally specified by OCORA (in this case, the responsible of the testing activities at this level shall use these test specifications). If not available or if not complete, the tests shall be designed by the responsible of the testing activities at this level 2. These tests only partially cover the functionalities of the Building Block: in fact, they are mainly interfaces oriented (D-Level requirements ensure interoperability but are quite limited on functional level). Therefore, additional tests are needed to verify and validate the implementation choices made by the supplier(s) that are not specified at OCORA level.	OCORA Core Building Block Test Plan		Supplier (e.g. Digital Map, AV…)
2 – Peripheral or Connectivity Block level	Integration	SW of the n Component(s) that are part of one same Peripheral or Connectivity Block are integrated together. Integration with one or several HW is also performed at this step.	Peripheral/Connectivity Block Integration Plan	Factory	Peripheral/Connectivity Device Supplier

Level	Activity	Scope	Documentation	Factory /Site	Responsible
	Testing	Peripheral and Connectivity Blocks are tested individually (Verification and Validation). **<u>Compliance with OCORA requirements:</u>** The tests performed shall at least cover the "Building Block Requirements" (D-Level requirements) specified by OCORA. These tests may be partially or totally specified by OCORA (in this case, the responsible of the testing activities at this level shall use these test specifications). If not or if not complete, the tests shall be designed by the responsible of the testing activities at this level 2. These tests only partially cover the functionalities of the Building Block: in fact, they are mainly interfaces oriented (D-Level requirements ensure interoperability but are quite limited on functional level). Therefore, additional tests are needed to verify and validate the implementation choices made by the supplier(s) that are not specified at OCORA level.	Peripheral/Connectivity Block Test Plan		
2 – Train Adapter Block level	Integration	SW of the n Component(s) that are part of one same Train Adapter Block are integrated together. Integration with one or several HW is also performed at this step.	Train Adapter Block Integration Plan	Factory	Train Adapter Block Supplier

Level	Activity	Scope	Documentation	Factory /Site	Responsible
	Testing	Train Adapter Blocks are tested individually (Verification and Validation). **<u>Compliance with OCORA requirements:</u>** The tests performed shall at least cover the "Building Block Requirements" (D-Level requirements) specified by OCORA. These tests may be partially or totally specified by OCORA (in this case, the responsible of the testing activities at this level shall use these test specifications). If not or if not complete, the tests shall be designed by the responsible of the testing activities at this level 2. These tests only partially cover the functionalities of the Building Block: in fact, they are mainly interfaces oriented (D-Level requirements ensure interoperability but are quite limited on functional level). Therefore, additional tests are needed to verify and validate the implementation choices made by the supplier(s) that are not specified at OCORA level.	Train Adapter Block Test Plan		
3 – CCS-OB Level	Integration	Building Blocks and Peripheral/Connectivity Blocks are integrated together to build the CCS-OB equipment. CCS-OB internal interfaces (Building Block ⇔ Building Block; Building Block ⇔ Peripheral Block; Building Block ⇔ Connectivity Block; Peripheral Block ⇔ Connectivity Block) are checked. At this step, Rolling Stock and other external interfaces are not integrated.	Factory CCS-OB Integration Plan	Factory	CCS-OB Integrator

Level	Activity	Scope	Documentation	Factory /Site	Responsible
	Testing	The whole CCS-OB equipment is tested in factory (Verification and Validation) without testing the external interfaces. **<u>Compliance with OCORA requirements:</u>** The tests performed shall at least cover the "System Requirements" (C-Level requirements) specified by OCORA and that are relevant for this level 3. These tests shall totally be specified by OCORA and the responsible of the testing activities at this level shall use the test specifications that are relevant for its project (depending on the Building Blocks used by the project). These tests only partially cover the functionalities of the CCS-OB: additional tests are needed to fully verify and validate the CCS-OB, including some possible project particularities.	Factory CCS-OB Test Plan		Factory CCS-OB Tester (can be the CCS-OB Integrator)
4 - Vehicle Level	Integration	The CCS-OB equipment is integrated in the vehicle. Interfaces with the Rolling Stock via the Train Adapter and some other CCS-OB external interfaces (e.g. external STM) are checked.	Site CCS-OB Integration Plan	Site (vehicle)	Vehicle Integrator (can be the CCS-OB Integrator)

Level	Activity	Scope	Documentation	Factory /Site	Responsible
	Testing	The CCS-OB equipment is tested in the vehicle (Verification and Validation) including the interfaces with the vehicle via the Train Adapter and some other external interfaces (e.g. external STM). **<u>Compliance with OCORA requirements:</u>** The tests performed shall at least cover the "System Requirements" (C-Level requirements) specified by OCORA and that are relevant for this level 4. These tests shall totally be specified by OCORA and the responsible of the testing activities at this level shall use the test specifications that are relevant for its project (depending on the Building Blocks used by the project). These tests only partially cover the functionalities of the CCS-OB: additional tests are needed to fully verify and validate the CCS-OB, including some possible project particularities.	Site CCS-OB Test Plan		Site CCS-OB Tester (can be the CCS-OB Integrator)
5 - System Level	Integration	The CCS-OB equipment and the CCS trackside equipment are integrated together. CCS-OB external interfaces with the trackside with real (Factory/Site) or simulated (Factory) radio transmission are checked.	CCS Integration Plan	Factory/Site	System Integrator (can be the CCS-OB Integrator)

Level	Activity	Scope	Documentation	Factory /Site	Responsible
	Testing	The CCS-OB equipment and trackside equipment are tested (Verification and Validation) together. **<u>Compliance with OCORA requirements:</u>** The tests performed shall at least cover the "System Requirements" (C-Level requirements) specified by OCORA and that are relevant for this level 5. These tests shall totally be specified by OCORA and the responsible of the testing activities at this level shall use the test specifications that are relevant for its project (depending on the Building Blocks used by the project). These tests only partially cover the functionalities of the CCS-OB: additional tests are needed to fully verify and validate the CCS-OB, including some possible project particularities.	CCS Test Plan		System Tester (can be the CCS-OB Integrator)

Table 1: Integration and Testing steps

These steps do not necessarily occur in chronological order. For instance, the CCS-OB equipment and the CCS trackside equipment can be integrated together in factory (step 5) before the CCS-OB equipment is integrated in the vehicle (step 4).

Note: Depending on the projects' particularities and the countries in which they are deployed, the actors who are responsible of some steps may differ. For instance, the Vehicle Integrator may be the Vehicle Keeper or the CCS-OB Integrator.

3.2.1 Documentation content activities

Documentation	Activities
The CCS Test Plan shall…	- Define CCS acceptation strategy: identify means (simulators, real hardware…) and location (factory or site). - Identify roles and responsibilities. - Identify deliverables (test specifications and test reports). - Describe the acceptation process regarding testing. Note: a different plan shall address the overall CCS acceptation process on top of it (also outside testing).
The CCS Integration Plan shall…	- Define CCS integration strategy and related process (steps identification) for the whole CCS-OB <=> CCS trackside integration (TMS, ATO wayside, digital register...). - Identify activities for each step. - Identify roles and responsibilities for each step. - Identify deliverables for each step (test specifications and test reports). - Identify means and tools for each step. Note: if needed, dedicated documents (Integration Plan and associated Site and/or Factory Test Specifications) can be created for specific interfaces. In this case, the CCS Integration can be used as a framework document that contains and references these dedicated documents.
The Site CCS-OB Test Plan shall…	- Define CCS test strategy (for on-site testing), while aiming to minimize the number of test cases to be performed on site (as they are costly and hard to set-up). - Identify roles and responsibilities. - Identify deliverables (test specifications and test reports). - Identify means. - Identify actors.
The Site CCS-OB Integration Plan shall…	- Define CCS-OB integration strategy and related process (steps identification) for the CCS-OB integration with the vehicle (TCMS and other Rolling Stock interfaces) and other CCS-OB external interfaces (e.g., STM if any). Note: this applies to the whole CCS-OB but also to specific modules, e.g., ATO with vehicle. - Identify activities for each step. - Identify roles and responsibilities for each step. - Identify deliverables for each step (test specifications and test reports for each interface). - Identify means and tools for each step.

Documentation	Activities
	Note: if needed, dedicated documents (Integration Plan and associated Site and/or Factory Test Specifications) can be created for specific interfaces. In this case, the Site CCS-OB Integration Plan can be used as a framework document that contains and references these dedicated documents.
The Factory CCS-OB Test Plan shall…	*Refer to CCS Test Plan requirements (but focus on CCS-OB).*
The Factory CCS-OB Integration Plan shall…	- Define CCS-OB integration strategy and related process (steps identification) for the several CCS-OB building blocks (ETP-OB, ATO-OB, LOC-OB...). - Identify activities for each step. - Identify roles and responsibilities for each step. - Identify deliverables for each step (e.g., Integration Report, test specifications and test reports for each interface). - Identify means and tools for each step.
The Peripheral/Connectivity/Train Adapter Block Test Plan shall…	- Define Peripheral/Connectivity/Train Adapter Block test strategy (for Factory testing). *For instance, at this level, the test strategy shall include more complex validation scenarios than at Component level.* Note: the test cases are specified in the Test Specification.
The Peripheral/Connectivity/Train Adapter Block Integration Plan shall…	*Refer to the OCORA Core Building Block Integration Plan.*
The OCORA Core Building Block Test Plan shall…	- Define Building Block test strategy (for Factory testing). *For instance, at this level, the test strategy shall include more complex validation scenarios than at Component level.* Note: the test cases are specified in the Test Specification.

Documentation	Activities
The OCORA Core Building Block Integration Plan shall…	- Define Building Block integration process (steps identification) for each OCORA Core Building Block (ETP-OB, ATO-OB...). - Identify activities for each step. - Identify roles and responsibilities for each step. - Identify means and tools for each step. - Identify deliverables for each step (e.g., Integration Report).
The Component SW Test Plan shall…	- Define SW test strategy. *For instance, at this level, the test strategy shall include unit-testing and code coverage testing.* Note: the test cases are specified in the Test Specification.
At all levels, Test Specifications shall…	- Define goals, actions and expected results. - Identify needed configurations (for type testing and the additional configurations when requested from evolutions). - Identify means, tools and actors.

Table 2: Documentation content activities

3.2.2 Level specific activities

Specific activities related to the Integration and Testing strategy that apply to particular levels among the ones defined in Table 1 are indicated in the Table 3 below.

Level	Activity	Description
0 - Platform Level	Qualification (HW/low SW level)	None. *The Platform Qualification (in accordance with the associated Qualification plan) shall fully be under the responsibility of the Platform supplier.*
1 - Component Level	SW Testing	None. *The Component SW Testing (in accordance with the associated Component SW Test Plan) shall fully be under the responsibility of the Component Supplier.*

Level	Activity	Description
2 – OCORA Core Building Block level	Integration	The OCORA Core Building Block Integration activity shall ensure that the functional interfaces of the Component(s) contained in the OCORA Core Building Block are consistent with their definition and therefore, in case of n>1 Components, that these Components are compatible with each other. The OCORA Core Building Block Integration activity shall also ensure that the Component(s) contained in the OCORA Core Building Block can be integrated with the expected hardware component (possibly several hardware components) and that the OCORA Core Building Block is compliant with the standardised Platform Independent API of the OCORA Safe Computing Platform. *An OCORA compliant project shall provide the tests objectives related to the "requirements" from TWS01 which should focus on the interfaces and therefore shall have the OCORA Core Building Block Integration activity under its responsibility (for OCORA Core Building Blocks with n>1 Components).*
		<u>From a standard perspective:</u> For the specification of software integration tests, the requirements are the same as for the specification of software component test (refer to the row below). For the specification of the software/hardware integration, tests shall be specified according to EN50657 resp. EN50128 Chapter 7 Paragraph 7.3.4.33 to .39. Chapter 7.3.4.39 of EN50657 resp. EN50128 requires the use of methods from Table A.5 and Table A.6: - Dynamic Analysis and Testing (A.13) including Equivalence Classes and Input Partition Testing (D.18), Performance Modelling (D.39), Structure-based Testing (D.50) and Test Case Execution from Boundary Value Analysis (D.4). - Functional and Black-box Testing (A.14) including Equivalence Classes and Input Partition Testing (D.18) and Boundary Value Analysis (D.4).

<table>
<tr><th>Level</th><th>Activity</th><th>Description</th></tr>
<tr><td rowspan="2"></td><td rowspan="2">Testing</td><td>The OCORA Core Building Block Testing activity shall define the tests mentioned in §2.1 which are relevant at the OCORA Core Building Block level: functional tests, safety tests, non-functional tests (including performance tests), cybersecurity tests.

The OCORA Core Building Block Testing activity shall also contain preliminary checks regarding the interfaces of the OCORA Core Building Block in order to facilitate the integration at CCS-OB level (next step) and identify potential issues at an early stage: functional, mechanical and electric compatibilities shall be checked.

The OCORA Core Building Blocks can be tested on computer host or on test bench, depending on the type of test to perform.

The OCORA Core Building Block Testing (in accordance with the associated OCORA Core Building Block Test Plan) shall fully be under the responsibility of the Component Supplier for OCORA Core Building Block with only one Component.
However, the OCORA Core Building Block Testing (in accordance with the associated OCORA Core Building Block Test Plan) shall fully be in the scope of an “OCORA compliant” project for OCORA Core Building Block with several (n>1) Components and therefore the OCORA compliant project shall define the related test objectives.</td></tr>
<tr><td><u>From a standard perspective:</u>

For the specification of software component tests, Chapter 7.3.4.32 and Chapter 7.4.4.10 of EN50657 resp. EN50128 require the use of methods from Table A.5:
- Dynamic Analysis and Testing (A.13) including Equivalence Classes and Input Partition Testing (D.18), Performance Modelling (D.39), Structure-based Testing (D.50) [including Test Coverage: Statement (D.50) and Test Coverage: Path (D.50)] and Test Case Execution from Boundary Value Analysis (D.4).
- Functional and Black-box Testing (A.14) including Equivalence Classes and Input Partition Testing (D.18) and Boundary Value Analysis (D.4).</td></tr>
<tr><td rowspan="2">2 – Peripheral or Connectivity Block level</td><td>Integration</td><td rowspan="2">Tests with both software and hardware must be performed (simple computer host tests are not sufficient). If the Peripheral or Connectivity Block is planned to be deployed on the OCORA Safe Computing Platform, it shall be checked that the Peripheral or Connectivity Block is compliant with the standardised Platform Independent API of the OCORA Safe Computing Platform.

It shall also be checked that Connectivity Blocks related to radio transmission are working correctly at this early stage, even if the radio transmission itself is only checked in the next integration levels (especially at level 5 – System level).

The Peripheral/Connectivity Block Integration & Testing (in accordance with the associated Peripheral/Connectivity Block Integration & Test Plans) shall fully be under the responsibility of the Peripheral/Connectivity Block Supplier.</td></tr>
<tr><td>Testing</td></tr>
</table>

Level	Activity	Description
2 – Train Adapter Block level	Integration Testing	Tests with both software and hardware must be performed (simple computer host tests are not sufficient). If the Train Adapter Block is planned to be deployed on the OCORA Safe Computing Platform, it shall be checked that the Train Adapter Block is compliant with the standardised Platform Independent API of the OCORA Safe Computing Platform. It shall be checked that Train Adapter Blocks are working correctly at this early stage, even if the complete correct behavior can only be checked in the next integration levels (especially at level 4 – Vehicle level). *The Train Adapter Block Integration & Testing (in accordance with the associated Train Adapter Block Integration & Test Plans) shall fully be under the responsibility of the Train Adapter Block Supplier.*
3 - CCS-OB Level	Integration	The Factory CCS-OB Integration activity shall ensure that the functional, mechanical and electric interfaces of the OCORA Core Building Blocks and Peripheral/Connectivity Blocks are consistent with their definition and therefore these OCORA Core Building Blocks and Peripheral/Connectivity Blocks are compatible with each other. The Factory CCS-OB Integration activity shall ensure that the OCORA Core Building Blocks and Peripheral/Connectivity Blocks can communicate with each other by the means of the CCN (CCS Communication Network) with its associated messaging protocol and/or the standardised Platform Independent API of the OCORA Safe Computing Platform. *The CCS-OB Integration activity shall fully be in the scope of an "OCORA compliant" project and therefore the OCORA compliant project shall define the related integration objectives.*
		From a standard perspective: For the specification of software integration tests, the requirements are the same as for the **Level 2.**
	Testing	The Factory CCS-OB Testing activity shall define the tests mentioned in §2.1 which are relevant at the CCS on-board level: functional tests, safety tests, non-functional tests (including performance tests), user tests, cybersecurity tests. The Factory CCS-OB Testing activity shall also contain preliminary checks regarding the interfaces of the CCS-OB in order to facilitate the integration at Vehicle and System levels (next steps) and identify potential issues at an early stage: functional, mechanical, electric and messaging protocol compatibilities shall be checked. *The CCS-OB Testing shall fully be in the scope of an "OCORA compliant" project and therefore the OCORA compliant project shall define the related test objectives.*

Level	Activity	Description
		<u>From a standard perspective:</u> Test of the overall software shall be specified according to EN50657 resp. EN50128 Chapter 7 Paragraph 7.2.4.16 to .19. For the specification of tests of the overall software, Chapter 7.2.4.18 of EN50657 resp. EN50128 requires the use of methods from Table A.7: - Functional and Black-box Testing (A.14), including Equivalence Classes and Input Partition Testing (D.18) and Boundary Value Analysis (D.4). - Performance Testing (A.18) including Response Timing and Memory Constraints (D.45), Avalanche-/Stress Testing (D.3) and Performance Requirements (D.40). Within the scope of the overall software test, the validator must define additional tests according to Chapter 7.7.4.3. These must stress the system with **complex scenarios** and reflect the actual requirements of the application.
4 - Vehicle Level	Integration	The Site CCS-OB Integration activity shall ensure that the functional, mechanical and electric interfaces between the CCS-OB and the vehicle are compatible. One part of the integration tests shall be static tests which check that all the functional information (I/O) defined on its interface are correctly exchanged between the CCS-OB and the vehicle via the Train Adapter. The Vehicle Integrator shall be able to activate the I/O manually by the means of a dedicated tool. *The CCS-OB Integration in the Vehicle shall fully be in the scope of an “OCORA compliant” project and therefore the OCORA compliant project shall define the related integration objectives.*
	Testing	The Site CCS-OB Testing activity shall define the tests mentioned in §2.1 which are relevant at the Vehicle level: functional tests, safety tests, non-functional tests (including performance tests), user tests, cybersecurity tests. These tests can be static or dynamic tests, depending on the target of test. *The CCS-OB Testing at Vehicle level shall fully be in the scope of an “OCORA compliant” project and therefore the OCORA compliant project shall define the related test objectives.*
5 - System Level	Integration	The CCS Integration activity shall ensure that the CCS-OB external interfaces with the trackside (balise, CCS trackside equipment) are compatible from a functional and messaging protocol point of view. The integration tests can be performed with real airgap transmission (mainly in Factory and with a limited number of tests on Site) or simulated airgap transmission (in Factory). *The CCS-OB Integration at System level shall fully be in the scope of an “OCORA compliant” project and therefore the OCORA compliant project shall define the related integration objectives.*

Level	Activity	Description
	Testing	The CCS Testing activity shall define the tests mentioned in §2.1 which are relevant at the System level: functional tests, safety tests, non-functional tests (including performance tests), user tests, cybersecurity tests. These tests can be static or dynamic tests and can be performed in Factory and on Site, depending on the target of test (the number of Site tests shall remain as limited as possible). These tests shall particularly focus on functionalities which involve both on-board and trackside equipment, which require synchronization between equipment and which can suffer from performance and communication issues due to time delays (e.g. trackside equipment handover, trackside order: pantograph to be lowered…). *The CCS-OB Testing at System level shall fully be in the scope of an "OCORA compliant" project and therefore the OCORA compliant project shall define the related test objectives.*

Table 3: Levels specific activities

3.2.3 Building Blocks specific activities

So far, OCORA project has only defined a list of candidates for Building Blocks. This list is just a proposal and is not frozen yet. Currently, OCORA project is still focusing on defining the logical and physical components that will, at the end, be grouped into OCORA building blocks.

Based on this current list of Building Blocks, specific activities related to the Integration and Testing strategy that apply to particular Building Blocks are indicated in the Table 4 below.

Building Block	Activity	Description
OCORA Core Building Block		
European Train Protection On-Board (ETP-OB) (components Vehicle Supervisor – VS + Mode & Level Manager – MLM + STM Controller -STMC + Physical ETCS Transponder Service – PETS + Cold Movement Detection – CMD + Euroradio components…)	Testing	Subset 76 tests related to ETCS Core functionalities shall be performed. To be completed in next OCORA releases.

Automatic Train Operation On-Board (ATO-OB)	Testing	**<u>2 - OCORA Core Building Block level</u>** Testing of the ATO-OB BB shall start at Level 2 in factory on host machine and/or on dedicated hardware. Software and non-functional tests (performance, coverage tests…) shall be performed at this testing level but not only: it is also possible to perform some functional tests at this early stage. In order to perform these functional tests, the test environment used at Level 2 shall allow to interface the ATO-OB BB with: - a module that simulates the inputs of the ATO-OB BB depending on the test scenario, - a simulated and configurable vehicle that moves on a virtual test track according to the ATO commands received from the ATO-OB BB. A part of the outputs of the train model – acceleration, speed, position… - can then be reused as inputs at the next implementation cycle of the ATO-OB BB software. At this stage, the train model used can almost be considered as "perfect" but, if possible, it shall be as representative as possible of the real vehicle in which the ATO-OB BB will be used in order to adjust the maximum number of parameters' values or at least have an initial rough idea about their setting before the characterization tests performed at levels 4 and 5. It shall also be possible to use a generic train model (if no information is available regarding the vehicle for instance) in order to test some of the functionalities of the ATO-OB BB. The virtual test track shall be representative of all the possible configurations that can be encountered in "real life", especially in terms of speed limits and topology. Dynamic tests shall be performed in various track configurations (speed limit, topology…) to check that operational needs covered by the ATO-OB BB are met and that for instance the outputs of the ATO-OB BB allow the vehicle to: - Start moving without unintentional rollback movement - Move at the authorized speed (ceiling speed, speed profile restriction, speed profile increase) - Accelerate/brake while ensuring passengers' comfort - Stop in the acceptable window around the targeted stopping point - Respect movement authorities associated to static or dynamic targets (e.g., downstream moving train, movement authority restriction or extension…) - … The supplier of the ATO-OB Building Block shall provide the expected documentation for this Level 2 (refer to 3.2.1: OCORA Core Building Block Integration Plan and OCORA Core Building Block Test Plan), assessing that the integration and testing activities have been correctly performed. **<u>3 – CCS-OB Level</u>** Functional tests can also be performed at this level, still in factory and on host machine or with the CCS-OB software integrated on its hardware. At this level, the ATO-OB BB is fully integrated in the CCS-OB with the other BBs. Therefore, the main differences with the tests performed at level 2 are that: - Inputs of the CCS-OB are simulated depending on the test scenario. Therefore, the test scenario must consider the expected behavior of the whole CCS-OB, in particular the test scenario must include the correct conditions that will set the CCS-OB in an automatic driving mode.

		- Consistency of both ATO and speed supervision functionalities can be easily observed and controlled since both functionalities are implemented by the CCS-OB (for instance, it can be checked that in any circumstances, the ATO traction and braking commands allow the train to run without triggering service brake or emergency brake commands due to the speed supervision function, with a reasonable margin with the SB or EB triggering speed). The same kind of train model as in level 2 can be used. The objectives of the dynamic functional tests can be nearly the same as the ones described for level 2. It may be easier to simulate the CCS-OB inputs than the ATO-OB BB inputs so tests performed at level 3 may be more complete than the ones performed at level 2. Moreover, tests performed at level 3 do not only focus on ATO functionalities. Tests related to other functionalities that use automatic driving modes (modes transitions, speed supervision…) also indirectly contribute to the testing of ATO functionalities and increase the level of confidence in the ATO-OB BB used as part of the CCS-OB. **4 - Vehicle Level/5 - System Level (on site)** At testing levels 4 and 5, tests are performed on site and no longer in factory. Outcome of the tests from levels 2 and 3 (related to ATO but also to functionalities ensuring the safety like speed supervision) is considered before giving the authorization to run tests on site in automatic driving modes. In case of lack of visibility at tests performed at level 2 that can be under the responsibility of the ATO-OB BB supplier, some constraints can be exported to authorize tests on site in automatic driving modes: human presence may be required in cabin. If possible, first tests performed on site (and most of them) shall be performed on a test track for which the constraints linked to operations and test organization are lighter than on regular tracks. Some missing information or inputs (for instance, lack of visibility at tests performed by suppliers or tests from previous levels not entirely performed or passed yet) can be tolerated to perform tests on test tracks but are not acceptable for tests performed on regular tracks. Longer tests on regular tracks can be performed after having acquired the sufficient level of confidence in the CCS-OB behavior through the tests performed at other levels or on test track. In addition, depending on the level of confidence and the testing status of BBs like ETP-OB that directly contribute to the safety (tests from previous levels not entirely performed or passed yet) and the topology of the test track (short distance between bumpers), first tests can be performed under the supervision of an additional external equipment which controls the speed of the train, if available. Even if such equipment is not a safety equipment, it can reinforce the safety of the tests until all the functions of the CCS-OB that contribute to the safety are completely validated. Note: such equipment already exists, based on GPS signals with a definition of the test track with kilometric points and associated speeds. The equipment is included in the EB control loop and a software can continuously check that it is in good working order. However, using this kind of equipment complicates the testing process since manual checks must be performed each time a cabin is opened. ATO can be considered as a generic function but it must be parameterized

		according to the rolling stock characteristics. Therefore, train characterization tests shall be performed in order to identify the brake/traction/cruising patterns and behavior of the vehicle and be able to build a set of parameters for the ATO-OB BB that is well adapted to the vehicle.
		Characterization tests consist of recording the behavior of the train (acceleration, speed…) with various measuring devices (accelerometer…) under particular conditions to integrate it in the transfer function of the ATO-OB BB (coefficients to be determined for each type of vehicle). Several tests can be performed: triggering of SB/EB, running resistance tests (traction and then coasting), tests with a given percentage of traction or brake at different speeds and with different brakes activated or not (pneumatic brake, electric brake…), response time identification, dead band tests (to determine the margin around which nothing happens and identify the minimal command of traction/brake that will make the vehicle react, with the objective to avoid pumping during the regulation phase)…
		Characterization tests allow the ATO commands to be more precise and adapted to the vehicle.
		Characterization tests must be performed on single units and then multiple units train if applicable for the project.
		Characterization tests may have to be repeated on several vehicles of the same type in case of variability observed in the fleet.
		
		Then, on site, simple functionalities are tested first and then the complexity of the tested functionalities increases by phases:
		- Manual driving modes (including fall-back states…).
		- Single unit and then multiple units train.
		- Transition to automatic driving modes: first, static tests are performed regarding:
		    ○ target computation,
		    ○ start conditions in automatic driving (target identified, train not located in an area where automatic driving is forbidden, rolling stock related checks…),
		    ○ fall-back modes (isolation of automatic driving modes).
		- Run in automatic driving modes at reduced speed (approximately 10 km/h). These tests allow the team to check the train departure phase in automatic driving and have first checks regarding the train behavior when it is running (following of the speed setpoint, stopping accuracy with a target located far from the train…).
		If the test track is delimited by bumpers, the train shall not approach the bumpers during these first dynamic tests in automatic driving.
		- Run in automatic driving modes at higher speed.
		- Tests with a safety related target (for instance: stopping in front of a bumper in automatic driving mode).
		
		At the end of each main phase, a committee (that includes the safety team) shall give its authorization before taking the next step.
		
		To check the stopping accuracy at operational stopping points, repeatability tests shall be performed: the stopping accuracy shall be evaluated during successive stops at the same operational point.
		
		Finally, to test a functionality like ATO, it is useful to have available a tool that allows the testing team to know the values of internal variables of the ATO-OB BB (else, the ATO-OB BB remains a complete black box and it is difficult to understand how it shall be tuned for instance). This kind of spyware can be provided by the ATO-OB BB supplier or by the CCS-OB Integrator and may also be useful at testing level 3.

Driver Advisory		To be completed in next OCORA releases.

Building Block	Activity	Description
System On-Board (DAS-OB)		
Digital Map Repository On-Board (DREP-OB)		To be completed in next OCORA releases.
Virtual ETCS Transponder Service (VETS)		To be completed in next OCORA releases.
National Train Protections (NTPs)		To be completed in next OCORA releases.
Peripheral Building Block		
Localisation On-Board (LOC-OB)	Testing	Subset 76 tests related to on-board localisation functionalities shall be performed. To be completed in next OCORA releases.
Perception On-Board (PER-OB)		To be completed in next OCORA releases.
Signal Converter (SCV)		To be completed in next OCORA releases.
Cabin Voice Radio (CVR)		To be completed in next OCORA releases.
Train Display System (TDS)		To be completed in next OCORA releases.
Virtual Train Coupling System On-Board (VTCS-OB)		To be completed in next OCORA releases.
Monitoring, Diagnostic, Configuration, Maintenance (MDCM-OB)		To be completed in next OCORA releases.
Remote Manual Train Operation On-Board (RMTP-OB)		To be completed in next OCORA releases.
Connectivity Building Block		
FRMCS On-board System		To be completed in next OCORA releases.
Train Adapter Building Block		

Building Block	Activity	Description
Functional Vehicle Adapter (FVA)		To be completed in next OCORA releases.
Wired I/O Control – SIL4 (WIOC-S4)		To be completed in next OCORA releases.
Wired I/O Control (WIOC)		To be completed in next OCORA releases.
Passenger Info System Adapter (PISA)		To be completed in next OCORA releases.

Table 4: Building Blocks specific activities

3.3 Evolution Management

The management of the CCS-OB with its building blocks during the whole vehicle lifetime (usually 30 years) is addressed by the OCORA program. This is key strategic topic that can drastically reduce the maintainability costs of CCS-OB systems when modularity is used efficiently.

This topic is developed by the RAMS group in a dedicated whitepaper [11] where a strong connexion is made with the Testing group regarding the testing activities required at OCORA scope when dealing with evolutions.

The following drawing presents the overall strategy of evolution management.

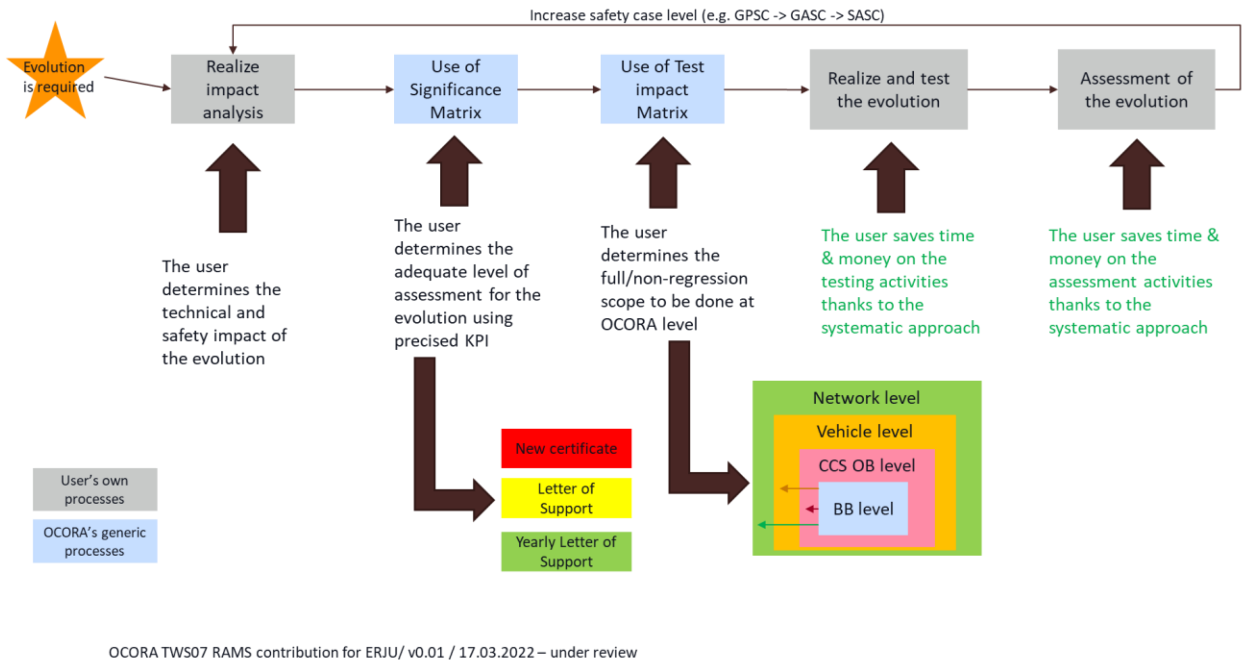

Figure 3: Evolutions management top level process

This process is composed of the following steps:

- An evolution is required: either the BB supplier has identified a need to update its system (e.g. new OCORA requirements, bug fixing) or the vehicle owner requires a change in the CCS-OB constitution (e.g. new BB, change of supplier for a BB).

- Realize impact analysis: this activity, performed by the user with his own process, aims at defining the impact of the modification from a technical point of view (e.g. system, sw/hw engineering). Evolutions must be handled in the user's change management database as well as any other evolution (i.e. not in OCORA scope).
- Use of significance matrix: this tool, defined by the RAMS group aims at determining the relevant level of assessment required based on the technical impact analysis. This is fully explained in [11].
- Use of test impact matrix: this tool, defined jointly with the RAMS and Testing groups aims at defining the different scopes of non-regression testing to be performed depending on the evolutions' impacts (i.e. which OCORA interfaces are impacted and non-impacted). This will help each user to easier define the testing strategy at his level but also for all above levels.

  This is illustrated in the figure below:

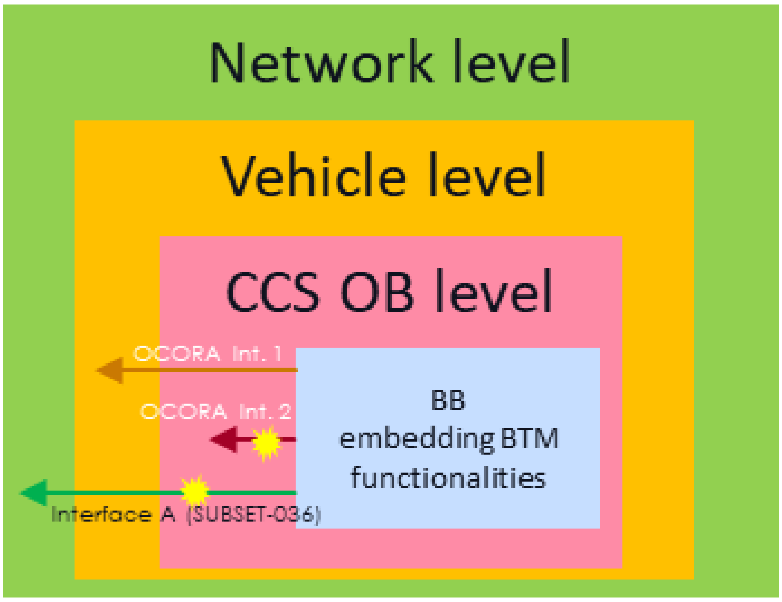

Figure 4: Integration and Testing activities sequencing

In our example, the impact analysis (second step of the process) showed that two interfaces are impacted by the evolution in the building block. The test matrix tool will provide

  - the technical non-regression scope at BB level for the *OCORA Interface 1* (as not impacted),
  - the full technical scope at BB level for the *OCORA Interface 2* (as impacted),
  - recommendation only for the *interface A* because the latter is outside OCORA scope and already covered by dedicated mandatory testing requirements (i.e. Subset-085).

The scope of tests defined by OCORA (i.e. full and non-regression) must be agreed with the industry and a panel of assessors to avoid being rechallenged any time a user wants to use them. This is strong pre-condition to get this process efficient for the users.

- Realize and test the evolution: this activity, performed by the user with its own process, represents the implementation of the evolution and then its testing.
- Assessment of the evolution: this activity, performed by the user with its own process, represents the assessment of the evolution with an assessor. It must be noticed here that this first version of the process [11] focuses on safety related BB submitted to OCORA requirements. A further release of this process will be extended to the management of non-safe OCORA compliant systems.

When the BB has been successfully re-assessed, the process is looped and starts again with increasing one level; CCS-OB, then vehicle level and finally system level (refer to §3.2.2). The evolution management process [11] will also present an assessment panel and technical tests scope for each level defined in §3.2.2. Obviously, the assessment and tests activities become lighter and lighter when increasing the levels (i.e. L3 to L5).

Finally, this process will ensure that only the adequate level of assessment and tests will be performed to safely authorise the system to go back in commercial service.

3.4 Model Based System Engineering and Arcadia method for CCS Integration and Testing activities

The concept of Model Based System Engineering (MBSE) and its application through the Arcadia method (with the support of the Capella tool) are described in [16] but this document mainly focuses on its use during the system design phase.

The Arcadia method and the Capella tool allow the different stakeholders and teams to share a common vision of the system and they can also be used for Integration and Testing activities, especially to help to build the tests specifications at various integration and testing levels, as early as possible in parallel of the design phase.

OCORA also plans to rely on the Arcadia method and the Capella tool to design the generic test bench used to integrate and test the CCS-OB: in this case the test bench is the system under design in the Capella project.

3.4.1 Tests scenarios for CCS-OB

As a reminder, Arcadia promotes four distinct perspectives that are all driven by a viewpoint approach and are defined in this order:

- Customer Operational Need Analysis,
- System Need Analysis,
- Logical Architecture,
- Physical Architecture.

For each perspective, Capella proposes different types of views that can be used to design the system according to particular requirements. Some of these views allow the integration and testing team to specify tests scenarios easily. Some examples are given below.

3.4.1.1 Sequence diagrams

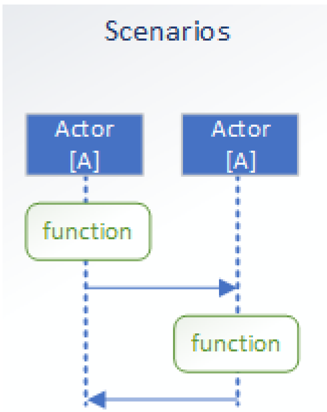

Figure 5: Sequence diagram

Sequence diagrams can easily be used to define scenarios of functional tests, since they described a sequence of events that involve the system and external actors.

Sequence diagrams defined in the Operational Need Analysis perspective describe high-level scenarios that will likely be usable at the upper levels of Integration and Testing activities (**4** – Vehicle Level and **5** – System Level).

Sequence diagrams are also defined in the lower Arcadia perspectives and become more detailed as the perspective is low. Depending on the functions involved in the described scenario, these sequence diagrams can be used at various levels of Integration and Testing activities (**3** – Building Block Level, **3** – CCS-OB Level, **4** – Vehicle Level and **5** – System Level) to design functional tests scenarios.

3.4.1.2 Functional chains

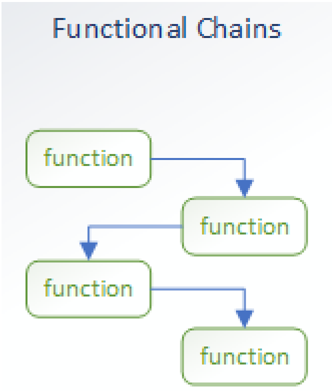

Figure 6: Functional chain

In functional chains, functions of the system are ordered and the functional exchanges that link them are described. A functional chain applies to a particular usage context and describes a possible path among all the possible paths of dataflow. Functional chains can be defined in all the Arcadia perspectives.

Capella can associate performance criteria to functional chains: for instance, latency constraints for functional chains carrying data from end to end.

Therefore, these functional chains can be used as a basis (or at least as a source of inspiration) to specify performance tests at various levels of Integration and Testing activities.

3.4.1.3 Class diagrams

Capella has adopted the Class Diagram from the Unified Modeling Language (UML) that allows data exchange to be modeled precisely.

Therefore, integration tests at various levels (**3** – CCS-OB Level, **4** – Vehicle Level and **5** – System Level) can be designed based on the class diagrams available for the OCORA model.

3.4.2 Design and definition of the CCS-OB Test Bench

It is proposed to use the Arcadia method and the Capella tool to design the generic test bench used to integrate and test OCORA compliant CCS-OB: in this case the test bench is the system under design in the Capella project and the OCORA compliant CCS-OB (or parts of it if only some Building Blocks are integrated together with software in the loop methods at **3** – CCS-OB Level) is only a part of this bigger system.

The OCORA Test Bench shall address all the needs expressed in this document regarding the Integration and Testing Strategy for the levels **3** – CCS-OB Level and **5** – System Level (Factory part).

These needs can be directly used as input for the Customer Operational Need Analysis which is the first perspective of the Arcadia method. Then, by applying the next steps of the Arcadia method, the System Need Analysis, Logical Architecture and Physical Architecture of the OCORA Test Bench can be easily designed.