OCORA

Open CCS On-board Reference Architecture

Testing Strategy

Guideline for Modular Testing

Document ID: OCORA-TWS09-020

Version: 1.01

Release: Delta

Date: 30.06.2021

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

Table of contents

Table of figures

Table of tables

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

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

2.1 Scope and Capabilities of the Integration and Testing

The Integration & Testing Strategy shall allow to integrate, verify and validate the complete Onboard CCS subsystem and its external interfaces. In the meantime, Testing Strategy shall particularly focus on the “OCORA Core” (refer to [7] for a complete definition).

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

The Integration & Testing Strategy shall allow to verify and validate that the building blocks within the “CCS On-Board” 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] 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

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 analyses 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.

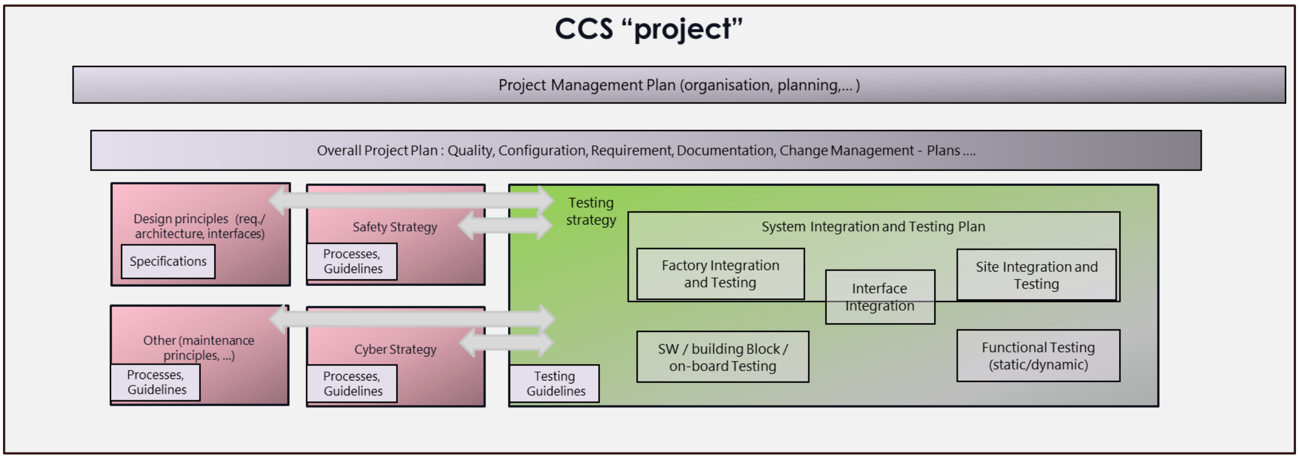
CCS “project”
Project Management Plan (organisation, planning,…)
Overall Project Plan : Quality, Configuration, Requirement, Documentation, Change Management - Plans ….
Design principles (req./ architecture, interfaces)
Specifications
Safety Strategy
Processes, Guidelines
Other (maintenance principles, …)
Processes, Guidelines
Cyber Strategy
Processes, Guidelines
Testing strategy
System Integration and Testing Plan
Factory Integration and Testing
Interface Integration
Site Integration and Testing
SW / building Block / on-board Testing
Functional Testing (static/dynamic)
Testing Guidelines

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 shall it 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 onboard CCS – vehicle interface
    - Addition of a new building block (e.g. AV for ATO)
    - Replacement of a building block (e.g. replacement of localization sensors or localization modules (VLS or 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
    - (…)
- 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 on-board building blocks (overall and operational use cases with trackside simulated), with simulated peripheral devices and then real devices
    - Integration of a CCS On-Board 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 On-Board 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. 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 Integration

During the integration activities, subsystems or components are assembled and installed to form an integrated system of higher level. 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.

3.1.2 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 means to answer the question **"have we built it correctly?"**

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.

3.1.3 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.

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

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

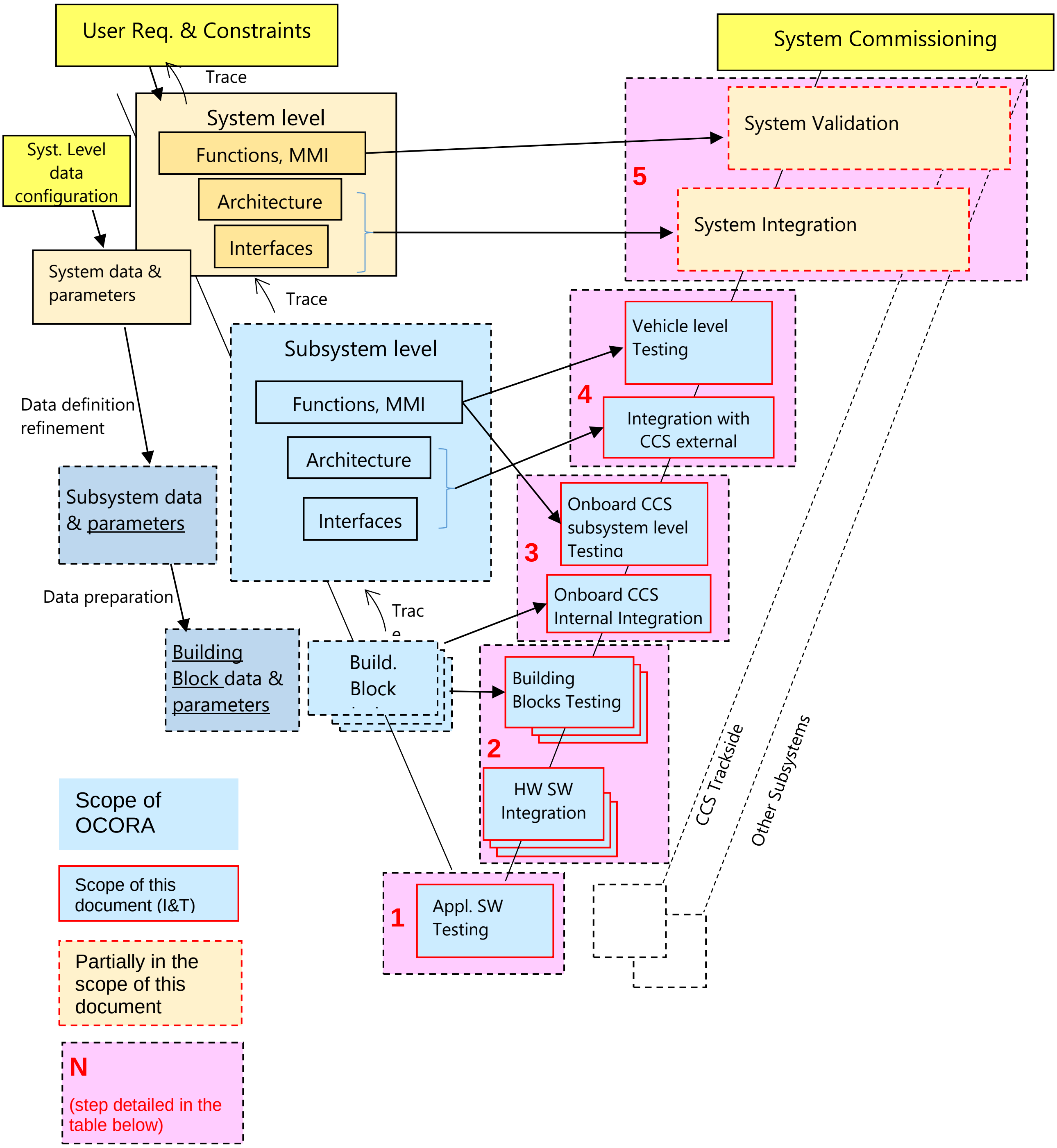

Figure 2: Integration and Testing activities sequencing

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 - Application Level	SW Testing	Application SW (configured) are tested individually (Verification and Validation).	Application SW Test Plan	Factory	Application Supplier (SW)
2 - Building Block level	Integration	SW of the n Application(s) that are part of one same Building Block are integrated together. Integration with one or several HW is also performed at this step.	Building Block Integration Plan	Factory	Application Supplier (which is also the Platform Supplier for ETCS Core) or On-board CCS Integrator (if n>1 and several Application Suppliers) NB: Application Supplier can be different from Platform Supplier for non ETCS Core (e.g. Digital Map, AV…)
	Testing	Building Blocks (configured) are tested individually (Verification and Validation).	Building Block Test Plan		
2 - Peripheral Block level	Integration	SW of the n Application(s) that are part of one same Peripheral Block are integrated together. Integration with one or several HW is also performed at this step.	Peripheral Block Integration Plan	Factory	Peripheral Device Supplier
	Testing	Peripheral Blocks are tested individually (Verification and Validation).	Peripheral Block Test Plan		
3 - On-board CCS Level	Integration	Building Blocks and Peripheral Blocks are integrated together to build the CCS on-board equipment. CCS on-board internal interfaces (Building Block ⇔ Building Block; Building Block ⇔ Peripheral Block) are checked. At this step, Rolling Stock and other external interfaces are not integrated.	Factory CCS on-board Integration Plan	Factory	On-board CCS Integrator
	Testing	The whole CCS on-board equipment is tested in factory (Verification and Validation) without testing the external interfaces.	Factory CCS on-board Test Plan		Factory On-board CCS Tester (can be the On-board CCS Integrator)

Level	**Activity**	**Scope**	**Documentation**	**Factory /Site**	**Responsible**
4 - Vehicle Level	Integration	The CCS on-board equipment is integrated in the vehicle. Interfaces with the Rolling Stock and some other CCS on-board external interfaces (e.g. external STM) are checked.	Site CCS on-board Integration Plan	Site (vehicle)	Vehicle Integrator (can be the On-board CCS Integrator)
	Testing	The CCS on-board equipment is tested in the vehicle (Verification and Validation) including the interfaces with the vehicle and some other external interfaces (e.g. external STM).	Site CCS on-board Test Plan		Site On-board CCS Tester (can be the On-board CCS Integrator)
5 - System Level	Integration	The CCS on-board equipment and the CCS trackside equipment are integrated together. CCS on-board 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 On-board CCS Integrator)
	Testing	The CCS on-board equipment and trackside equipment are tested (Verification and Validation) together.	CCS Test Plan		System Tester (can be the On-board CCS Integrator)

Table 1: Integration and Testing steps

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

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

3.2.1 Level specific requirements

Specific requirements related to the Integration and Testing strategy that apply to particular levels among the ones defined in Table 1 are indicated in the Table 2 below.

Level	Activity	Specific Requirements
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 - Application Level	SW Testing	None. *The Application SW Testing (in accordance with the associated Application SW Test Plan) shall fully be under the responsibility of the Application Supplier.*
2 - Building Block level	Integration	The Building Block Integration Plan shall ensure that the functional interfaces of the Applications contained in the Building Block are consistent with their definition and therefore these Applications are compatible with each other. The Building Block Integration Plan shall ensure that the Applications contained in the Building Block can be integrated with the expected hardware component (possibly several hardware components). *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 Building Block Integration Plan under its responsibility (for Building Blocks with n>1 Applications).*
	Testing	The Building Block Test Plan shall define the tests mentioned in §2.1 which are relevant at the Building Block level: functional tests, safety tests, non-functional tests (including performance tests), cybersecurity tests. The Building Block Test Plan shall also contain preliminary checks regarding the interfaces of the Building Block in order to facilitate the integration at On-board CCS level (next step) and identify potential issues at an early stage: functional, mechanical and electric compatibilities shall be checked. The Building Blocks can be tested on computer host or on test bench, depending on the type of test to perform. *The Building Block Testing (in accordance with the associated Building Block Test Plan) shall fully be under the responsibility of the Application Supplier for Building Block with only one Application. However, the Building Block Testing (in accordance with the associated Building Block Test Plan) shall fully be in the scope of*

Level	Activity	Specific Requirements
		an "OCORA compliant" project for Building Block with several (n>1) Applications and therefore the OCORA compliant project shall define the related test objectives.
2 - Peripheral Block level	Integration	Tests with both software and hardware must be performed (simple computer host tests are not sufficient). It shall also be checked that Peripheral 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 Block Integration & Testing (in accordance with the associated Peripheral Block Integration & Test Plans) shall fully be under the responsibility of the Peripheral Block Supplier.*
	Testing	
3 - On-board CCS Level	Integration	The Factory CCS on-board Integration Plan shall ensure that the functional, mechanical and electric interfaces of the Building Blocks and Peripheral Blocks are consistent with their definition and therefore these Building Blocks and Peripheral Blocks are compatible with each other. The Factory CCS on-board Integration Plan shall ensure that the Building Blocks and Peripheral Blocks can communicate with each other by the means of the CCN (CCS Communication Network) and its associated messaging protocol. *The CCS on-board Integration 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 Factory CCS on-board Test Plan 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 on-board Test Plan shall also contain preliminary checks regarding the interfaces of the CCS on-board 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 on-board Testing shall fully be in the scope of an "OCORA compliant" project and therefore the OCORA compliant project shall define the related test objectives.*
4 - Vehicle Level	Integration	The Site CCS on-board Integration Plan shall ensure that the functional, mechanical and electric interfaces between the CCS on-board and the vehicle are compatible. 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 on-board and the vehicle. The Vehicle Integrator shall be able to activate the I/O manually by the

Level	Activity	Specific Requirements
		means of a dedicated tool. *The CCS on-board 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 on-board Test Plan 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 on-board 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 Plan shall ensure that the CCS on-board 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 on-board 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.*
	Testing	The CCS Test Plan 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 on-board 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 2: Levels specific requirements

3.2.2 General requirement allocation

X: requirement applicable to this level

(X): requirement will also be addressed at upper level than the one of onboard CCS.

General requirement allocation	L1	L2	L3	L4	L5	Not level specific
Scope and Capabilities						
The Integration & Testing Strategy shall allow to integrate, verify and validate the complete Onboard CCS subsystem and its external interfaces. In the meantime, Testing Strategy shall particularly focus on the "OCORA Core" (refer to [7] for a complete definition).			X	(X)	(X)	
The Integration & Testing Strategy shall allow to verify and validate the modularity properties of the Onboard CCS subsystem as defined in [7].			X			
The Integration & Testing Strategy shall allow to verify and validate that the building blocks within the "CCS On-Board" support the whole functional scope of OCORA, for all grades of automation.	X	X	X	(X)	(X)	
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 [7])		X	X	(X)	(X)	
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.			X			
The Integration &Testing Strategy shall take into account that the functionality of some of the hardware components may vary.	X	X	X			
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 fulfils the functional requirements and interface specifications assigned to this test object. These tests include ERTMS Tests (e.g. Subset 76).	X	X	X	(X)	(X)	
▪ Safety tests	X	X	X	(X)	(X)	
▪ Non-functional tests: performance tests, Maintainability Tests, Environmental (climate, EMC) Tests, Load tests, Stress tests, Endurance tests	X	X	X	(X)	(X)	
▪ User tests: testing by end users who perform specific tasks under real-life conditions.					(X)	
▪ Cybersecurity tests		?	X	(X)	(X)	

General requirement allocation	L1	L2	L3	L4	L5	Not level specific
The Integration &Testing Strategy shall consider degraded modes for each kind of test type defined above.	X	X	X	(X)	(X)	
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	X	X	X	(X)	(X)	
▪ Site Acceptance Tests				(X)	(X)	
The Integration &Testing Strategy shall define the different levels of integration, verification and validation (like system test, sub-system test, component test…).						X
Actors, Process and Methods						
The Testing activity shall start as early as possible in the process.						X
Early testing steps shall be proposed.						X
The requirements shall be mastered (and their releases) during the whole cycle of development and validation.						X
The Testing documentation shall be well structured down to test cases.						X
The Interface Integration Plans for each interface shall be well structured (according to each interface) and mastered with clear steps (what/how/who…).						X
The Interface Integration Plans shall be converged between all stakeholders involved.						X
Each milestone of the Integration & Testing process shall be clearly defined.						X
The Integration & Testing effort shall be adapted accordingly to the needs of each step.						X
The risk of having many actors /many tools… shall be reduced by having a common environment (eg MBSE and its Testing) where specific tools are limited to stakeholders' specific activities.						X
A system integrator (or system integrators but with an overall system integrator above) shall be designated.						X
A clear process for bugs/anomaly tracing until corrections are made (among the different stakeholders) supported by ad hoc tools shall be proposed.						X
When possible, safety demonstration shall also rely on additional and complementary methods, other than test and validation (use of formal method for instance).						X

General requirement allocation	L1	L2	L3	L4	L5	Not level specific
The Integration & Testing Strategy shall lead to a minimal effort in case of an update of a component:						X
▪ Software update						X
▪ Addition of a new onboard CCS – vehicle interface						X
▪ Addition of a new building block (e.g. AV for ATO)						X
▪ Replacement of a building block (e.g. replacement of localization sensors or localization modules (VLS or VL))						X
▪ Replacement of an adapter (e.g. FVA replaced)						X
▪ Addition of a new peripheral device (e.g. BTM, LTM…)						X
▪ Hardware exchange (e.g. new processor)						X
▪ Cybersecurity upgrade						X
▪ (…)						
The Integration & Testing Strategy shall be organized in well-defined successive and complementary steps. An example is given below:						X
▪ Integration and testing of the HW (operating system test cases, bus communication test cases: load and performance tests)	X	X				
▪ Integration of the runtime environment (testing of the interfaces between OCORA runtime environment and vehicle apps by using vehicle app simulators)		X				
▪ Integration of CCS on-board building blocks (overall and operational use cases with trackside simulated), with simulated peripheral devices and then real devices		X	X			
▪ Integration of a CCS On-Board 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			X	(X)	(X)	
▪ CCS On-Board and Interoperability with Trackside in Lab			X	(X)	(X)	
▪ Test Reference Vehicle on Reference Track: interoperability on reference track with real trackside			X	(X)	(X)	
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.						X

General requirement allocation	L1	L2	L3	L4	L5	Not level specific
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.						X
Tools and Environment						
The Testing Strategy shall rely on a test environment automized as far as possible.	X	X	X	(X)	(X)	
A powerful test environment allowing configuration testing, degraded modes…shall be available.			X			
A “reference” test environment shall be proposed and mastered.		X	X		(X)	
The Testing Strategy shall rely on a flexible line representation, where all particular and relevant configurations can be added.	?	?	X		(X)	
Early verification and validation using model-in-the-loop simulation shall be foreseen.						X
The test environment shall support model-in-the-loop, software-in-the-loop and hardware-in-the-loop testing.						X
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.	X	X	X	(X)	(X)	
A common reusable set of scenarios shall be maintained with an incremental approach at each system release.			X	(X)	(X)	

Table 3: General requirement allocation