OCORA

Open CCS On-board Reference Architecture

Modularisation Roadmap Proposal

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Revision history

Version	Change Description	Initial	Date of change
1.00	First version to be published with OCORA R4.	AL	04.07.2023
1.10	Updates according to input received from various readers.	AL	09.11.2023
1.11	Updates according to coreteam feedback	AL	23.11.2023

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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-BWS03-020 – Guiding Principles

[7] OCORA-BWS04-010 – Problem Statements

[8] OCORA-TWS02-030 – OCORA Addendum to SUBSET-147

[9] OCORA-TWS03-010 – SCP – Computing Platform for Railway Applications – Whitepaper

[10] OCORA-TWS03-020 – SCP – High-Level Requirements

[11] OCORA-TWS03-030 – SCP – Initial Specification of the PI API between Application and Platform

1 Introduction

1.1 Purpose of the document

The purpose of this document is to propose a CCS On-Board (CCS-OB) modularisation and a corresponding roadmap, showing how the CCS-OB modularisation can evolve over time.

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

1.2 Applicability of the document

The present document is currently considered informative. Subsequent releases of this document will be developed based on a modular and iterative approach, evolving within the progress of the OCORA collaboration.

1.3 Context of the document

This document is published as part of an OCORA Release, together with the documents listed in the Release Notes [1]. If you are interested in the context and the motivation that drives OCORA we recommend reading the Introduction to OCORA [5], the Guiding Principles [6], and the Problem Statements [7]. The reader should also be aware of the Glossary [2] and the Question and Answers [3].

1.4 Problem statement summary

The Control Command and Signalling On-Board (CCS-OB) systems installed today, mainly consist of the European Train Control System (ETCS) with its ETCS Data Only Radio (EDOR), the Cabin Voice Radio On-Board (CVR-OB), and the National Train Protection Systems (NTPs) needed for the area of use of the vehicle.

The high Total cost of Ownership (TCO) of these systems, combined with the difficulty to upgrade a vehicle with ETCS functionality and to update already existing ETCS systems to the latest functionality/version, is a major concern of the railways, hindering quick deployment of ETCS in Europe.

Over the course of the next decade, the connectivity technology (ETCS data and cabin voice) needs to be migrated from GSM-R to FRMCS, and new functionality such as ETCS moving block as well as Automated Train Operation (ATO) is envisioned to be added. This increases the complexity of the CCS-OB system and will accentuate the concern mentioned.

Refer to document [7] for a more detailed problem statement.

1.5 Introduction to modularity

One of OCORA's goals is to improve the maintainability of the CCS-OB system. The TCO of a CCS-OB needs to be reduced. Upgrades and updates must be deployable within month rather than years.

Having a modular architecture with a well-defined number of subsystems is a prerequisite to improve the maintainability of any complex system. In the OCORA terminology, the subsystems of CCS-OB are called building blocks.

- A **Building Block** is a sourceable unit of the CCS on-board system (hardware and/or software), having standardised functionality, standardised PRAMSS requirements (including Tolerable Functional Failure Rate [TFFR], Safety Integrity Level [SIL] and Safety Related Application Conditions [SRAC]), standardised interfaces (on all OSI Layers) towards other building blocks and/or external systems.

  Building Blocks are separately sourceable from different suppliers and capable of being integrated by a third party.

  There are two types of building blocks: a) Hardware Building Blocks and b) Software Building Blocks.

- **Hardware Building Blocks** consist of hardware and typically software that provide the building block's functionality. They exclusively communicate with each other and with external systems through the CCS Communication Network (CCN) using standardised interfaces.

- **Software Building Bocks** consist of software that provide the building block's functionality. They are deployed on an instance of the Generic Safe Computing Platform (SCP) and shall communicate with each other through the standardised Platform Independent Application Programming Interface (PI-API). Communication with computing platform external building blocks and systems is realised by the Computing Platform (integrating with the CCN).

  Software Building Blocks are portable i.e., they may be deployed on different Computing Platform implementations.

A modular CCS-OB architecture, consisting of building blocks as per the definition above, allows for individual exchangeability (interchangeability) and migrateability (upgradeability) of the building blocks.

Exchangeability (Interchangeability) is the ability to replace one or multiple building blocks with (a) respective building block(s) of (an)other supplier(s), without affecting other building blocks of the train or the overall CCS on-board system.

Migrateability (Upgradability) is the ability to introduce changes to one or multiple building blocks, without affecting other building blocks or the overall CCS on-board system.

To improve maintainability and availability of any system, the number of hardware elements should be kept at a minimum. To reduce the number of hardware elements needed for a CCS On-Board (CCS-OB) system, functionality should be implemented in software applications rather than as functionality running on dedicated hardware.

Once functionality is implemented in software applications (software building blocks) the portability (platform independence) of the software building becomes a requirement to continue ensuring exchangeability (interchangeability).

Portability (Platform Independence) is achieved when a functional application, based on the generalized abstraction, runs un-changed on different (computing) platform implementations. For this, the functional application shall only use external functions through a defined application programming interface (API).

To further improve the maintainability and to protect the investments, the CCS-OB must be evolvable. To ensure evolvability (flexibility) of the CCS-OB system, a standardized communication infrastructure and well defined, open interfaces of all the building blocks are needed.

Evolvability (Flexibility) is the ability to extend the functionality of an CCS On-Board system without the involvement of the original supplier and to easily adopt to new technologies.

Modularity with the purpose of having “plug and play”-like exchangeability as defined in the OCORA context, requires detailed interface specifications as well as harmonised requirement specifications (functional and non-functional) for all identified building blocks.

Defining and maintaining these interface and requirement specifications to the level needed for the desired “plug and play”-like exchangeability, requires a substantial effort. Therefore, the number of building blocks need to be a result of a well-balanced analysis of the effort needed to develop and maintain the respective specifications against the business needs (expected benefits).

Due to the high effort needed to develop the necessary interface and requirement specifications, a roadmap on how the modularity can evolve is essential.

This document proposes the modularisation of CCS-OB and its roadmap. OCORA believes that the proposed number of building blocks is reasonable, and the roadmap provides an evolvable path, protecting the investments of the industry and the railways alike.

The target dates proposed for the different steps refer to when the corresponding specifications are available for building prototypes. The final specifications would be available a few years later. Considering the typical TSI CCS transition regime of up to 7 years, the availability of the functionality on the market can be up to 10 years after the proposed target dates for the specifications. Considering this, the proposed roadmap is challenging but feasible.

2 ETCS / CCS-OB modularisation as per the TSI CCS

The ETCS system specifications require that the ETCS system is split in two subsystems: the ETCS On-Board (ETCS-OB) and the ETCS Trackside (ETCS-TS). These two subsystems are separately sourceable from different suppliers. Hence, they are in line with the OCORA definition for building blocks and prove the feasibility of splitting a system with high SIL into separate subsystems, sourceable from different suppliers.

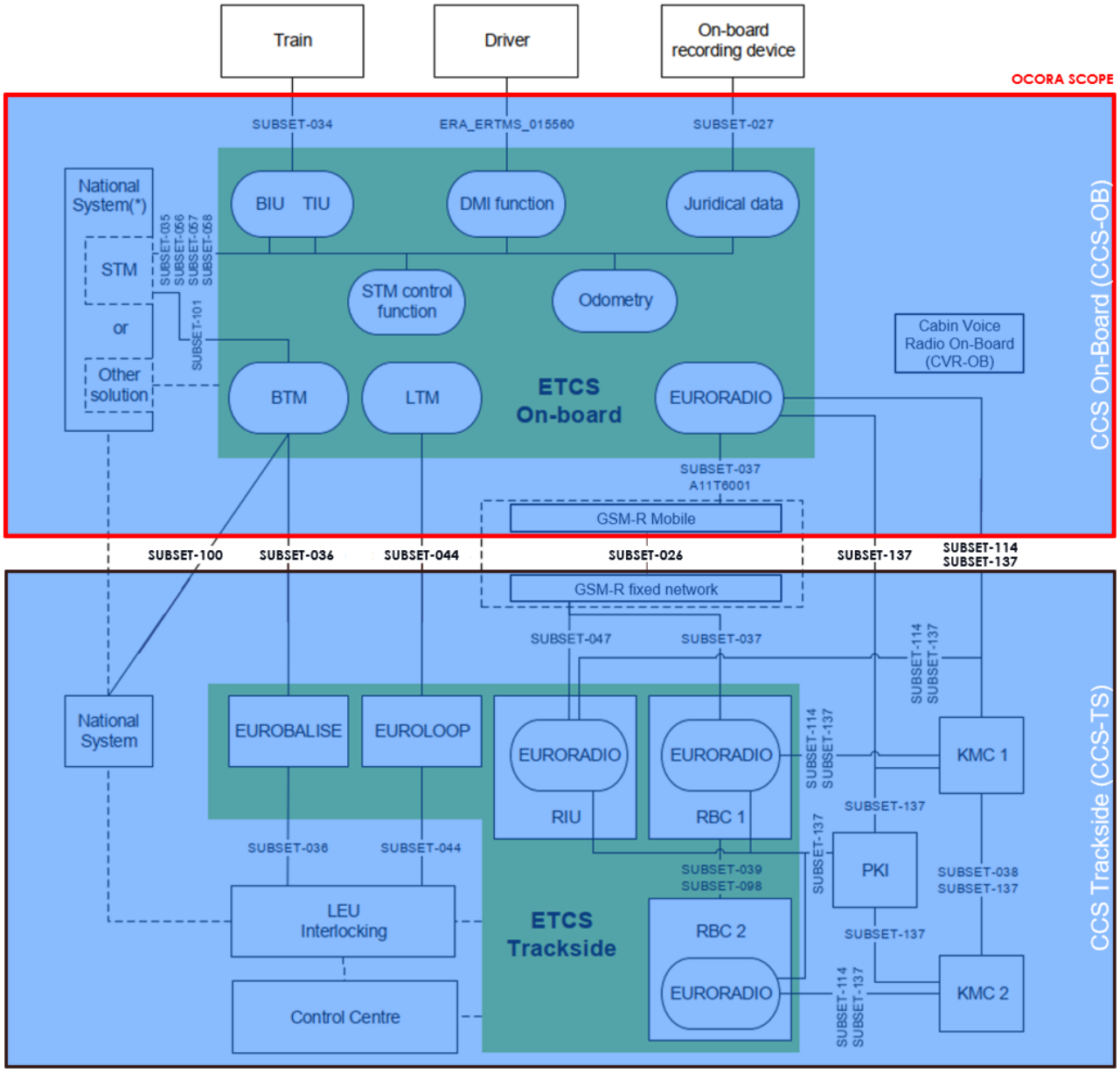

Figure 1: ETCS / CCS-OB modularisation as per the TSI CCS

OCORA is focussing on the onboard architecture. Therefore, the following chapters of this document are addressing the CCS On-Board (CCS-OB) and its modularisation.

2.1 CCS-OB modularisation as per TSI 2016, amended in 2019 & 2020

The TSI CCS 2016 with its specifications of the ETCS On-Board (ETCS-OB) system foresees a certain modularity of the CCS-OB. For that reason, interfaces between the ETCS-OB and the Specific Transmission Module (STM), the Rolling Stock, and the GSM-R Modem (EDOR) are specified.

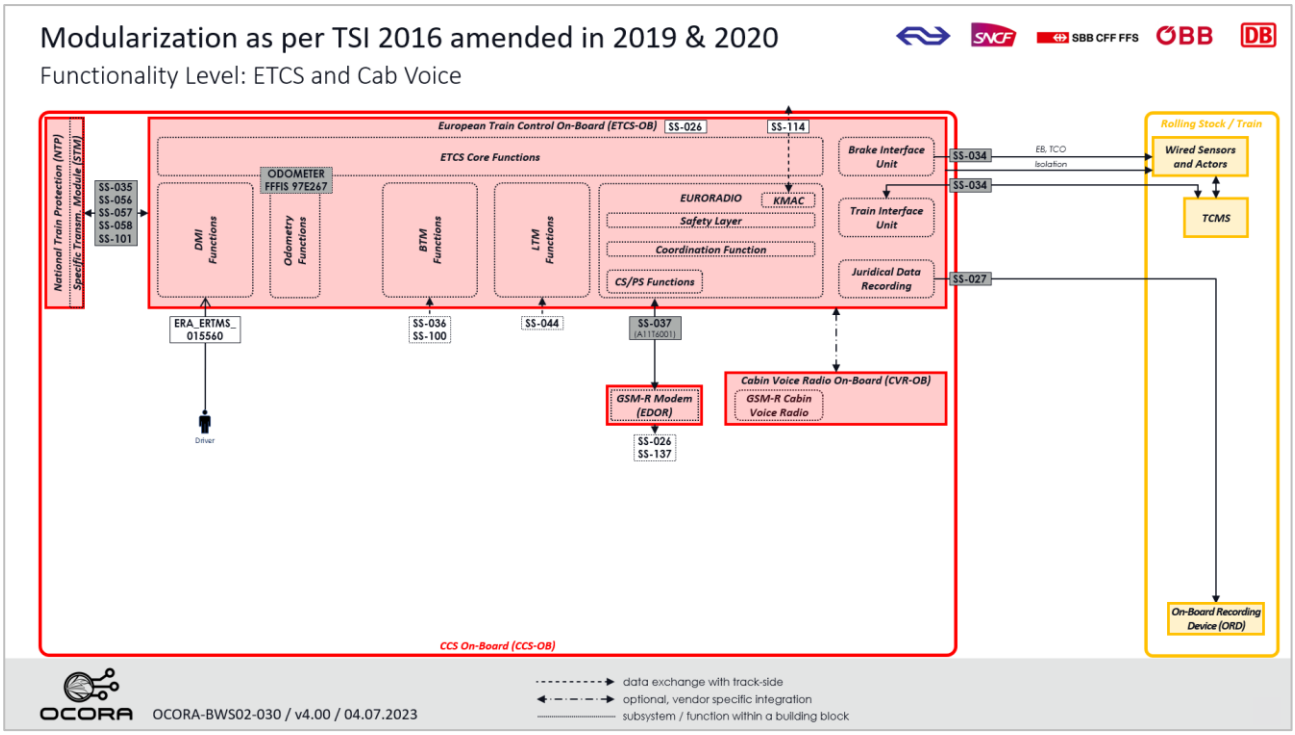

Figure 2: CCS-OB modularisation as per TSI 2016, amended in 2019 & 2020

There is a mandatory Form-Fit-Function Interface Specification (FFFIS) between the ETCS-OB and the STM (SUBSET-035, SUBSET-056, SUBSET-057, SUBSET-058, SUBSET-101). This allows the NTP to be consider a building block, following the definition of OCORA.

There is a mandatory Functional Interface Specification (FIS) between ETCS-OB and the Rolling Stock (SUBSET-034, SUBSET-027). A more detailed specification is also available (SUBSET-119). However, this specification is ambiguous and is missing details. In addition, it is listed in the application guide as informative specification only. As a result, upgrading a vehicle with ETCS functionalities or updating an already existing ETCS system on a vehicle can be cumbersome and may need substantial involvement of the original train / ETCS / TCMS manufacturer/supplier.

There is a mandatory Functional Interface Specification (FIS) between the ETCS-OB and the GSM-R Modem (SUBSET-037). As a result, exchangeability (interchangeability) between ETCS-OB and the GSM-R Modem, as per the definition of OCORA, is not reached. Hence, the GSM-R Modem (EDOR) cannot be considered a building block as per OCORA's definition.

There are no standardized interface specifications available between ETCS-OB and Cabin Voice Radio On-Board (CVR-OB) since there is no essential need. However, some train manufacturers/vendors integrated the CVR through vendor specific interfaces. While standalone CVR system can be considered CCS-OB building blocks as per the definition of OCORA, CVR-OBs with vendor specific implementations are not.

The TSI CCS 2016 also includes a Form-Fit-Function Interface Specification (FFFIS) to implement the odometry functions in a separate building block. But this specification is only referenced in the application guide as informative specification. Therefore, it is not mandatory and not necessarily implemented by the manufacturers. Hence, the Odometry is integral part of the ETCS-OB and not a separate building block.

2.2 CCS-OB modularisation as per TSI 2023

The modularity concept of the TSI CCS continues to evolve with the TSI CCS 2023. Most notably, there is a heavily improved mandatory specification of the interface between the ETCS-OB and the Rolling Stock (SUBSET-119) and a first version of the CCS Consist Network specification (SUBSET-147).

The TSI CCS distinguishes in the transition regime, among others, between “existing vehicle designs” and “newly developed vehicle designs, requiring first authorisation”. There are also many other transition regimes, depending on the TSI change. Figure 3 identifies the building blocks for “newly developed vehicle designs, requiring first authorization”. The yellow marked components (square boxes), functions (rounded boxes), and interfaces identify the differences between TSI CCS 2016 and TSI CCS 2023.

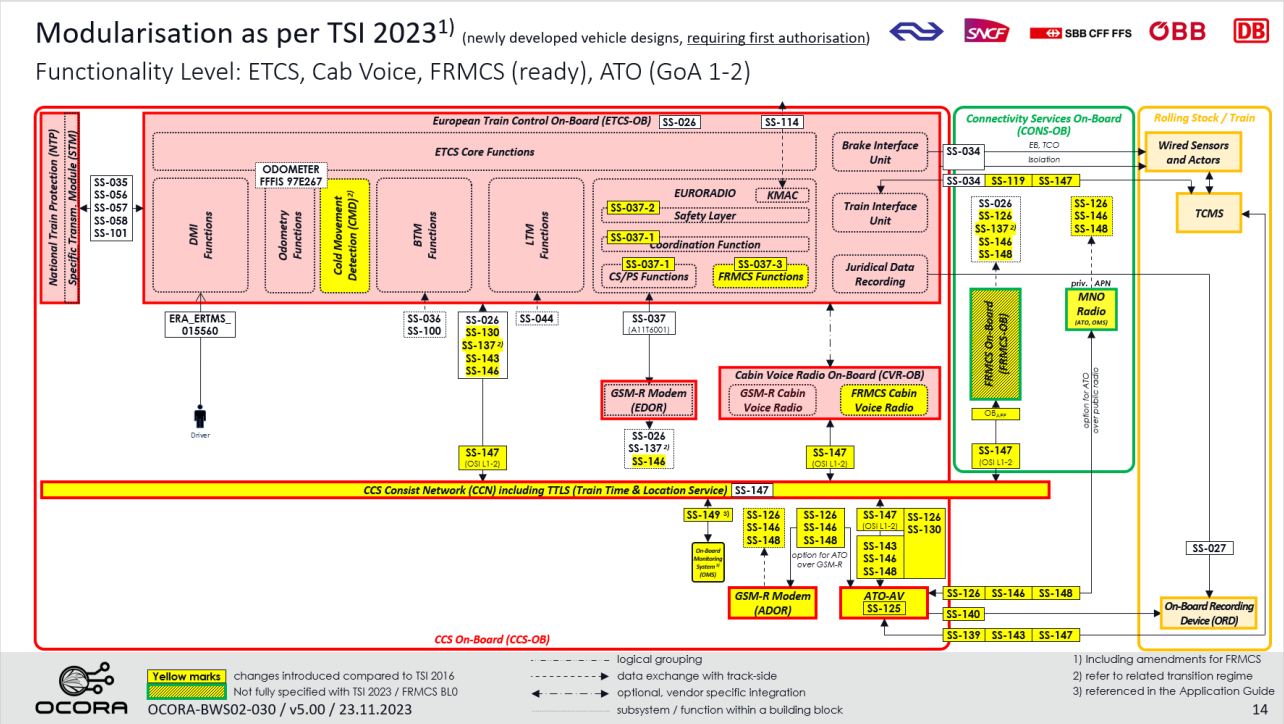

Figure 3: CCS-OB modularisation as per the TSI 2023 – newly developed vehicle designs

Remark: the FRMCS On-Board is not sufficiently specified with the TSI 2023 / FRMCS BL0 to allow for the respective product development. Amendments to the TSI CCS 2023 are expected to be published in the years 2024 through 2027 to close this gap. The graphic above shows the expected architecture, once the amendments are available.

As a result of the transition regime, vehicles ordered based on the TSI 2023 may embed different CCS-OB implementations, depending on whether the supplier uses an “existing vehicle design” or decides for a “newly developed vehicle design, requiring first authorisation” and depending on the TSI CCS adaptation strategy the supplier is following (early adapters vs. late adapters).

Figure 4 identifies the minimum changes (yellow marked components, functions, and interfaces) between the TSI 2016 and 2023 in case the supplier is using an “existing vehicle design” and follows a “late adaptation” strategy of the TSI CCS.

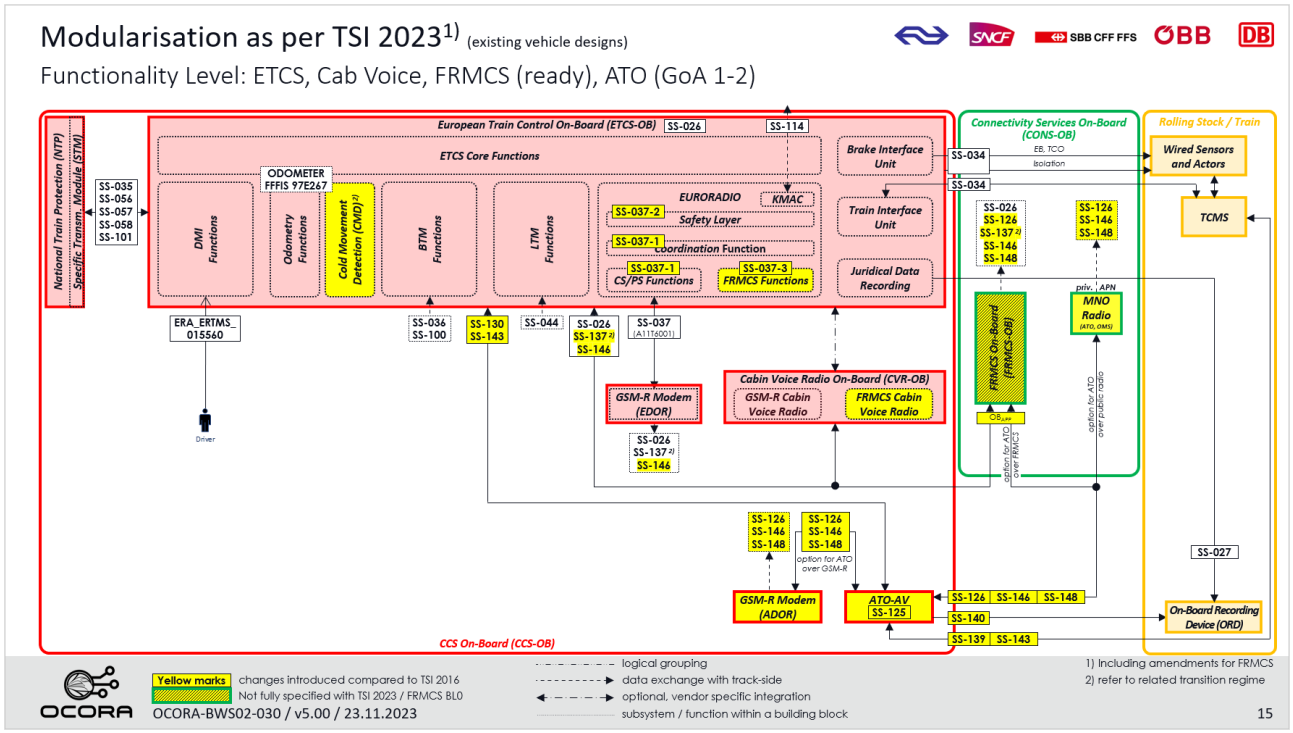

Figure 4: CCS-OB modularisation as per the TSI 2023 – existing vehicle designs

The main differences between Figure 3 and Figure 4 is the missing CCS Consist Network (CCN), which is the basis for the modularity of future CCS-OB solutions. Also, the missing SUBSET-119 is a key difference, hindering a more simplified replacement of the ETCS-OB in the future.

If exchangeability, migrateability and evolvability is important for a railway undertaking, respective requirements must be formulated when tendering a vehicle, an ETCS upgrade of a vehicle or an ETCS update.

OCORA is in the process to prepare the respective requirements that can be used by tendering organisations to consider the points above. This allows to simplify the tender preparation and should reduce the variety of the solutions the industry needs to prepare/provide. The requirements will be provided in the OCORA release R5, scheduled for December 2023.

3 OCORA modularisation proposal for new vehicles

This section is addressing "new vehicles" (newly purchased vehicles) and not the upgrades of vehicles with ETCS functionality or updates of the ETCS on vehicles in operation. For those cases refer to chapter 4.

When purchasing "new vehicles", they can either be based on an "existing vehicle designs" or on a "newly developed vehicle designs, requiring first authorisation" (refer to chapter 2). In this section, we assume that "new vehicles" are based on the TSI CCS 2023 architecture required for "newly developed vehicle designs, requiring first authorisation“.

OCORA is further assuming that "new vehicles" are equipped with a TCMS compliant with SUBSET-119, SUBSET-139, and SUBSET-147 (incl. OCORA addendums). If this is not the case (e.g., for re-orders with an upgrade or update of the ETCS), an adapter shall be implemented on the rolling stock side (refer to the chapter 4). In case of non-compliance with SUBSET-119 or SUBSET-139, and their OCORA addendums, this adapter is on a functional level (OSI layer 7). In case of non-compliance with SS-147 and its addendum, the adapter must convert the respective OSI layers 1 – 6.

3.1 OCORA modularisation proposal based on TSI 2023

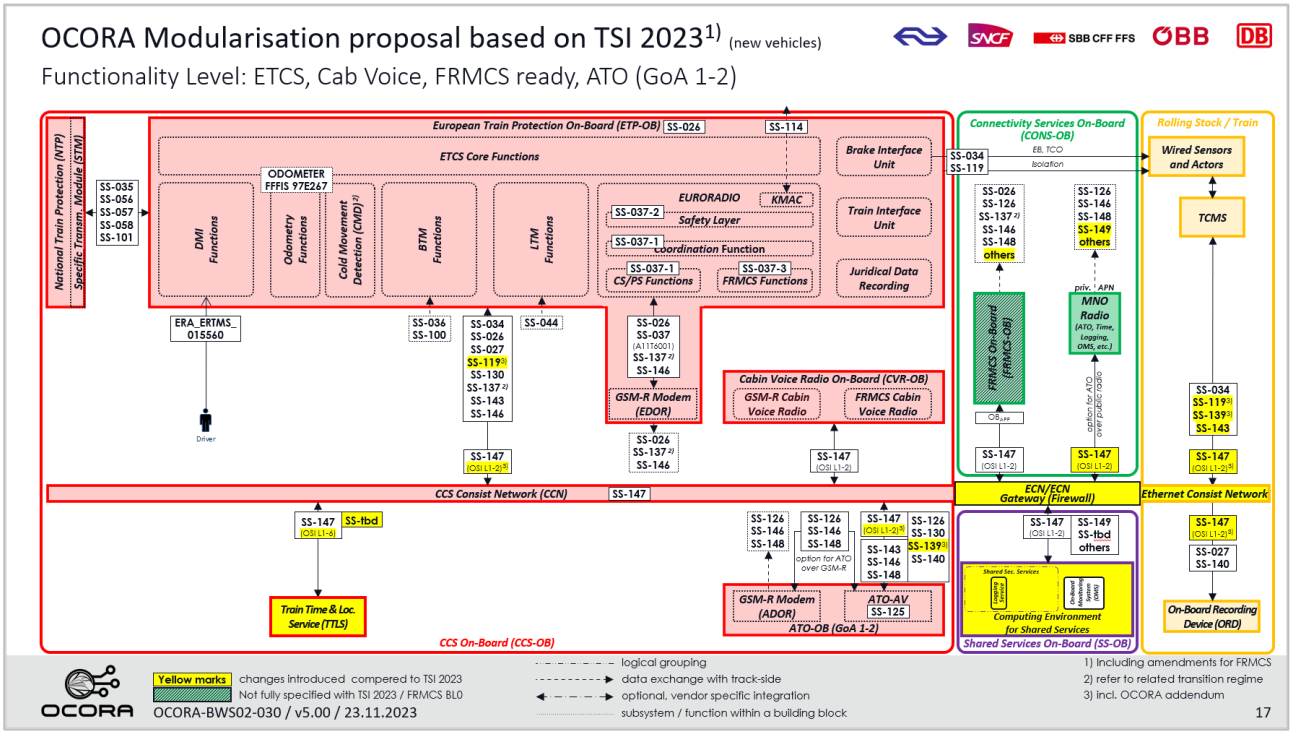

Figure 5: OCORA modularisation proposal based on TSI 2023 – new vehicles

In addition to the TSI CCS 2023 specifications, OCORA suggest considering the following aspects (highlighted in yellow) when ordering vehicles based on the TSI CCS 2023:

- SUBSET-147 unambiguously defines OSI layers 1 & 2. To ensure exchangeability of the building blocks connected to the CCN, also the OSI layers 3 – 6 need to be standardised. Hence, the OCORA addendum to SUBSET-147 (refer to document [8]) closes this gap.
- SUBSET-119 and SUBSET-139 still have some ambiguous definitions. The OCORA addendum to SUBSET-119 and SUBSET-139 (planned publishing date: OCORA release R5, December 2023) closes this gap.
- The TSI CCS 2023 leaves it to the suppliers of the vehicle, where the Time Service, the Logging Service, the Location Service and the Onboard Monitoring System is hosted. OCORA suggest hosting all these services/systems on a computing platform dedicated to run Shared Services On-Board (SS-OB).

- The TSI CCS 2023 leaves it to the suppliers of the vehicle, how the Logging Service is used. OCORA is currently evaluating, if this gap needs to be closed and how it could be addressed.
- The TSI CCS 2023 leaves it to the suppliers of the vehicle, how the Location Service is used by applications (e.g. by OMS, FRMCS-OB). The protocols and the date format is not defined. OCORA is planning to update the OCORA addendum to SUBSET-147 (refer to document [8]) to closes this gap.
- While the communication of the OMS with the trackside is defined in SUBSET-149, the respective potential communication for the Logging Service, and the Location Service are not defined in the TSI CCS 2023. OCORA is currently evaluating, if this gap needs to be closed and how it could be addressed.
- The communication of the Time Service with the trackside is ambiguously defined in SUBSET-147. OCORA is planning to update the OCORA addendum to SUBSET-147 (refer to document [8]) to closes this gap.
- To address cyber security aspects, OCORA recommends introducing an ECN/ECN gateway with firewall functionality to connect the CCS On-Board (CCS-OB) with the Connectivity On-Board (CONS-OB), the Rolling Stock/Train, and the Shared Services On-Board (SS-OB).
- The TSI CCS 2023 leaves it to the supplier of the vehicle, how the Onboard Recording Device (ORD) connects with the CCS On-board. OCORA suggest connecting the ORD via the mentioned ECN/ECN gateway.
- The TSI CCS 2023 does not specify, how the Train Control and Management System (TCMS) connects with the CCS On-board. OCORA suggest connecting the TCMS via the mentioned ECN/ECN gateway. The Emergency Brake (EB), the Traction Cut-Off (TCO), and the isolation remain hard-wired.

OCORA is in the process to compile the respective requirements that can be used by tendering organisations to consider the points above. This allows to simplify the tender preparation and should reduce the variety of the solutions the industry needs to prepare/provide. The requirements will be provided in the OCORA release R5, scheduled for December 2023.

3.2 OCORA modularisation proposal based on TSI >2023

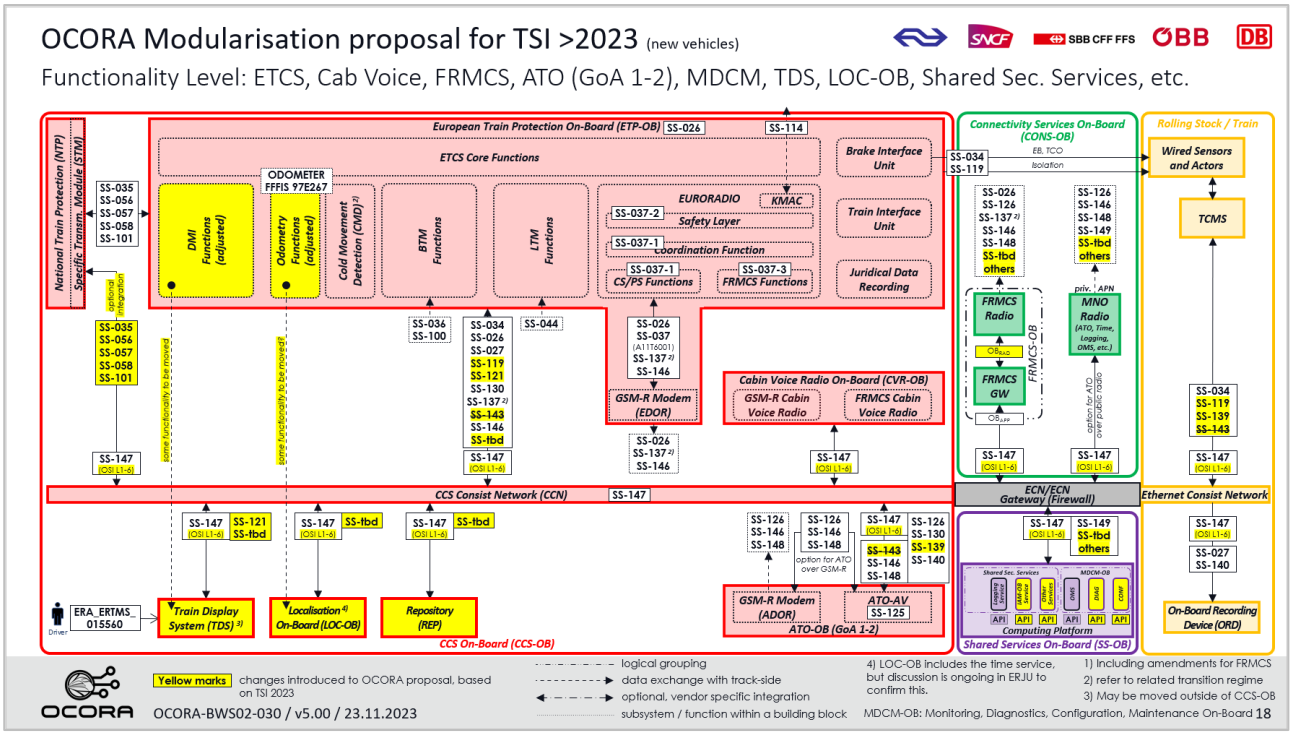

Figure 6: OCORA modularisation proposal based on TSI >2023 – new vehicles

OCORA suggest considering the following aspects (highlighted in yellow) for the TSI CCS >2023:

- The CCS Consist Network (CCN) is not fully specified in the TSI CCS 2023. To ensure exchangeability of the building blocks connected to the CCN, also the OSI layers 3 – 6 need to be standardised. The points addressed in OCORA addendum to SUBSET-147 (publishing date: OCORA release R4, July 2023) shall be used to finalise the specifications. Also, SUBSET-143 shall be fully integrated in SUBSET-147.
- The SUBSET-119 and SUBSET-139 still leave some room for interpretation. The points addressed in OCORA addendum to SUBSET-119 and SUBSET-139 (planned publishing date: OCORA release R5, December 2023) shall be used to finalise the specifications.
- Today, the interface between the EVC and STM is based on a Profibus FDL interface (EN50170, lower layers). Only the lower Profibus layers are used for the communication. This is very specific, therefore only a very limited number of components is supporting this railway specific usage. The Profibus standard is obsolete (withdrawn) while a new common CCS Consist Network will be mandatory for CCS components in newly developed vehicle designs (SUBSET-147). It is expected that NTPs / STMs will need to be supported for more than 25 years. Therefore, existing STMs need to be redeveloped due to obsolescence reasons. OCORA suggests: the Profibus between ETCS and STM should remain valid while the new CCS Consist Network according to SUBSET-147 should become mandatory for newly developed STMs. ETCS shall still support the Profibus interface during a transition period.
- The introduction of a Train Display System (TDS) that can be used by different applications (e.g. ETCS, TCMS, CVR, DAS, etc.). To what extend functionality has to be moved from the ETCS into the TDS, needs to be analysed (refer also to OCORA-TWS01-201 – Train Display System – Discussion Paper).
- The introduction of a Localisation On-Board (LOC-OB) system to provide continues, absolute safe train position functionality. To what extend odometry functionality needs to be moved from the ETCS into the LOC-OB, needs to be analysed.
- The introduction of a repository (digital map) to support continues, absolute safe train positioning.
- The FRMCS Radio is expected to have a different lifespan than the FRMCS gateway and the railway undertakings want to be able to separately source the FRMCS Radio. Therefore, the splitting the FRMCS-OB in two building blocks, separated by a standardized OB_{RAD}, should be envisioned.
- The introduction of Identity- and Access Management (IAM), Diagnosis- (DIAG) and Configuration (CONF) services.

OCORA is working with the ERJU System Pillar and Innovation Pillar to address the above points.

3.3 OCORA modularisation proposal based on TSI >>2023

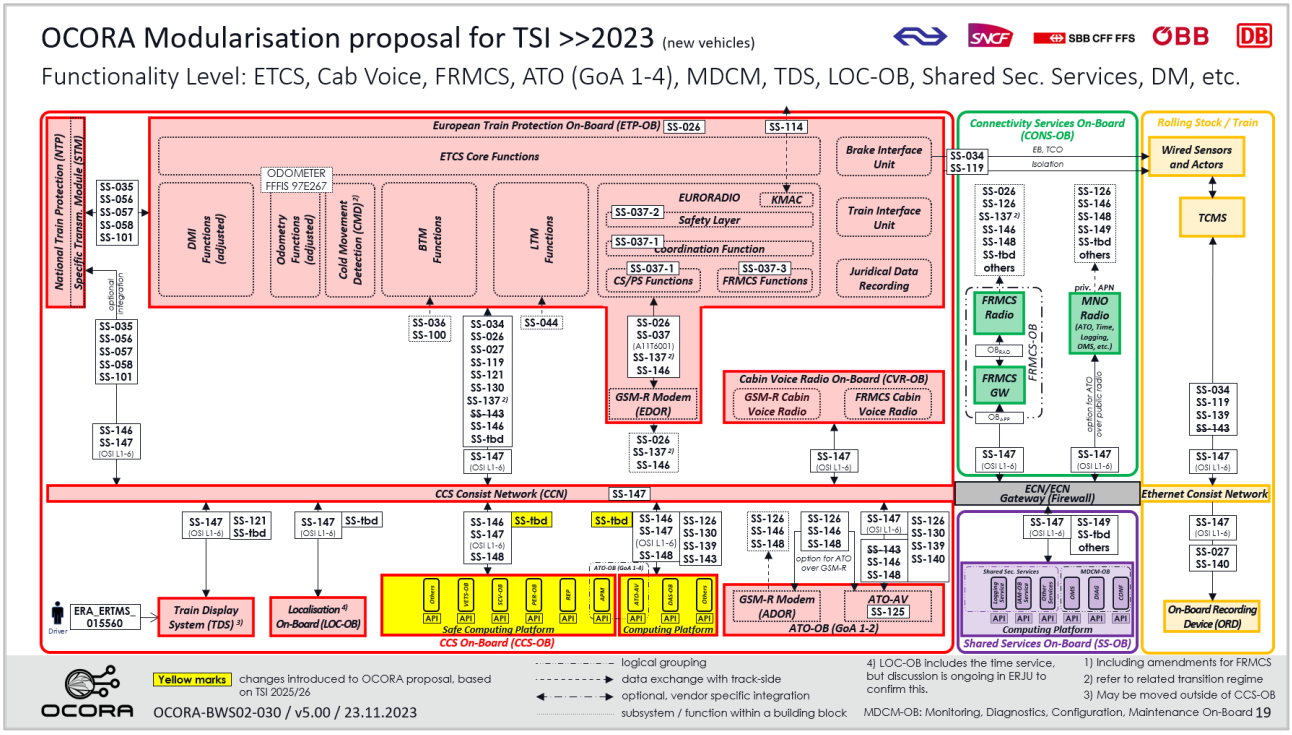

Figure 7: OCORA modularisation proposal based on TSI >>2023 – new vehicles

OCORA suggest considering the following aspect (highlighted in yellow) for the TSI CCS >>2023:

- The introduction of a Computing Platform and a Safe Computing Platform, allowing to deploy functionality as software applications without the need for dedicated hardware. Refer also to documents [9], [10], and [11] for more details.
- A standardise API would be needed to continue to support exchangeability (interchangeability) of functionality (applications) that is (are) deployed on the Computing Platform.
- The Computing Platform and a Safe Computing Platform support a simplified deployment of new functionality such as:
  a) Virtual ETCS Transponder Service On-Board (VETS-OB)
  b) Signal Converter On-Board (SCV-OB)
  c) Perception On-Board (PER-OB
  d) Automatic Processing Module (APM)
  e) Driver Advisory System On-Board (DAS-OB)

OCORA is working with the ERJU System Pillar and Innovation Pillar to address the above points.

3.4 OCORA modularisation vision

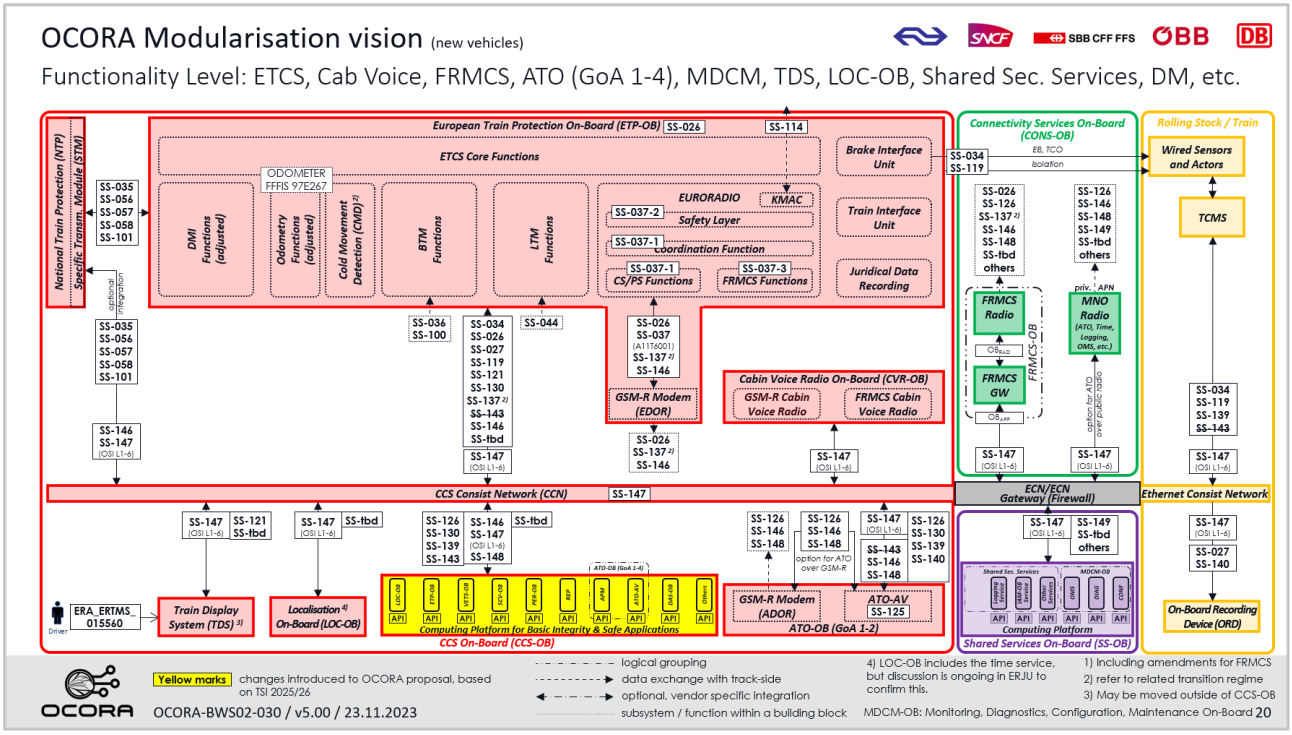

Figure 8: OCORA modularisation vision – new vehicles

OCORA suggest considering the following aspect (highlighted in yellow) as a vision for the future:

- To make better use of hardware resources, the introduction of a combined Computing Platform for Basic Integrity (BI) and Safe applications must be envisioned. Refer also to documents [9], [10], and [11] for more details.
- ETCS core functions such as the ETP-OB and the LOC-OB can also be deployed on a combined BI/Safe Computing platform.

The OCORA collaboration is working with the ERJU System Pillar and Innovation Pillar to address the above points.

4 OCORA modularisation proposal of vehicles in operations

This section is addressing "vehicles in operation" in need of an "ETCS upgrade" or "ETCS updates". An "ETCS upgrade" refers to the 1st installation of an ETCS system on a vehicle while the “ETCS updates” refers to updating a vehicle with a newer version of ETCS.

"Vehicles in operation" can include re-orders of vehicles with the need for an "ETCS upgrade" or "ETCS update".

OCORA is assuming that "vehicles in operations" are not equipped with a TCMS compliant with SUBSET-119, SUBSET-139, and SUBSET-147 (incl. OCORA addendums).

Deploying an ETCS or updating an ETCS on a "vehicle in operation" requires adapting to the specifics of the vehicle and/or its already existing ETCS system. OCORA suggests, that all the needed adaptations are implemented on the rolling stock side. Refer to the Functional Vehicle Adapter (FVA) and the Wired I/O Control (WIOC) in Figure 9. This allows to limit the variety of the ETCS systems, reducing development, integration, and maintenance efforts. However, other solutions may be more economical for certain "vehicles in operation".

4.1 OCORA modularisation proposal based on TSI 2023

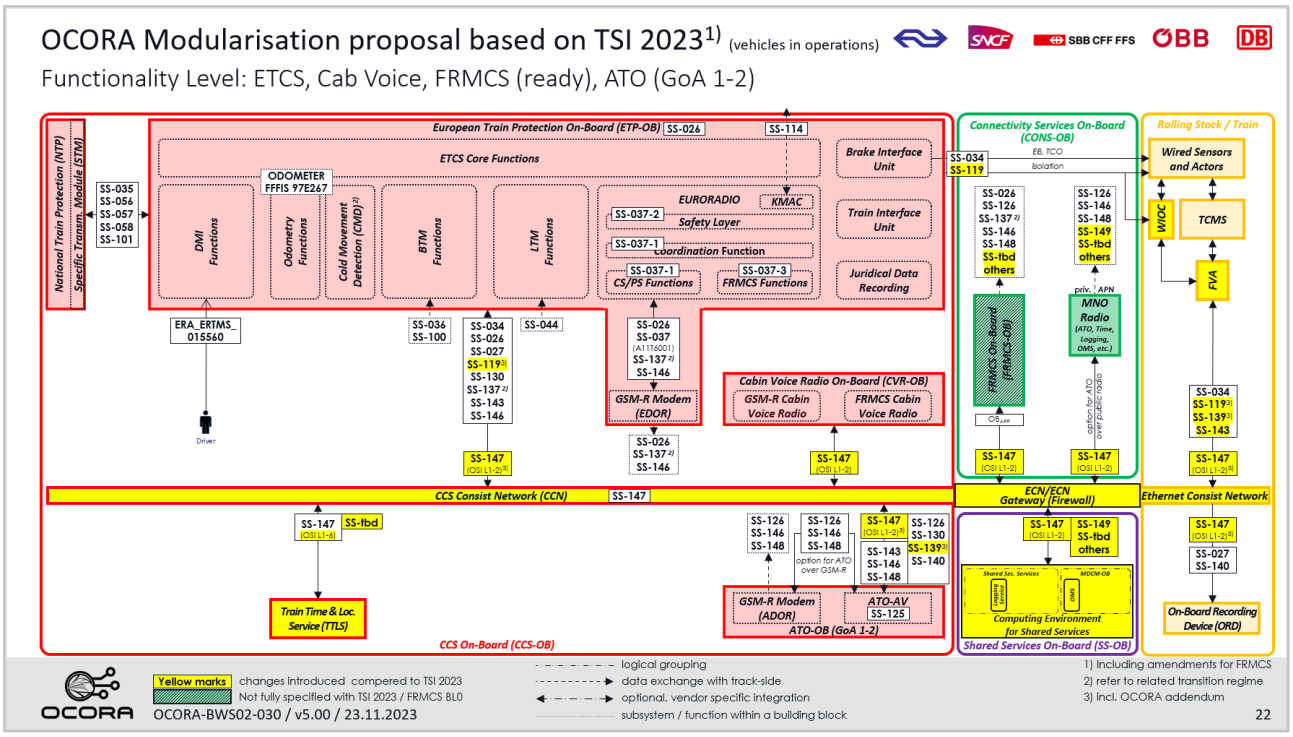

Figure 9: OCORA modularisation proposal based on TSI 2023 – vehicles in operations

In addition to the TSI CCS 2023 specifications, OCORA suggests considering the following aspects (highlighted in yellow) when ordering "ETCS upgrades" or "ETCS updates" based on the TSI CCS 2023:

- The needed adaptations to the specifics of the vehicle are implemented on the rolling stock side. For that reason, a Functional Vehicle Adapter (FVA) and the Wired I/O Control (WIOC) is implemented. This allows to limit the variety of the ETCS systems, reducing development, integration, and maintenance efforts.
- SUBSET-147 unambiguously defines OSI layers 1 & 2. Layers 3 – 6 are not unambiguously defined. Hence, the OCORA addendum to SUBSET-147 (publishing date: OCORA release R4, July 2023) closes this gap.
- SUBSET-119 and SUBSET-139 still have some ambiguous definitions. The OCORA addendum to SUBSET-119 and SUBSET-139 (planned publishing date: OCORA release R5, December 2023) closes this gap.

- The TSI CCS 2023 leaves it to the suppliers of the vehicle, where the Time Service, the Logging Service, the Location Service and the Onboard Monitoring System is hosted. OCORA suggest hosting all these services/systems on a computing platform dedicated to run Shared Services On-Board (SS-OB). While the communication of the OMS with the trackside is defined in SUBSET-149, the respective potential communication for the Time service, the Logging and the Locations Service are not defined in the TSI CCS 2023. OCORA is currently evaluating, if and how this gap can be addressed.
- To address cyber security aspects, OCORA recommends introducing an ECN/ECN gateway with firewall functionality to connect the CCS On-Board (CCS-OB) with the Connectivity On-Board (CONS-OB), the Rolling Stock/Train, and the Shared Services On-Board (SS-OB).
- The TSI CCS 2023 leaves it to the supplier of the vehicle, how the Onboard Recording Device (ORD) connects with the CCS On-board. OCORA suggest connecting the ORD via the mentioned ECN/ECN gateway.
- The TSI CCS 2023 does not specify, how the Train Control and Management System (TCMS) connects with the CCS On-board. OCORA suggest connecting the TCMS via the mentioned ECN/ECN gateway. The Emergency Brake (EB), the Traction Cut-Off (TCO), and the isolation remain hard-wired.