OCORA

Open CCS On-board Reference Architecture

Localisation On-Bord (LOC-OB)

Introduction

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Revision history

Version	Change Description	Initial	Date of change
1.01	Official version for OCORA Release R1	SM	03.12.2021
2.20	Version for OCORA Release R2	SM	24.06.2022

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-TWS01-035 – CCS On-Board – Architecture

[8] OCORA-TWS01-101 – Localisation On-Board (LOC-OB) – Requirements

[9] EUG-21E109 – Vehicle Locator Concept Architecture, LWG, version 1.0, 2021-07-15

[10] RCA.Doc.40 – RCA Poster, BL0, R2, Version 0.2 (0.B), Sprint 22, 2021-05-27

[11] EUG-22E126 – LOC-OB System Definition & Operational Context, LWG, version 1.0, 2022-05-30

[12] EUG-22E135 – LOC-OB Risk Analysis, LWG, version 1.0, 2022-05-30

1 Introduction

1.1 Purpose of the document

The purpose of this document is to give an overview of the envisioned OCORA Localisation On-Board (LOC-OB) system, to provide useful information to railway undertakings (RUs) in terms of preparing OCORA/RCA compliant tenders, and to prepare for Europe's Rail Joint Undertakings System & Innovation Pillar.

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].

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

If you are an organisation interested in developing on-board CCS building blocks according to the OCORA standard, information provided in this document can be used as input for your development.

1.2 Applicability of the document

The document is considered informative for OCORA compliant on-board CCS solutions. 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]. 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].

This document is an introduction to OCORA's Localisation On-Board (LOC-OB). A more detailed view on the LOC-OB system is described in document [11] and further information, especially the requirements LOC-OB has towards some of its actors and a first set of system requirements for LOC-OB, can be found in document [8]. A first version of the LOC-OB Risk analysis can be found in document [12].

2 Goals of the OCORA Localisation On-Board (LOC-OB)

2.1 Definition / Involved components / System context

The OCORA component Localisation On-Board (LOC-OB) consists of the Vehicle Locator (VL) and the Vehicle Locator Sensors (VLSs).

In the context of the concept architecture [9] published by the Localisation Working Group (ERTMS Users Group), the LOC-OB consists of the Vehicle Locator (VL) and the train-based Sensor Data.

2.1.1 Vehicle Locator (VL)

The Vehicle Locator (VL) is a safe CCS On-Board logical component that uses sensor data and supporting information to provide train location output information safely and reliably. The Vehicle Locator (VL) is able to provide the absolute and relative position of the front end of the train, train orientation information as well as kinematic parameters such as speed, acceleration, or rotational angles; hence, the VL is more than just a logical odometry component.

2.1.2 Vehicle Locator Sensors (VLS)

This logical component includes the functionality the locator sensors are providing. For example, Sensor Data (train-based) can be grouped into the following (non-exhaustive) types [9]:

- GNSS Receiver. Autonomous geo-spatial positioning and time information based on satellite navigation systems.
- Inertial sensors. Provides the specific force, angular rate, and the orientation of the body by using a combination of accelerometers and gyroscopes.
- Rotational sensors. Provides speed (e.g., tachometer, speed probe) and travelled distance (e.g., wheel revolution counter) measurements.
- Radar-based sensors. Distance and speed measurements, e.g., doppler radar, LiDAR, LGPR. May also be used to determine position information if used along with a sensor map.
- Optical sensors. Sensors based on image acquisition and analysis to recognise known elements from trackside that may be referenced if used along with a sensor map, e.g., visual odometry, object recognition.
- Other sources. Other not explicitly identified sensor data sources gathered/measured on-board that may provide useful input information to the VL (e.g., radio-based technologies like FRMCS, WLAN, Ultra-Wideband).

2.2 Why separating localisation from ETCS core?

In today's ETCS implementations, the LOC-OB functionality is part of the monolithic ETCS On-Board Unit. Since innovation cycles for the LOC-OB are expected to occur more frequently than for the remaining part of the ETCS On-Board Unit (e.g., Automatic Train Protection - On-Board (ATP-OB)), it is essential that the LOC-OB is a separate logical component, containing just the functionality needed to locate safely and reliably the train and its orientation on the track and determining associated kinematic parameters of the vehicle. With a separation of the LOC-OB functionality, guiding principles such as modularity and single-responsibility are fulfilled leading to reduced complexity in terms of testing and certification of conformity. Standardising the external interfaces of LOC-OB allows to leverage new localisation technologies in the future without the need to modify the remaining part of the ETCS On-Board functionality. Moreover, the LOC-OB architecture intends to break the strong coupling of the on-board ETCS logic and balise technology (LRBG) to allow vendors to produce industry-independent localisation products by adhering to the standardised interfaces.

These are very important aspects, since the LOC-OB is requiring a safe implementation and already many changes for the CCS on-board, impacting the LOC-OB, are foreseeable. New functionalities (game changers) with potential impact on the LOC-OB are:

- FRMCS
- ATO
- Train integrity detection for ETCS L3
- GNSS augmentation
- Digital map

It is the goal of the OCORA architecture team to build a LOC-OB model that is mostly agnostic to these changes, and where not possible, does already consider the upcoming changes in the design. Further details will be provided in subsequent versions of the OCORA architecture documentation.

Appendix B of document [7] contains, on a very high-level, a first proposed split of functionality between the VS, and VL, based on SUBSET-026, chapter 4.5. The OCORA architecture team is aware that splitting the functionality only based on the SUBSET-026, chapter 4.5 is not sufficient, because the subset does not provide all requirements. SUBSET-026 is providing the mandatory requirement specifications only. A more detailed separation and a first version of a VL model, identifying additional requirements to SUBSET-026, can be expected in subsequent OCORA documentation releases.

3 Localisation principles

3.1 Current ETCS localisation principles

In the current ETCS specification (see for more details SUBSET-026, chapter 3) the train position is determined always longitudinal along the route, regardless of the complexity of the track layout. The train position information defines the position of the train front in relation to a balise group. The balise group identifies a unique common reference location between the onboard and the trackside which is called last relevant balise group (LRBG). Therefore, the train position is the distance of the estimated train front end position from the last relevant balise group.

The train position information includes:

- The estimated train front end position, defined by the estimated distance between the LRBG and the front end of the train
- The train position confidence interval (sets the safety boundary for the estimated position), defined by the min/max safe front ends
- Directional train position information in reference to the balise group orientation of the LRBG (position of the train front end from the side of the LRBG, train orientation, train movement direction).

The confidence interval to the train position shall refer to the distance to the LRBG and shall consider:

- On-board over-reading amount and under-reading amount (odometer accuracy plus the error in detection of the balise group location reference)
- The location accuracy of the LRBG (Q_LOCACC)

The confidence interval increases in relation to the distance travelled from the LRBG depending on the accuracy of odometer equipment until it is reset when another balise group becomes the LRBG.

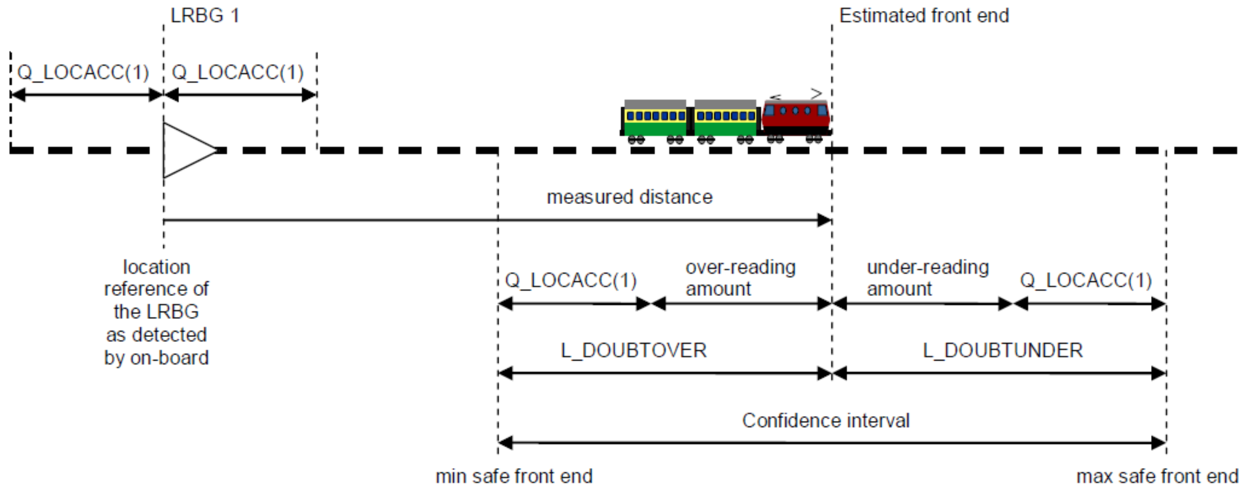


Figure 1: SUBSET-026, chapter 3, figure 13c describes how the confidence interval is calculated

The odometry system of current ETCS is based on wheel revolution counters and additional sensors (radar and/or accelerometer). The accuracy of the odometry is defined as a linear function from the last relevant balise group. The current specification for the performance of the odometry is described in SUBSET-041, chapter 5.3.1.1.

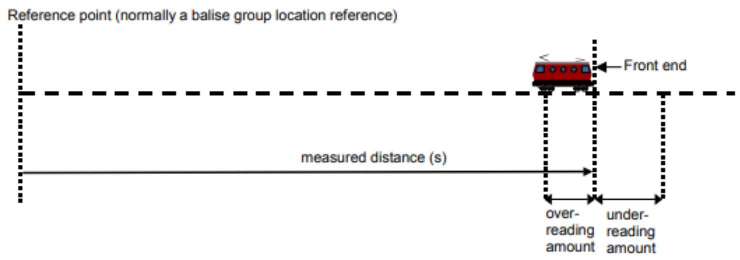
Description	Accuracy of distances measured on-board
Start Event	not applicable
Stop Event	not applicable
Value	for every measured distance s the accuracy shall be better or equal to ± (5m + 5% s), i.e. the over reading amount and the under reading amount shall be equal to or lower than (5m + 5% s). 
Notes	This performance requirement includes the error for the detection of a balise location, as defined in the Eurobalise specifications. Also in case of malfunctioning the on-board equipment shall evaluate a safe confidence interval.

Figure 2: SUBSET-041, chapter 5.3.1.1 describes the accuracy of distances measured on-board

3.2 OCORA Localisation On-Board (LOC-OB) principles

Sharing localisation information not only with ATP-OB (logical component of CCS-OB) but also with other (future) on-board actors through a standardised interface is a key objective of the LOC-OB architecture.

The LOC-OB shall provide localisation information such as 1D position relative to a reference point, orientation, speed and acceleration of the train which complies with the current ERTMS/ETCS principle (distance and orientation from a LRBG and a speed) and can also provide additional localisation information such as:

- The absolute (3D) geographic positioning (Long, Lat, Alt),
- The vector velocity within the 3D coordinate system based on the track axis,
- The vector acceleration within the 3D coordinate system based on the track axis,
- The attitude (roll, pitch, and yaw angles) of the coach where sensors are installed.

This localisation information is computed by the LOC-OB based on data provided by sensors and supporting information (e.g., digital map, augmentation data, routing information) upon availability. Refer to chapter 5 on page 11 for different implementation variants.

A more complete description of the desired localisation outputs and inputs can be found in the LOC-OB System Definition & Operational Context, chapter 5.2 and 6 [11].

For providing the 1D positioning, LOC-OB is using a reference point. As of now, the reference point is a LRBG but to take full advantage of the Digital Map, in the future, any designated point of the track on the map could be used as a reference point.

As a conclusion, the LOC-OB architecture facilitates to open the space for new sensor technologies to not least resolve the dependency to today's balises that are seen as a "single-technology choice" for reference points. Despite the tendency of reducing trackside assets such as balises and moving towards enhanced on-board localisation sensor technologies, the performance of the localisation system is seen as a key requirement to improve the capacity and the availability of the line, and shall be further improved, i.e., higher accuracy of the estimated position/speed and (more regularly) reducing the confidence interval to a minimum.

4 LOC-OB in the context of the CCS-OB architecture

Localisation On-Board (LOC-OB) contains the Vehicle Locator (VL) and Vehicle Locator Sensor (VLS) functionality. The figure below identifies the LOC-OB component in the overall CCS-OB architecture and depicts all interfaces to all currently know CCS-OB actors and CCS-OB components.

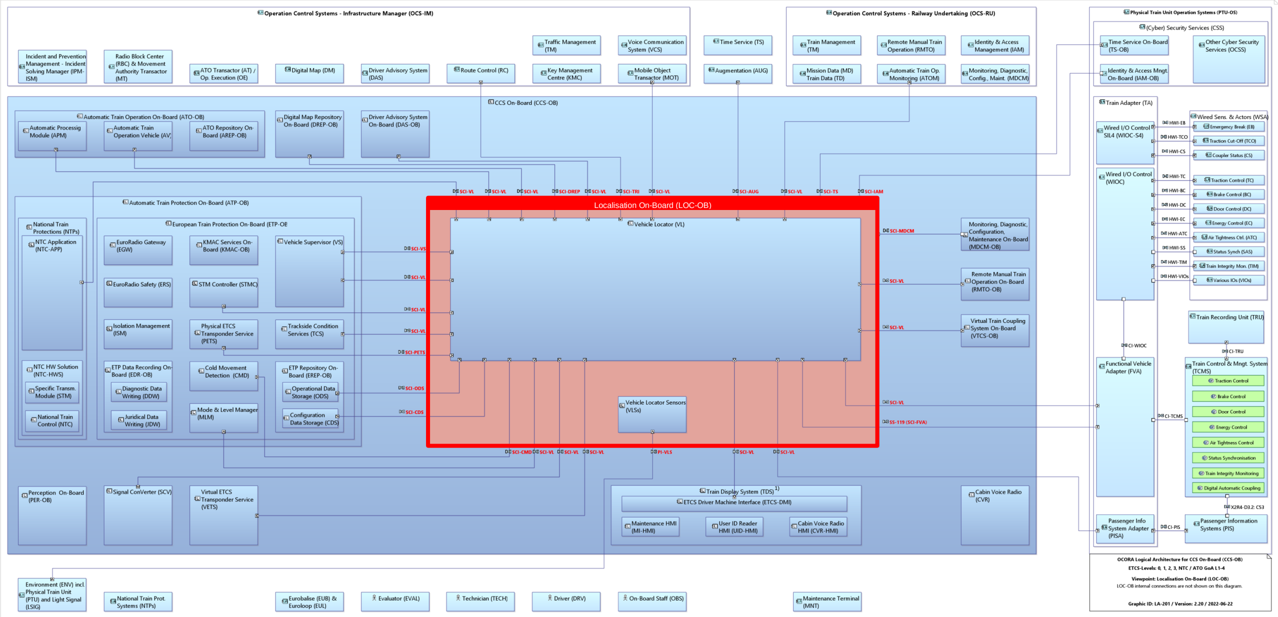


Figure 3: Localisation On-Board (LOC-OB)

Notes: refer to Appendix A1 for large scale representation
1) may be moved into the PTU-OS / LOC&PAS domain.
SS-nnn: respective subset contains information for the interface.

4.1.1 Interfaces

The following table lists all LOC-OB interfaces. Refer to Figure 3 to identify the currently foreseen LOC-OB communication partners. The interface of the type "Provider" indicates that the LOC-OB building block is providing this interface. The interface of the type "Consumer" indicates that the LOC-OB building block uses these interfaces.

Name	Description	Type
SCI-VL	Standard Communication Interface – Vehicle Locator	Provider (P)
SCI-DREP	Standard Communication Interface – Digital Map Repository	Consumer (C)
SCI-TRI	Standard Communication Interface – Train Routing Information	Consumer (C)
SCI-AUG	Standard Communication Interface – Augmentation	Consumer (C)
SCI-TS	Standard Communication Interface – Time Service	Consumer (C)
SCI-IAM	Standard Communication Interface – Identity and Access Management	Consumer (C)
SCI-MDCM	Standard Communication Interface – Monitoring, Diagnostic, Configuration, Maintenance	Consumer (C)
SS-119 (FVA)	SUBSET-119 – Functional Vehicle Adapter	Consumer (C)
PI-VLS	Perception Interface – Vehicle Locator Sensors	Consumer (C)
SCI-CMD	Standard Communication Interface – Cold Movement Detection	Consumer (C)
SCI-CDS	Standard Communication Interface – Configuration Data Storage	Consumer (C)
SCI-ODA	Standard Communication Interface – Operational Data Storage	Consumer (C)
SCI-PETS	Standard Communication Interface – Physical ETCS Transponder Service	Consumer (C)
SCI-VS	Standard Communication Interface – Vehicle Supervisor	Consumer (C)

Table 1 LOC-OB Interfaces

Note: Standard Communication Interfaces for which the LOC-OB is the service provider (P), shall be exposed on the CCN to be available to an arbitrary number of current and future applications.

5 Implementation variants

In this section, the impact of inputs considered not mandatory for the LOC-OB system for OCORA Release R2 are briefly analysed and discussed. Despite declaring some components as “not mandatory” hereafter, LOC-OB must achieve at least the performance as specified today in SUBSET-026 and SUBSET-041 for backward compatibility purposes.

The table is to be read as follows: *What is the impact/limitation on the LOC-OB system* *with* *or* *without* *“xyz” (e.g., TIS) information available.*

Component	With	Without
Train Integrity Status Management (TIS)	Safe train length and train integrity status from the Train Integrity Status Management (TIS) are critical inputs for LOC-OB to facilitate “cab anywhere supervision” in the future.	The LOC-OB must be physically located in the very first (leading) vehicle if the train can potentially be separated.
Digital Map On-Board (DM-OB) and Train Routing Info (TRI)	Digital maps together with Routing Information can be used as supporting information by the sensor fusion logic of the LOC-OB to fix positioning errors arising in GNSS/INS sensors (e.g., due to the gradient and curve of the tracks) and in general to improve the LOC-OB positioning performance when using GNSS/INS sensors. In addition, digital maps are considered as critical inputs needed by LOC-OB for safe absolute train positioning.	Errors arising in GNSS/INS sensors (e.g., due to gradient and curve of the tracks) cannot be properly addressed and might adversely impact the LOC-OB positioning performance.
Cold Movement Detection (CMD)	The last stored position and movement indicator provided by CMD is used to shorten the time needed to initialize the LOC-OB system after awakening from a non-power mode. Note: In the future, if the LOC-OB is ‘always ON’ then the CMD may not be necessary.	Increased initialisation time of the LOC-OB system until safe and preferably accurate localisation output is produced.
Augmentation (AUG)	A LOC-OB that uses GNSS sensors for safe absolute train positioning needs GNSS augmentation data (e.g., EGNOS) in order to improve the positioning accuracy and the safety logic.	Both safety and positioning performance of the safe absolute train positioning output of LOC-OB, making use of GNSS sensors, will be adversely impacted if no GNSS augmentation service is available/used.

Table 2 Implementation variants describing the impacts of the optional LOC-OB actors

Appendix A Large scale graphics

A1 Localisation On-Board (LOC-OB) – logical architecture

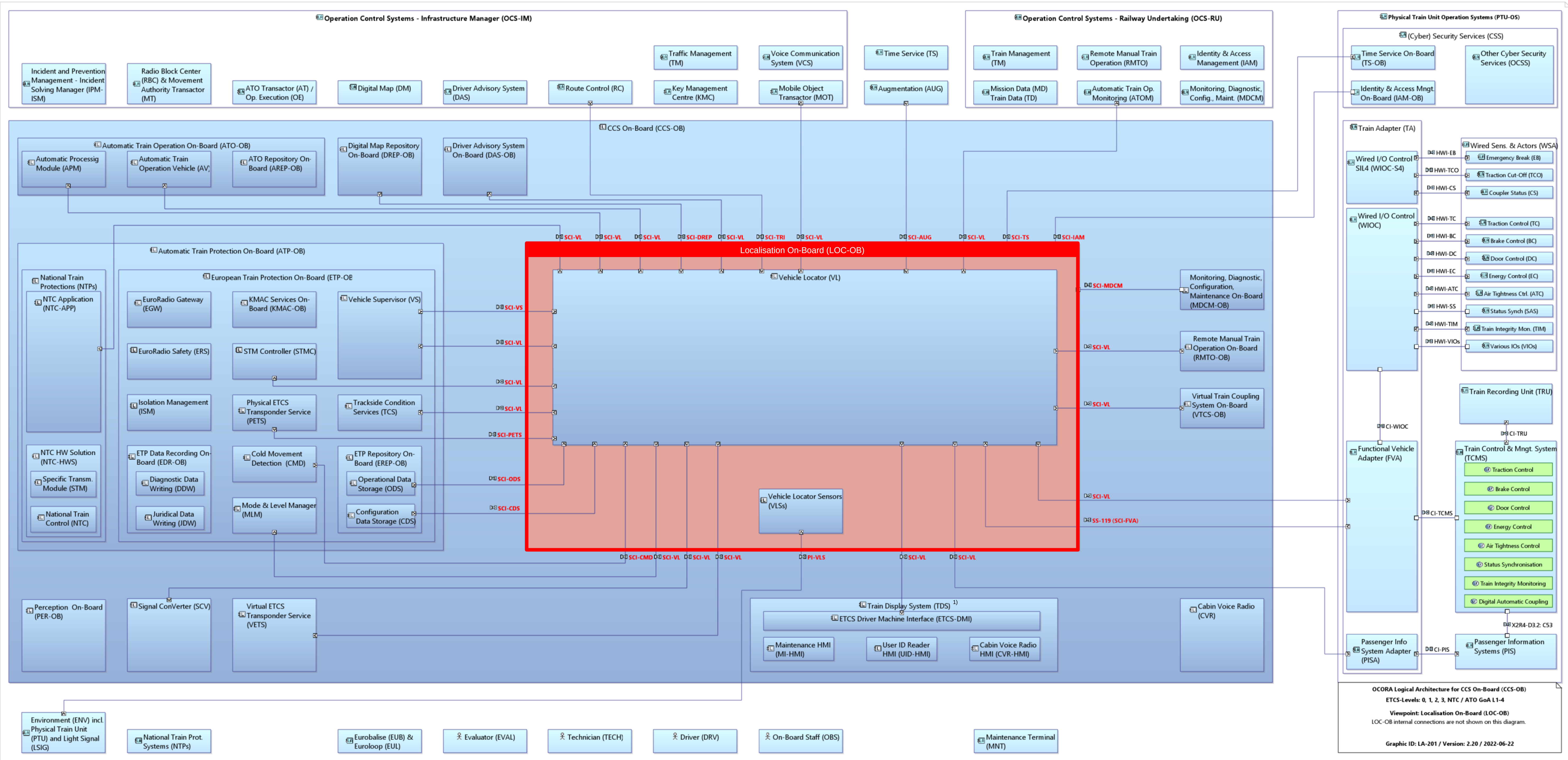


Figure 4: Localisation On-Board (LOC-OB) – logical architecture (large scale representation)

1) may be moved into the PTU-OS / LOC&PAS domain.
SS-nnn respective subset contains information for the interface.