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
3.00	Consistency updates and minor improvements as part of OCORA Release R3	SM	08.12.2022

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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-TWS01-035 – CCS On-Board – Architecture

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

[10] EUG-22E126 – LOC-OB System Definition & Operational Context, LWG, version 1.1, 2022-12-08

[11] EUG-22E135 – LOC-OB Risk Analysis, LWG, version 1.1, 2022-12-23

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 systems, 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]. The technical context is outlined in the OCORA System Architecture [7] and the CCS On-Board Architecture [8].

This document is an introduction to OCORA's Localisation On-Board (LOC-OB) architecture. A more detailed view on the LOC-OB system is described in document [10] 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 [9]. A first version of the LOC-OB Risk analysis can be found in document [11].

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 LOC-OB System Definition & Operational Context [10] published by the Localisation Working Group (ERTMS Users Group), the LOC-OB consists of the Vehicle Locator (VL) and the train-based localisation sensor data.

2.1.1 Vehicle Locator (VL)

The Vehicle Locator (VL) is a safe CCS On-Board logical component that uses localisation 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, localisation sensor data (train-based) can be grouped into the following (non-exhaustive) types [10]:

- 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 localisation 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 (not necessarily related to hardware upgrades) 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 monitoring system 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 [8] 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 of the train position shall refer to the distance of 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.

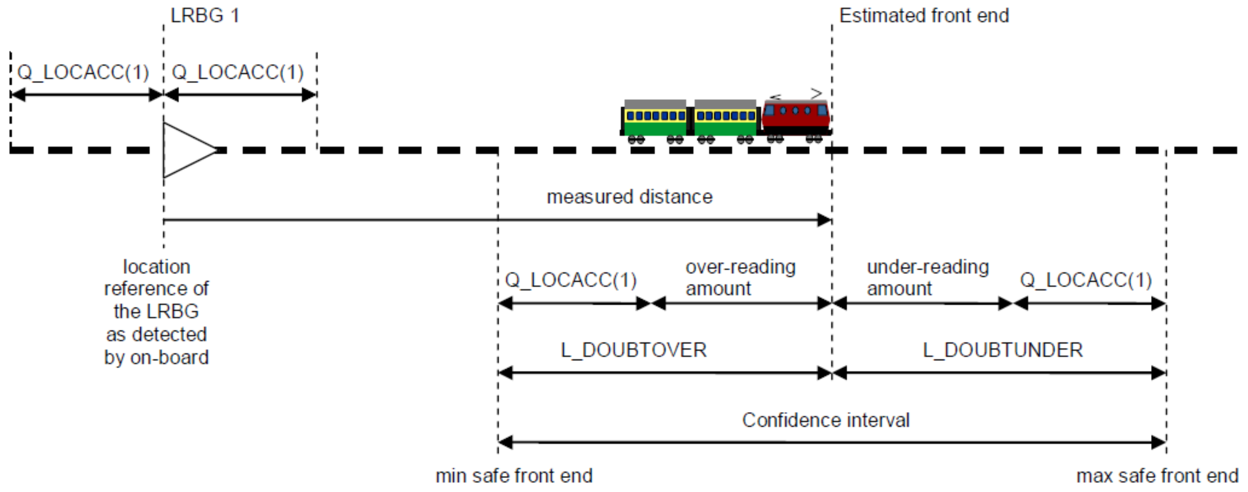


Figure 1: SUBSET-026, chapter 3, figure 13c describes how the confidence interval is calculated

The odometry system of current ETCS implementations 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.

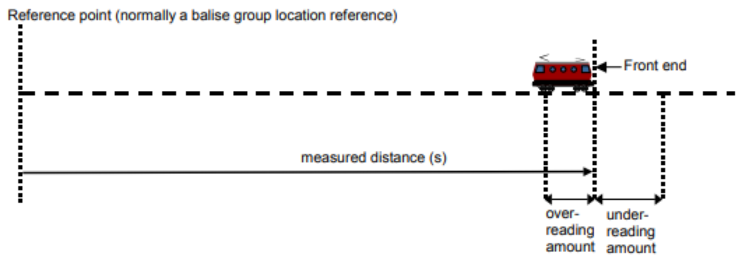
Description	Accuracy of distances measured on-board
Start Event	not applicable
Stop Event	not applicable
Value	for every measured distance s the accuracy shall be better or equal to ± (5m + 5% s), i.e. the over reading amount and the under reading amount shall be equal to or lower than (5m + 5% s). 
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 along the track relative to a reference location, 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) and attitude rates 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 [10].

For providing the 1D positioning, LOC-OB is using a reference location. As of now, the reference location 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 location if the designated point is shared with all the 1D consumers of LOC-OB.

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 locations. 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 OCORA System Architecture and depicts all LOC-OB interfaces to all currently known actors and components.

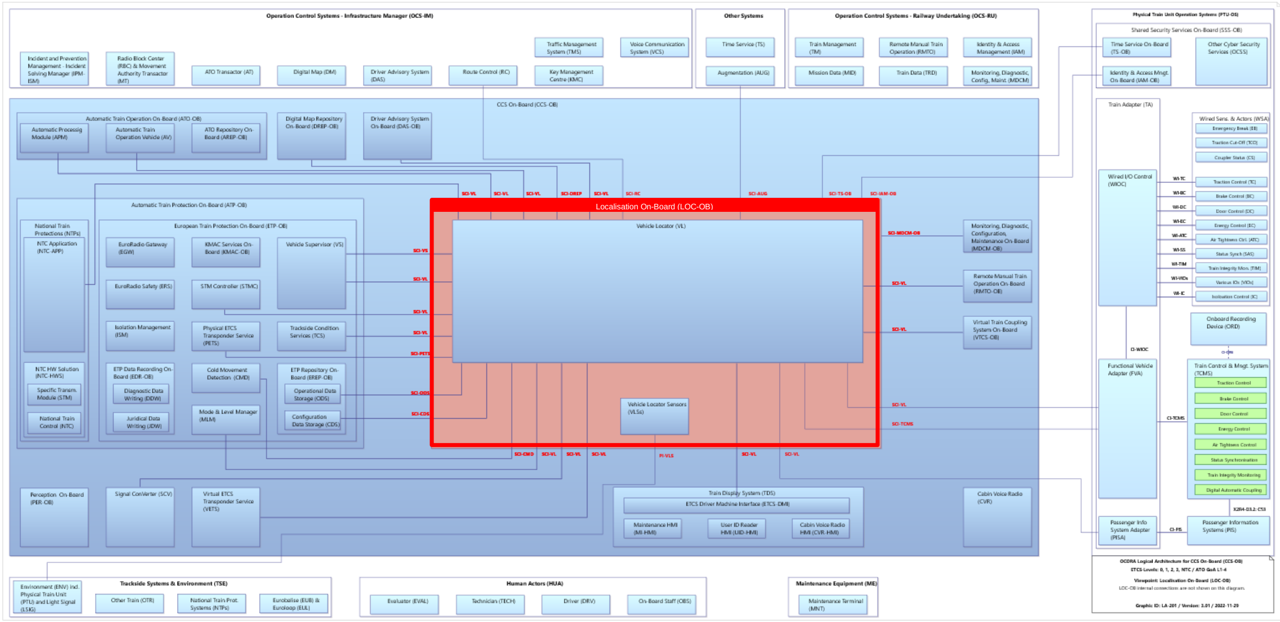


Figure 3: Localisation On-Board (LOC-OB)

Notes: refer to Appendix A1 for large scale representation

4.1 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-OB	Standard Communication Interface – Digital Map Repository On-Board	Consumer (C)
SCI-RC	Standard Communication Interface – Route Control *(formerly: Train Routing Information)*	Consumer (C)
SCI-AUG	Standard Communication Interface – Augmentation	Consumer (C)
SCI-TS-OB	Standard Communication Interface – Time Service On-Board	Consumer (C)
SCI-IAM-OB	Standard Communication Interface – Identity and Access Management On-Board	Consumer (C)
SCI-MDCM-OB	Standard Communication Interface – Monitoring, Diagnostic, Configuration, Maintenance On-Board	Consumer (C)
SCI-TCMS	Standard Communication Interface – Train Control & Management System *(formerly: 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-ODS	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 are briefly analysed and discussed. Despite declaring some components as “not mandatory” hereafter, LOC-OB shall achieve a considerable performance increase compared to today’s specification in SUBSET-026 and SUBSET-041.

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

Component / Function	With	Without
Train Integrity Status *[provided through TCMS]*	Train integrity status are critical inputs for LOC-OB to facilitate “cab anywhere supervision” in the future. Further details on rationale see “LOC-OB_SF-104: Acquire Train Integrity” in [10].	The LOC-OB must be physically located in the very first (leading) vehicle if the train can potentially be separated.
Digital Map Repository On-Board (DREP-OB) and Route Control (RC)	Digital maps together with Routing Information can be used as supporting information by the sensor fusion logic of the LOC-OB to reduce 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. Further details on rationale see “LOC-OB_SF-101: Acquire Digital Map” and “LOC-OB_SF-102: Acquire Route” in [10].	Reference locations used for safe absolute train positioning are limited to physically installed objects detected by the train such as balises in the track bed. Solutions depending on absolute GNSS positions and/or track geometry signatures are not feasible for safe train front end 1D position as required by ETCS. Especially, the usage of 3D information in the sensor fusion logic to map match GNSS and balises to reference locations on track edges is not feasible.
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. Further details on rationale see “LOC-OB_SF-109: Acquire Cold Movement” in [10].	Increased initialisation time of the LOC-OB system until safe and preferably accurate localisation output is produced.

Component / Function	With	Without
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. Further details on rationale see “LOC-OB_SF-103: Acquire Augmentation” in [10].	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.
Eurobalise Telegram and Last Relevant Balise Group (LRBG) *[provided through PETS and VS]*	Used as the absolute position marker (reference location) as defined in the current ERTMS/ETCS specification. Further details on rationale see “LOC-OB_SF-107: Acquire Eurobalise Telegram” and “LOC-OB_SF-108: Acquire Last Relevant Balise Group (LRBG)” in [10].	An alternative means of reference location to the currently used balise group is required. Hint: Not feasible with the current ERTMS/ETCS CCS TSI Baseline 3 but proposed for future baselines to remove dependency to balise technology.

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

6 Migration constraints

As presented in chapter 5 the availability or unavailability of variants may impact the performance of the LOC-OB as specified in documents [10] and [9]. In some migration scenarios, an existing line may be operated with trains equipped with legacy odometry systems and trains equipped with the LOC-OB system. In this context a first step in the development of the LOC-OB shall achieve at the minimum the following goals:

1. **LOC-OB shall be developed as an independent component from the core ETCS system**. 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 (see chapter 2.2 for rationale).
2. **LOC-OB shall implement and fulfil requirements of the standardised interfaces as defined in documents [10] and [9].** Standardised input interfaces need to be implemented by LOC-OB only if needed by the internal LOC-OB logic, e.g., SCI-AUG (augmentation) might or might not be relevant depending on the sensor mix used. Preferably, standardised hardware interfaces shall be implemented by a LOC-OB system supplier from the beginning such that additional functionality can be leveraged at any time by applying software updates.
3. **LOC-OB shall ensure backward compatibility.** The aim is to operate the line with trains using legacy odometry systems and LOC-OB systems without changing physical locations of installed balises.
4. **LOC-OB shall meet improved odometry performance**. The performance as specified today in SUBSET-026 and SUBSET-041 shall be achieved with an improvement of the odometry accuracy from 5% to 2% of the distance run (see subset 041 § 5.3.1.1).
5. **LOC-OB shall ensure operation according to the implementation variants in chapter 5**. Impacts and limitations of each variant need to be carefully analysed to choose the best solution for the given use cases of the IM and/or RU.

The migration strategy and the definition of the various steps may depend on the IM and/or RU. Once the final step of the migration strategy is deployed, the LOC-OB shall achieve all performances as specified in documents [10] and [9].

Appendix A Large scale graphics

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

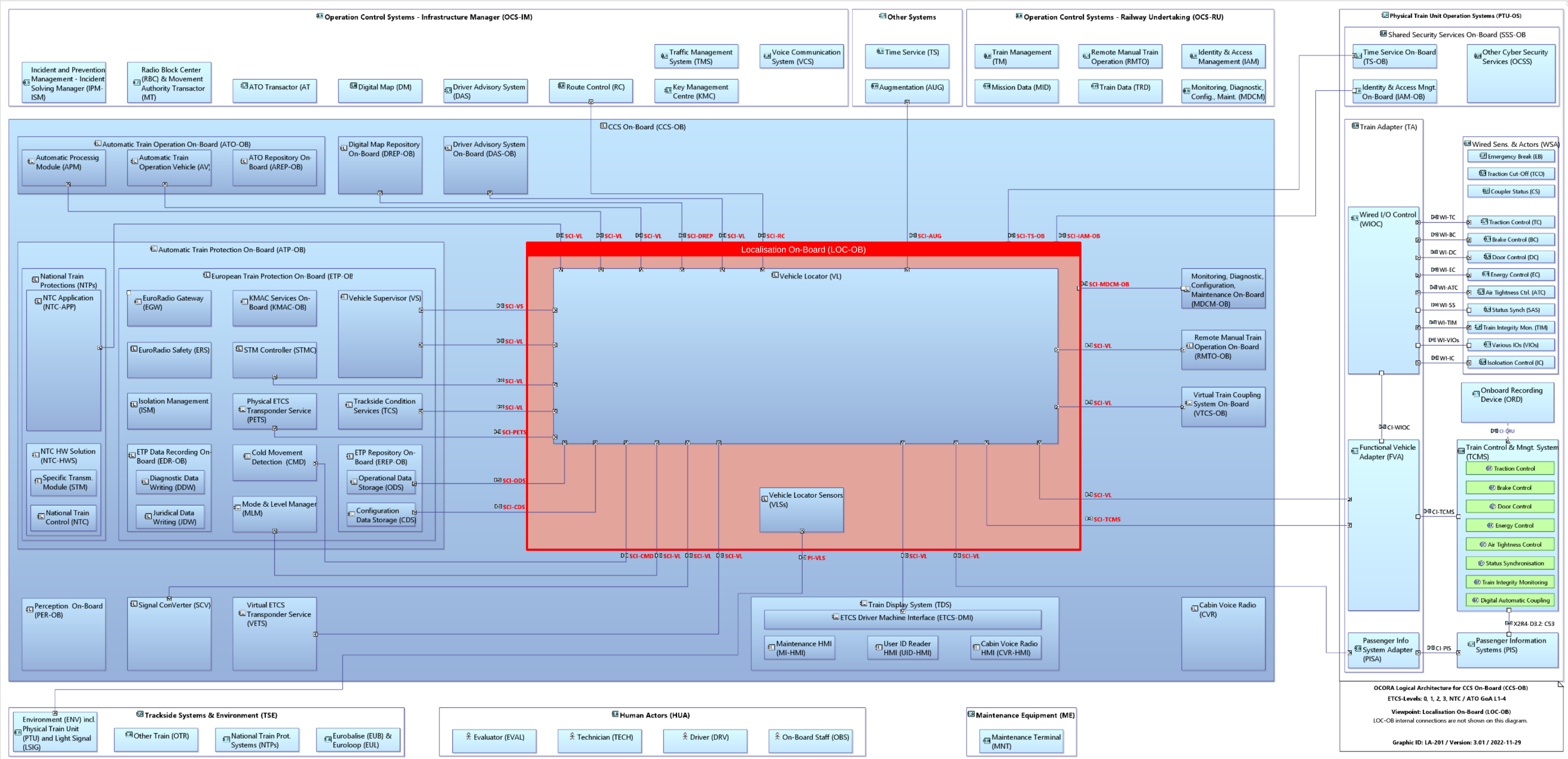


Figure 4: Localisation On-Board (LOC-OB) – logical architecture (large scale representation)