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LOCALISATION WORKING GROUP (LWG)

LOC-OB System Definition & Operational Context

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Modification history

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0a	11.01.2022	Initial draft suggestion of outline revised in two working sessions	SBB (SM) SNCF (KL)
0b	17.11.2022	Outline agreed between SBB/SNCF	SBB (SM) SNCF (KL/SEF)
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0d	27.01.2022	Outline agreed among core team members	SBB (SM/SO) SNCF (KL/SEF/VB) DB (AG/AI/MK)
0e	01.03.2022	Draft version of most important chapters relevant for risk analysis	SBB (SM) SNCF (KL/SEF) DB (AG/AI) EUG (DC)
0f	21.04.2022	1st release candidate (all chapters completed)	SBB (SM) SNCF (KL/SEF) DB (AG/AI) EUG (DC)
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1.0	30.05.2022	1st published version	-

Table of Contents

1 List of References and Acronyms

References

LWG.Doc.021	EUG/LWG VL Concept Architecture, v1, 15/07/2021
19E100	EUG/LWG Localisation Performance Requirements, v3, 10/12/2019
18E112	EUG/LWG High Level Users' Requirements, v2, 10/12/2019
OCORA-TWS01-030	OCORA-TWS01-030-System-Architecture, v2.01, 03.12.2021
OCORA-TWS01-100	OCORA-TWS01-100_Localisation-On-Board-(LOC-OB)_Introduction, v1.01, 03.12.2021
OCORA-TWS01-101	OCORA-TWS01-101_Localisation-On-Board-(LOC-OB)_Requirements, v1.0, 26.11.2021
RCA.Doc.14	RCA Terms and Abstract Concepts, v0.4, 26.04.2022, BL0 R4
RCA.Doc.40	RCA Architecture Poster, v0.4 (0.A), 26.04.2022, BL0 R4
RCA.Doc.59	RCA Digital Map System Definition, v0.5, 22.04.2022, BL0 R4
RCA.Doc.68	RCA Concept: Track Occupancy, v0.4, 28.04.2022, DRAFT
RCA.Doc.69	RCA Map Object Catalogue, v0.2, 16.03.2022, BL0 R4
EGNSS-R	European GNSS Navigation Safety Service for Rail
EN 45545	Railway applications - Fire protection on railway vehicles
EN 50121	Railway applications - Electromagnetic compatibility General
EN 50125	Railway applications - Environmental conditions for equipment
EN 50126	Railway applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
EN 50155	Railway applications - Rolling stock - Electronic equipment
EN 50159	Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems
EN 61373	Railway applications - Rolling stock equipment - Shock and vibration tests
EN 61703	Mathematical expressions for reliability, availability, maintainability and maintenance support term
CLC/TS 50701:2021	Railway applications – Cybersecurity
IEC 60721	Classification of environmental conditions
SS023	ERTMS/ETCS Glossary of Terms and Abbreviations, 3.3.0, 13.05.2016
SS026	ERTMS/ETCS System Requirements Specification, 3.6.0, 13.05.2016
SS035	ERTMS/ETCS Specific Transmission Module FFFIS, 3.2.0, 16.12.2015
SS036	ERTMS/ETCS FFFIS for Eurobalise, 3.1.0, 17.12.2015
96S126	ERTMS/ETCS RAMS Requirements Specification (Chapter 2 – RAM), v6, 30.09.1998
97s066	ERTMS/ETCS Environmental Requirements, v5, 30.09.1998
ERA_CSM	Common Safety Methods
ERJU_WorkPgm	Europe's Rail Joint Undertaking Multi-Annual Work Programme, v1.0, December 2021

SR40.Loc.Integrity	Integrity Measures and Verification for Train Localisation, v1.2, 28.08.2020

Table 1: List of References

Acronyms

ATO	Automatic Train Operation
ATP-OB	Automatic Train Protection - On-Board
AUG	Augmentation
CCS	Control Command & Signalling
CDS	Configuration Data Storage
CENELEC, CLC	Comité Européen de Normalisation Électrotechnique
CMD	Cold Movement Detection
DM-OB	Digital Map On-Board
EBD	Emergency Brake Deceleration
EGNSS	European Global Navigation Satellite System
EOA/LOA	End Of Authority / Limit of Authority
ERGO	Experts in Rail for EGNSS Operational use
ERJU	Europe’s Rail Joint Undertaking
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
EUSPA	European Union Agency for the Space Programme
FRMCS	Future Railway Mobile Communication System
FVA	Functional Vehicle Adapter
GNSS	Global Navigation Satellite System
IEC	International Electrotechnical Commission
IM	Infrastructure Manager
IVC	International Visibility Code
LGPR	Localizing Ground Penetrating Radar
LiDAR	Light Detection and Ranging
LOC-OB	Localisation On-Board
LRBG	Last Relevant Balise Group

LWG	Localisation Working Group
MAACI	Max Accepted Acceleration Confidence Interval
MAAO	Max Accepted Acceleration Overestimation
MAAU	Max Accepted Acceleration Underestimation
MAD	Mean Administrative Delay
MAPCI	Max Accepted Position Confidence Interval
MAPO	Max Accepted Position Overestimation
MAPU	Max Accepted Position Underestimation
MASCI	Max Accepted Speed Confidence Interval
MASO	Max Accepted Speed Overestimation
MASU	Max Accepted Speed Underestimation
MDCM	Monitoring, Diagnostic, Configuration, Maintenance
MLD	Mean Logistic Delay
MP	Movement Permission
MRT	Mean Repair Time
MTTR	Mean Time To Restore
OCORA	Open CCS On-board Reference Architecture
ODS	Operational Data Storage
OSS	On-Board Security Services
PETS	Physical ETCS Transponder Service
PIS	Passenger Information System
RAMS	Reliability, Availability, Maintainability & Safety
RCA	Reference CCS Architecture
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS	Restriction of Hazardous Substances
RU	Railway Undertaking
SBAS	Satellite-Based Augmentation System
SBI	Service Brake Intervention
SR	Staff Responsible
STM	Specific Transmission Module

SuC	System under Consideration
TIMS	Train Integrity Monitoring System
TIS	Train Integrity Status Management
TMS	Traffic Management System
TRI	Train Routing Info
TS	Technical Specification
TSI	Technical Specifications for Interoperability
TS-OB	Time Services On-Board
VL	Vehicle Locator
VLS	Vehicle Locator Sensors
VS	Vehicle Supervisor
WLAN	Wireless Local Area Network

Table 2: List of Acronyms

2 Glossary and Definitions

2.1.1.1 Terms not explicitly mentioned in this chapter but used in this document can be found in the RCA Glossary [RCA.Doc.14].

2.1.1.2 Accuracy. The difference between true and computed value. This value can be for example a position or a velocity. Accuracy requirement is associated with a probability such as, for an estimated position at a specific location, the position uncertainty is within the accuracy requirement with the defined probability.

2.1.1.3 Attitude. Describes the orientation of a rigid body with respect to a fixed coordinate system. Used interchangeably with rotational angles, yaw-pitch-roll, or Euler angles.

2.1.1.4 Bogie reference frame. The bogie reference frame {o} is placed along the bogie axis (see Figure 1). During straight paths, is oriented as {t}.

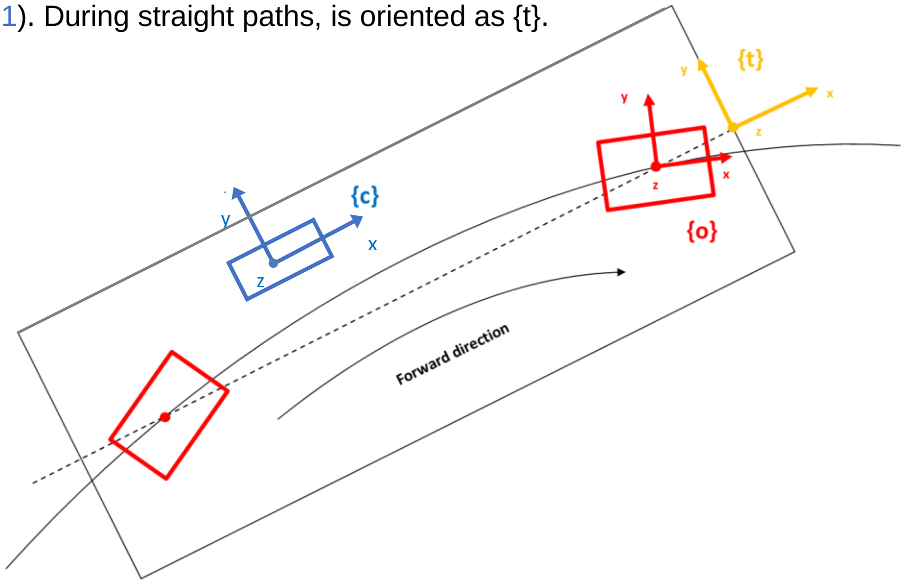

Figure 1: On board reference frames: front train {t}, bogie {o} and carriage {c} reference frames.

2.1.1.5 Cab. The space in the power unit or driving unit of the train containing the operating controls and providing shelter and seats for the driver or engine crew [SS023]. In modern locomotives, the driver's cabs are located at the ends of the vehicle. Locomotives used in shunting are often managed with a central driver's cab.

2.1.1.6 Carriage reference frame. The carriage reference frame can be regarded as the reference frame where the sensors are installed (see Figure 1). Its orientation coincides with {t}.

2.1.1.7 Digital Map / MAP [RCA.Doc.14]. Digital Map is a set of functions providing track and trackside infrastructure information in the form of structured Map Data, including quality criteria for the data. In addition, it also ensures map management functions like map versioning, download of Map Data.

2.1.1.8 Estimated Distance. It is expressed as the distance between a reference point and the estimated train front end position.

2.1.1.9 Estimated Speed. The speed the ERTMS/ETCS localisation on-board equipment estimates the train is running at, with the highest probability according to the physical characteristics of the train and to the localisation working conditions.

2.1.1.10 Estimated Train Front End Position. The position the ERTMS/ETCS localisation on-board equipment estimates the train front is at, with the highest probability according to the physical characteristics of the train and to the localisation working conditions. Also referred to as “Estimated Position” [SS023].

2.1.1.11 Generic Functions. Generic functions common to every functional box (diagnostic, maintenance and access control) in the context of RCA and OCORA.

2.1.1.12 Localisation Information. Set of spatial values referenced to the rail network, and kinematic variables referenced to the train, that enable determining the position of the train in a specific point of the network and its dynamic behaviour from its speed, acceleration, and orientation values.

2.1.1.13 Map Data [RCA.Doc.14]. Map Data is provided to the consuming systems. During the operation, the Map Data is used to support system specific functions, e.g. for support with Onboard localization, generating ETCS movement authorities or other specific use cases.

The Map Data includes a build-up set of edges along with associated nodes (e.g. points, buffer stops), the relevant infrastructure characteristics (e.g. curve radius and gradients), and location information (e.g. specific reference points, balises). The Map Data remain unchanged during operation phase until the next provisioning of Map Data.

A detailed description of Map Data can be found in the RCA Map Object Catalogue [RCA.Doc.69].

2.1.1.14 Reference point. Estimated distances are given in relation to this point that is known on-board (although not necessarily geographically) and trackside. Also referred to as “Reference Location” or “Location Reference” [SS023].

2.1.1.15 Sensor Data. Data that responds to some type of input from the physical environment and helps to locate the vehicle. These data can come from elements deployed on tracks such as Eurobalises or other on-board equipment that can acquire data from the environment or the kinematic characteristics of the vehicle itself.

2.1.1.16 Supporting Information. Information not directly translatable into localisation information but needed to provide the desired output. This information will be used by internal VL processes to enable, improve or validate localisation information.

2.1.1.17 Train. One or more railway vehicles hauled by one or more traction units, or one traction unit travelling alone, running under a given operational number from an initial fixed point to a terminal fixed point [SS023].

2.1.1.18 Train front end reference frame. The Train front end reference frame {t} represents the nominal reference frame of the vehicle to be tracked (see Figure 1). The origin of the reference frame will be placed at the train front end. For what concerns the orientation, the x-axis is directed along the vehicle longitudinal axis (positive forward), the z-axis is directed along the vertical direction (positive upward) and as a consequence the y-axis lies in the horizontal plane, pointing to the left.

2.1.1.19 True ground train acceleration. Is the real acceleration of the train along the track axis.

2.1.1.20 True ground train position. Is the real position of the train front-end on the track.

2.1.1.21 True ground train speed. Is the real speed of the train along the track axis.

2.1.1.22 Vehicle. Vehicle is the generic term for all railway vehicles (locomotives, railcars, coach, freight wagon and special vehicles). A railway vehicle is identified by a unique vehicle number.

2.1.1.23 VL Output Consumers. Grouping of on-board and trackside consumers of localisation information. Further details on identified consumers can be found in [OCORA-TWS01-100].

3 Scope of the Document

3.1.1.1 The purpose of this document is to give an overview of the envisioned 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.

3.1.1.2 LOC-OB shall be considered for the Europe's Rail Joint Undertaking (ERJU) Innovation Pillar flagship area that covers "absolute safe train positioning, highly accurate and safe, incorporating new sensory" [ERJU_WorkPgm].

3.1.1.3 This document is based on the LWG High Level Users' Requirements document [18E112].

3.1.1.4 This document is further seen as an input for several further LWG activities/deliverables that will ultimately lead to revised ERTMS/ETCS specifications (TSI) in order to enable new enhanced localisation principles covering a more holistic localisation system.

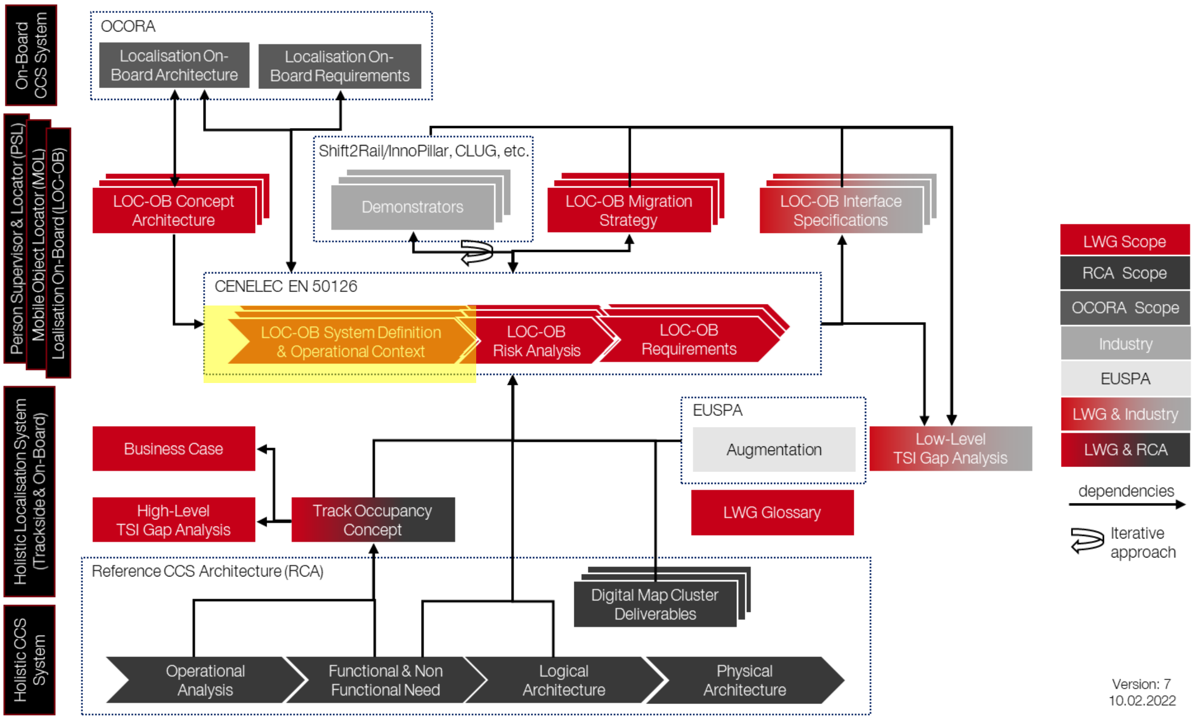

Figure 2: LWG Documentation Structure - LOC-OB System Definition & Operational Context – yellow area.

3.1.1.5 This document follows the structure/topics that are to be covered in phase 2 of a system definition according to CENELEC [EN 50126] but only where it makes sense from a user requirements or tendering perspective.

3.1.1.6 The future users of LOC-OB have decided to structure the content (system definition, risk analysis, requirements, etc.) as per [EN 50126] to enable suppliers reusing content for their official CENELEC process as part of their product development. However, it is neither the intention to describe all necessary content as per [EN 50126] nor to conduct all the CENELEC phases. Hence, it is not the intention to perform a homologation (get a safety approval from authority) based on this document.

3.1.1.7 The objectives of the LOC-OB system definition are

a) define the LOC-OB system objectives and its mission profile;

b) define the functions to be provided by the LOC-OB system;

c) define the boundary of the LOC-OB system (incl. interfaces);

d) establish the operational system and performance requirements influencing the characteristics of the LOC-OB system;

Requirements that need to be met as part of the system's operational context (e.g., performance requirements or RAMSS requirements/strategy/condition) are described as part of this system definition (see chapter 7) and will be further detailed along with rationales, in a later stage, in an updated version of the LOC-OB Requirements deliverable [OCORA-TWS01-101]. Requirement figures and safety declarations are preliminary (first assumptions) and will need to be further challenged and revised.

3.1.1.8 It is not the intention of this document to design and specify system internals but rather describe the LOC-OB system in its environment in terms of inputs and outputs (black box).

4 System Objective and Mission Profile

4.1.1.1 In today's ETCS implementations, the LOC-OB functionality is part of the monolithic ETCS On-Board Unit.

4.1.1.2 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.

4.1.1.3 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.

4.1.1.4 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.

4.1.1.5 Thus, with standardised LOC-OB interfaces in place (e.g., that cover performance, technical interface conformity and the allocated tolerable hazard rate), updates to the internal LOC-OB logic such as

a) adding new types or generations of sensors (e.g., from a simple GPS to a multi-frequency multi-constellation GNSS receiver)

b) improving fusion algorithms output quality (e.g., higher accuracy)

c) considering additional standardised data sources in the fusion algorithms (e.g, train routing information, augmentation information delivered through terrestrial dissemination)

will not trigger a re-certification (homologation) of the entire ETCS On-Board Unit if the standardised interfaces are not impacted by the change.

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

4.1.1.7 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:

a) The absolute (3D) geographic positioning (Long, Lat, Alt),

b) The vector velocity within the 3D coordinate system based on the track axis,

c) The vector acceleration within the 3D coordinate system based on the track axis,

d) The attitude (roll, pitch, and yaw angles)

Refer to chapter 5.2 for the various System Functions.

4.1.1.8 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 7.5.2 for different implementation variants.

4.1.1.9 The LOC-OB architecture facilitates the use of new sensor technologies that could provide an accurate position, providing more possibilities compared to today's scenario where only physical balises are taken as reference points to determine the actual position.

4.1.1.10 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.

4.1.1.11 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.

4.1.1.12 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. Refer to chapter 7.3 for details on Performance Requirements.

4.1.1.13 Minimising the cases where the operational accuracy targets are not fulfilled (e.g., only in case of hardware failure or unavailability of key input data to LOC-OB) is another key requirement. Refer to chapter 7.4 for details on RAMS Requirements.

5 System Description

5.1 System Architecture

5.1.1 LOC-OB in the Context of the CCS On-Board Architecture

5.1.1.1 RCA defines the overall reference CCS architecture [RCA.Doc.40] and delegates the definition of the CCS On-Board architecture to OCORA.

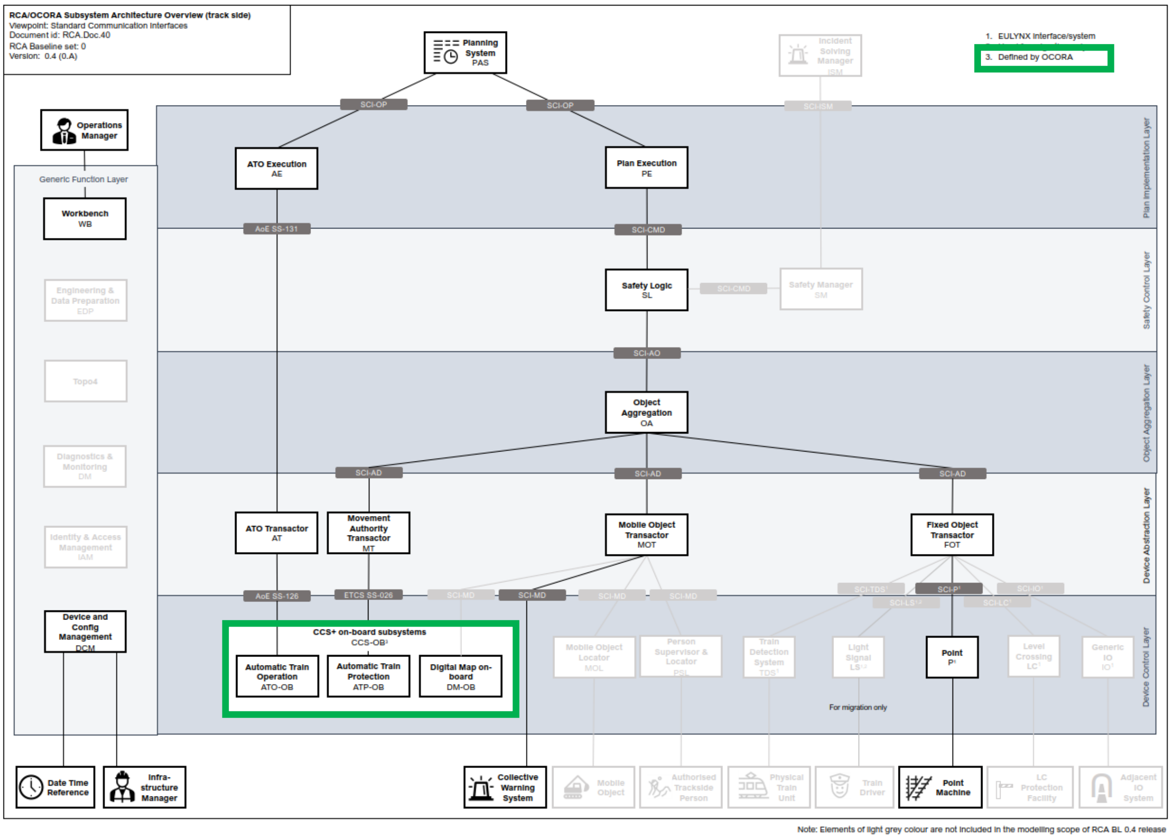

Figure 3: Reference CCS Architecture Poster (BL0 R3) [RCA.Doc.40]. CCS On-Board (CCS-OB) – green border.

5.1.1.2 OCORA defines the reference architecture for CCS on-board [OCORA-TWS01-030].

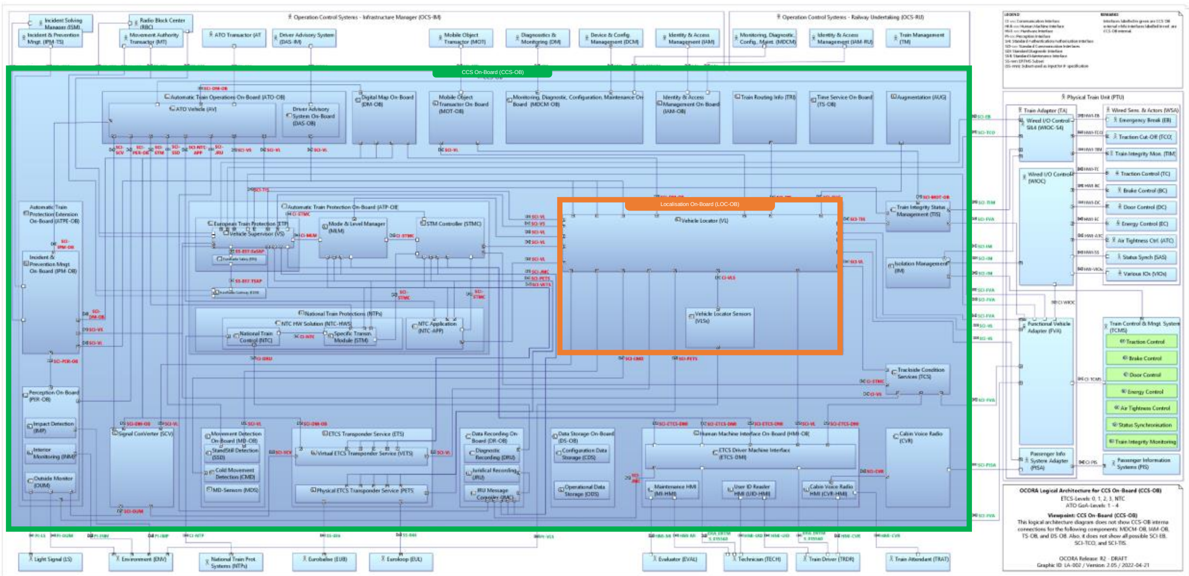

Figure 4: OCORA Logical Architecture for CCS On-Board (CCS-OB) – green border. Localisation On-Board (LOC-OB) – orange border.

5.1.1.3 EUG/LWG has created a concept architecture that combines/integrates major on-board localisation architectures from current and previous initiatives and innovation projects (e.g., OCORA, RCA, CLUG, X2R2) into one single reference architecture.

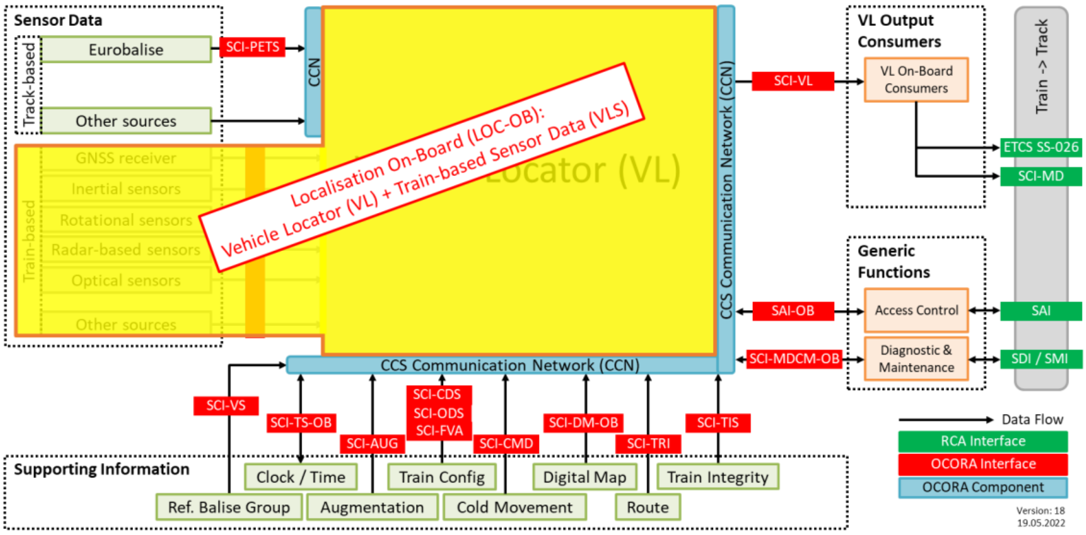

Figure 5: EUG/LWG Concept Architecture with corresponding RCA/OCORA interfaces

5.1.1.4 LOC-OB is the logical block whose main responsibility is to determine and provide localisation information of the train to other on-board systems.

5.1.1.5 On-board systems in turn consume the localisation information and may pass it to further systems (incl. trackside systems, e.g., as part of position reports [SS026]).

5.1.1.6 The two primary purposes of the EUG/LWG concept architecture are

a) to provide an on-board localisation reference architecture for future innovation projects

b) to be aligned with the OCORA reference architecture on a higher architectural abstraction level

5.1.1.7 The architecture content of this LOC-OB System Definition document is the logical continuation of the detailing of the EUG/LWG concept architecture, taking into account the OCORA architecture.

5.1.2 LOC-OB Architecture (VL, VLS)

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

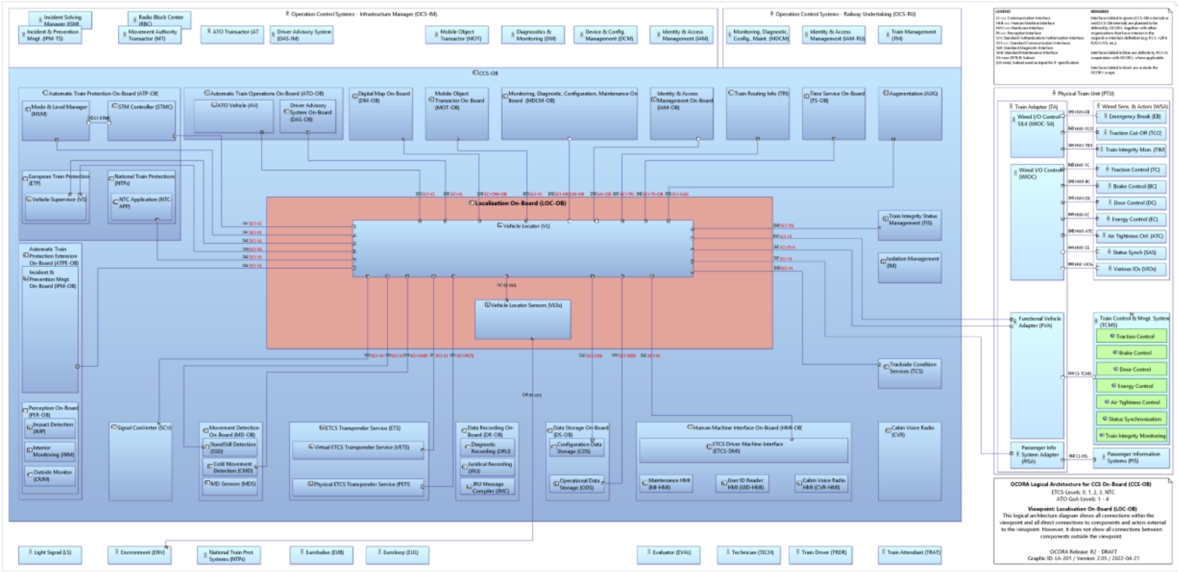

Figure 6: OCORA Logical Architecture for Localisation On-Board (LOC-OB) – reddish area.

5.1.2.2 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. [OCORA-TWS01-100]

5.1.2.3 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 [LWG.Doc.021]:

a) GNSS Receiver. Autonomous geo-spatial positioning and time information based on satellite navigation systems.

b) Inertial sensors. Provides the specific force, angular rate, and the orientation of the body by using a combination of accelerometers and gyroscopes.

c) Rotational sensors. Provides speed (e.g., tachometer, speed probe) and travelled distance (e.g., wheel revolution counter) measurements.

d) 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.

e) 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.

f) 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).

5.1.3 Internal Logic (black box)

5.1.3.1 The system definition of LOC-OB is following the black box approach, i.e., only the inputs and outputs of LOC-OB have been identified and described.

5.1.3.2 Internal functions of LOC-OB (incl. the choice of localisation sensor technologies) will not be defined as part of this document.

5.1.3.3 The supplier is responsible for deciding on the technical solution in compliance with the agreed system requirements, system functions, and system interfaces.

5.2 System Functions

5.2.1 Purpose, Notation, Out-of-Scope Functions

5.2.1.1 System Functions describe the interactions with the System under Consideration (SuC), in our case LOC-OB.

5.2.1.2 An initial allocation of [SS026] On-Board Functions to LOC-OB is documented in [OCORA-TWS01-030, Appendix C].

5.2.1.3 In the following sub-chapters system functions are described based on one of the three prefixes:

a) Provide (LOC-OB_SF-**0xx**): Output function of LOC-OB

b) Acquire (LOC-OB_SF-**1xx**): Input function of LOC-OB

c) Control (LOC-OB_SF-**2xx**): Bi-directional function of LOC-OB covering aspects such as timing, authentication, authorisation, diagnostics, and maintenance

5.2.1.4 Each system function is described with a rationale for its purpose and its data properties.

5.2.1.5 Following functions are NOT allocated to the LOC-OB system:

a) Generation and transmission of the Train Position Report [SS026, chapter 3.6.5.1.4]

b) Determination of the train integrity status (TIMS-status)

c) Determination of (safe) train length

d) Detection of cold movement (CMD)

e) Determination of standstill

f) Determination of track occupancy

g) Current SubSet-035 odometer function information for STM system [SS035]

h) Determination of the last relevant balise groups (LRBGs)

5.2.2 LOC-OB_SF-001: Provide safe Train Front End 1D Position

5.2.2.1 Rationale: This function covers the localisation-related logic of the current ETCS specification [SS026] in regard to determining the longitudinal train front end position along the route, regardless of the complexity of the track layout. The information provided by this function is consumed by various on-board functions [SS026, Appendix C], for example, to supervise the train position, train movements, and to populate the train position report [SS026, chapter 8.6.4] with localisation information. It is assumed that ATO on-board is using this function too, for example, to adapt the traction and brake commands, if necessary, and to stop the train accurately at the platform.

5.2.2.2 Data properties: Following, a list of identified data properties that are provided as part of the function's output. Data property terms used in this function are illustrated in Figure 7.

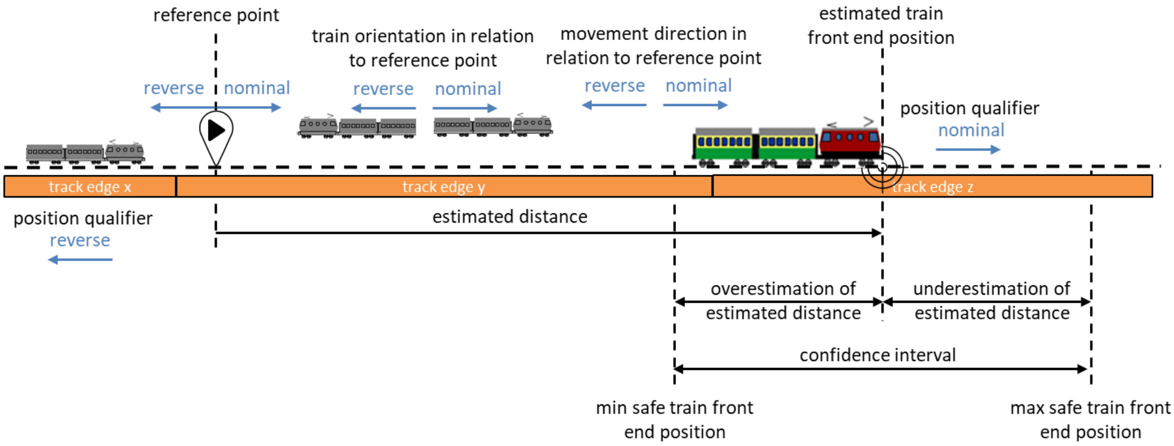

Figure 7: Illustration of terms used in LOC-OB_SF-001: Provide safe Train Front End 1D Position.

5.2.2.2.1 Reference point id. Unique identifier of the element from which an estimated distance is given. Comparable to NID_LRBG but not limited to balise technology [SS026], i.e., could be any point on the track edge. The reference point id is determined by either of the two options:

a) Reference balise group id is received through function LOC-OB_SF-108 and passed through this function.

b) LOC-OB determines the reference point by supporting information of the digital map.

5.2.2.2.2 Train orientation. Orientation of the train in relation to the direction of the reference point. Comparable to Q_DIRLRBG but not limited to balise technology [SS026].

5.2.2.2.3 Movement direction. Direction of train movement in relation to the direction of the reference point, i.e., towards or away from the reference point. Comparable to Q_DIRTRAIN but not limited to balise technology [SS026].

5.2.2.2.4 Position qualifier. It tells on which side of the reference point the estimated train front end position is. Comparable to Q_DLRBG but not limited to balise technology [SS026].

5.2.2.2.5 Estimated distance. Distance along the track between the last relevant reference point and the estimated train front end position. Comparable to D_LRBG but not limited to balise technology [SS026].

5.2.2.2.6 Underestimation of the estimated distance. The safe distance along the track the train may have travelled further than the estimated train front end position. Comparable to L_DOUBTUNDER but not limited to balise technology [SS026].

5.2.2.2.7 Overestimation of the estimated distance. The safe distance along the track the train may have travelled shorter than the estimated train front end position. Comparable to L_DOUBTOVER but not limited to balise technology [SS026].

5.2.2.2.8 Track edge id. Identifier of the track edge on which the estimated train front end position is located. By using a digital map, the parameters “train orientation” and “position qualifier” can be derived based on the “reference point id” and the “track edge id”. Only populated if system is using a digital map based on a node/edge-model.

5.2.2.2.9 Map reference data. Map parts validated by LOC-OB that cover the area between the min safe train front end position and the max safe train front end position. Map reference data is defined in [RCA.Doc.59]. Only populated if system is using a digital map.

5.2.2.2.10 Train front end safety property. This output, considering the train integrity and the train composition definition data, will determine if the localisation information can be considered safe or non-safe.

LOC-OB installed at the front end of the train	Inseparable in regular operation[1]	TIMS installed	train integrity status	train front end safety property
Y	n/a	n/a	n/a	safe
N	Y	n/a	n/a	safe
N	N	Y	confirmed	safe
N	N	Y	Integrity lost / no information	not safe
N	N	N	n/a	not safe

Table 3: Determination scenarios for the "train front end safety property"

5.2.2.2.11 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid. Rationale: Needs to be safe to help consumers to decide on freshness of information.

5.2.2.2.12 System status. Health of the system function and its output information.

5.2.3 LOC-OB_SF-002: Provide safe Train Speed

5.2.3.1 Rationale: This function covers the localisation-related logic (e.g., to supervise the speed profile and the braking curve) of the current ETCS specification [SS026] in regard to determining the longitudinal train speed along the route. The information provided by this function is consumed by various on-board functions [SS026, Appendix C], for example, to supervise the train speed, train movements, and to populate the train position report [SS026, chapter 8.6.4] with localisation information. It is assumed that ATO on-board is using this function too, for example, to adapt the traction and brake commands, if necessary, and to stop the train accurately at the platform.

5.2.3.2 Data properties: Following a list of identified data properties that are provided as part of the function's output.

5.2.3.2.1 Estimated train speed. Absolute (1D) estimated speed value along the track, referred to the vehicle where the LOC-OB is installed.

5.2.3.2.2 Underestimation train speed. The safe upper bound of the speed of the vehicle where the LOC-OB is installed.

5.2.3.2.3 Overestimation train speed. The safe lower bound of the speed of the vehicle where the LOC-OB is installed.

[1] For example, a railcar (a self-propelled railway vehicle designed to transport passengers)

5.2.3.2.4 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid. Rationale: Needs to be safe to help consumers to decide on freshness of information.

5.2.3.2.5 System status. Health of the system function and its output information.

5.2.4 LOC-OB_SF-003: Provide safe Train Acceleration

5.2.4.1 Rationale: This function covers the localisation-related logic (e.g., to supervise the speed profile and the braking curve) of the current ETCS specification [SS026] in regard to determining the longitudinal train acceleration along the route. The information provided by this function is consumed by various on-board functions [SS026, Appendix C], for example, to calculate deceleration in curves as part of the speed and distance monitoring function. It is assumed that ATO on-board is using this function too, for example, to adapt the traction and brake commands, if necessary, and to stop the train accurately at the platform.

5.2.4.2 Data properties: Following a list of identified data properties that are provided as part of the function's output.

5.2.4.2.1 Estimated train acceleration. Absolute (1D) estimated acceleration value along the track, referred to the vehicle where the LOC-OB is installed.

5.2.4.2.2 Underestimation train acceleration. The safe upper bound of the acceleration of the vehicle where the LOC-OB is installed.

5.2.4.2.3 Overestimation train acceleration. The safe lower bound of the acceleration of the vehicle where the LOC-OB is installed.

5.2.4.2.4 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid. Rationale: Needs to be safe to help consumers to decide on freshness of information.

5.2.4.2.5 System status. Health of the system function and its output information.

5.2.5 LOC-OB_SF-004: Provide 3D Position and Uncertainty

5.2.5.1 Rationale: This non-safe function outputs the estimated train front end position (i.e., vehicle where the LOC-OB is installed) along with an uncertainty in a three-dimensional (3D) reference system. The information provided by this function is, for example, beneficial for diagnostic purposes or can be consumed by the Passenger Information Systems (PIS) to visualise the position of the train in a map to passengers.

5.2.5.2 Data properties: Following, a list of identified data properties that are provided as part of the function's output.

5.2.5.2.1 3D Position. 3-axis coordinates for the train front end position. These coordinates are track constrained.

5.2.5.2.2 3D Position uncertainty. Covariance matrix of the 3-axis coordinates, from which, among other things, the standard deviation of the 3D position can be determined.

5.2.5.2.3 Coordinate system: Type of coordinate system for 3-axis coordinates.

5.2.5.2.4 Track edge id. Identifier of the track edge on which the estimated 3D train front end position is located. Only populated if system is using a digital map based on a node/edge-model.

5.2.5.2.5 Map reference data. Map parts validated by LOC-OB that cover the area of the 3D position uncertainty. Map reference data is defined in [RCA.Doc.59]. Only populated if system is using a digital map.

5.2.5.2.6 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid.

5.2.5.2.7 System status. Health of the system function and its output information.

5.2.6 LOC-OB_SF-005: Provide 3D Velocity and Uncertainty

5.2.6.1 Rationale: This non-safe function outputs the estimated velocity, referred to the vehicle where the LOC-OB is installed, along with an uncertainty in a three-dimensional (3D) coordinate system. The information provided by this function is, for example, beneficial for diagnostic purposes or can be consumed by the Passenger Information Systems (PIS) to visualise the speed and direction of the train in a map to passengers.

5.2.6.2 Data properties: Following, a list of identified data properties that are provided as part of the function's output.

5.2.6.2.1 3D Velocity. Value given for the different axes in reference to a coordinate system. Output related to the position where sensors providing the information are installed.

5.2.6.2.2 3D Velocity uncertainty. Covariance matrix of the velocity value per axis, from which, among other things, the standard deviation of the 3D velocity can be determined.

5.2.6.2.3 Coordinate system: Type of coordinate system for the interpretation of the velocity axis.

5.2.6.2.4 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid.

5.2.6.2.5 System status. Health of the system function and its output information.

5.2.7 LOC-OB_SF-006: Provide 3D Acceleration and Uncertainty

5.2.7.1 Rationale: This non-safe function outputs the estimated acceleration, referred to the vehicle where the LOC-OB is installed, along with an uncertainty in a three-dimensional (3D) coordinate system. The information provided by this function is, for example, beneficial for diagnostic purposes.

5.2.7.2 Data properties: Following, a list of identified data properties that are provided as part of the function's output.

5.2.7.2.1 3D Acceleration. Value given for the different axes in reference to a coordinate system. Output related to the position where sensors providing the information are installed.

5.2.7.2.2 3D Acceleration uncertainty. Covariance matrix of the acceleration value per axis, from which, among other things, the standard deviation of the 3D acceleration can be determined.

5.2.7.2.3 Coordinate system: Type of coordinate system for the interpretation of the acceleration axis.

5.2.7.2.4 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid.

5.2.7.2.5 System status. Health of the system function and its output information.

5.2.8 LOC-OB_SF-007: Provide 3D Attitude (rotational angles) and Uncertainty

5.2.8.1 Rationale: This non-safe function outputs the estimated attitude and rate of change in attitude, referred to the vehicle where the LOC-OB is installed, along with an uncertainty in a three-dimensional (3D) coordinate system. The information provided by this function is, for example, beneficial for diagnostic purposes.

5.2.8.2 Data properties: Following, a list of identified data properties that are provided as part of the function's output.

5.2.8.2.1 Attitude. Rotational angles (yaw, pitch, roll) related to the position where sensors providing the information are installed.

5.2.8.2.2 Attitude uncertainty. Covariance matrix of the rotational angles, from which, among other things, the standard deviation of the rotational angles can be determined.

5.2.8.2.3 Attitude rate of change. Rate of change of rotational angles (yaw, pitch, roll) related to the position where sensors providing the information are installed.

5.2.8.2.4 Attitude rate of change uncertainty. Covariance matrix of the rate of change of rotational angles, from which, among other things, the standard deviation of the rate of change of rotational angles can be determined.

5.2.8.2.5 Coordinate system: Type of coordinate system for the interpretation of the rotational angles.

5.2.8.2.6 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid.

5.2.8.2.7 System status. Health of the system function and its output information.

5.2.9 LOC-OB_SF-008: Provide Estimated Distance Travelled (since power-on)

5.2.9.1 Rationale: The estimated distance travelled since LOC-OB was powered on (independent of reference points such as LRBGs) is needed to satisfy initialisation requirements (see chapter 7.3.7 and [OCORA-TWS01-101]) and STM requirements [SS035, e.g., chapter 12.3/12.1.1.6]. For example, the train driver travels in Staff Responsible (SR) mode until a reference point is identified and confirmed.

5.2.9.2 Data properties: Following a list of identified data properties that are seen useful as part of the function's output.

5.2.9.2.1 Estimated distance travelled. Distance along the track travelled since LOC-OB was powered on. A positive movement direction is defined as a movement in the forward direction in relation to cab A and is indicated with an increasing distance value [SS035]. A negative movement direction is defined as a movement in the backward direction in relation to cab A and is indicated with a decreasing distance value [SS035]. Comparable to D_Est [SS035].

5.2.9.2.2 Estimated distance max. The most positive position of the vehicle with all over- and under-reading amounts accumulated since the last power-on of LOC-OB. Comparable to D_Max [SS035].

5.2.9.2.3 Estimated distance min. The most negative position of the vehicle with all over- and under-reading amounts accumulated since the last power-on of LOC-OB. Comparable to D_Min [SS035].

5.2.9.2.4 Validity timestamp. Time stamping of the output, i.e., the time when the localisation information was valid. This time information allows an STM to extrapolate distance to fit its algorithms and processing cycles [SS035].

5.2.9.2.5 System status. Health of the system function and its output information.

5.2.10 LOC-OB_SF-101: Acquire Digital Map

5.2.10.1 Rationale: Map Data is used by sensor fusion algorithms that are based on absolute positioning determination

a) at start of mission, LOC-OB requests a map area based on the estimated train front end position and a big enough buffer around the train front end position.

b) for subsequent map data requests, either the neighboured map parts in direction of travel are requested or the relevant map data is fetched based on available route data (LOC-OB_SF-102).

Map data improves localisation accuracy and supports 3D as well as 1D positioning.

5.2.10.2 Data properties: Following a list of identified data properties that are seen useful as part of the function’s output.

5.2.10.2.1 Map reference data. Set of information containing

a) Map version data: Unique version id of (part of) the Map Data

b) Map id data: Unambiguous/unique reference to a certain part of the whole Map Data (id).

c) Map integrity data: Suitable information (protection data such as hash) to reveal potential transmission or processing faults.

5.2.10.2.2 Map data objects. Various objects of tier 0 to tier 3 relevant for localisation purposes as specified in [RCA.Doc.69], such as

a) Tier 0 - Common objects: Geo-Coordinates

b) Tier 1 - Base network topology objects: Track Node, Track Edge, Track Navigability

c) Tier 2 - Spatial topology objects: Track Edge Point, Track Edge Section, Linear Contiguous Track Area

d) Tier 3 - Domain objects: Track Geometry (Gradient, Curve, Cant), ETCS Balise, ETCS Balise Group, Tunnel

Track Nodes, Curves, and domain objects that refer to a Track Edge Point, need a Geo-Coordinate.

The above-mentioned tiers are just for grouping purposes but are not part of the actual on-board data model structure.

5.2.11 LOC-OB_SF-102: Acquire Route

5.2.11.1 Rationale: An interlocked (safe) train path uniquely assigned to a train/vehicle. This information is seen useful to fetch the required map data for the train path ahead and to validate the determined position by the LOC-OB against track selectivity, e.g., at startup after vehicle has moved during power-off mode (degraded mode). It might also be used to determine track selectivity, e.g., if the vehicle position is known prior to passing a switch point and to decide whether it turned left or right.

In RCA terminology, a route is defined as a "Movement Permission (MP)" that is an authorisation for a particular Trackbound Movable Object to move in a defined direction, with a defined speed, along a defined path (a contiguous stretch of Track Edge Sections) on the track network [RCA.Doc.14].

5.2.11.2 Data properties: Following a list of identified data properties that are seen useful as part of the function's output.

5.2.11.2.1 Linear Contiguous Track Area: Groups an ordered and directional number of topologically connected Track Edge Sections such that they form exactly one path [RCA.Doc.69]. *Note: This only specifies the data property identified based on the definition of the Map Object catalog (static map information). Route information (dynamic map information) are not provided by the Digital Map On-Board (DM-OB) logical component but by OCORA's Train Routing Info (TRI) logical component.*

5.2.12 LOC-OB_SF-103: Acquire Augmentation

5.2.12.1 Rationale: Augmentation data leads to more accurate localisation information (along-track position, along-track speed) and faster estimation of accurate localisation after startup of the LOC-OB in operation. It enhances GNSS localisation information to support functionalities such as track selectivity.

While GNSS augmentation data through space-based augmentation systems (SBAS) can be consumed directly by GNSS receivers (see chapter 5.1.2.3), the purpose of this system function is to receive augmentation data through a terrestrial dissemination service with the advantage of not being always dependent on the visibility of augmentation satellites.

Augmentation data is not limited to GNSS and could be supporting information such as temporary slippery conditions (rail friction coefficient) that can be regarded by the sensors and/or fusion logic to improve the overall performance.

5.2.12.2 Data properties: Operational requirements, safety requirements and system feared events are being identified by ERGO (Experts in Rail for EGNSS Operational use), a working group set-up by EUSPA [EGNSS-R]. Hence, data properties are not further detailed at that point in time.

5.2.13 LOC-OB_SF-104: Acquire Train Integrity

5.2.13.1 Rationale: Train Integrity Information is needed for composition of trains where LOC-OB is not installed at the front end of the train (cab anywhere) and the train is separable (coupling equipment in place) in regular operation. Hence, the safe train front end position (LOC-OB_SF001) can be tagged as "unsafe" if train integrity is no longer confirmed.

5.2.13.2 Data properties: Following a list of identified data properties that are seen useful as part of the function's output.

5.2.13.2.1 Train integrity status. As specified by [SS026, chapter 3.6.5.2.3a].

a) No train integrity information

b) Train integrity information confirmed by integrity monitoring device

c) Train integrity information confirmed (entered) by driver

d) Train integrity lost

5.2.14 LOC-OB_SF-105: Acquire static Train Configuration

5.2.14.1 Rationale: Static train configuration data containing disposition information, such as, the sensor/antenna installation location. This information is needed to determine the estimated train front end position and the estimated speed of the train at a pre-defined reference location within the vehicle (e.g., if multiple speed sensors installed at various physical locations within the vehicle contribute to one common speed value).

5.2.14.2 Data properties: This is a generic function available not only to LOC-OB and returns static configuration values for localisation configuration parameters.

5.2.15 LOC-OB_SF-106: Acquire dynamic Train Configuration

5.2.15.1 Rationale: Operational data such as train length (valid for a single train journey), cab status, etc., represent dynamic train configuration. For example, the status of the driver's cabs (e.g., active, open, closed) is required by LOC-OB to determine the normal driving direction and the train front end.

5.2.15.2 Data properties: Not yet identified, but operational data (most probably) needs to be collected from different systems, e.g., Functional Vehicle Adapter (FVA), Operational Data Storage (ODS).

5.2.16 LOC-OB_SF-107: Acquire Eurobalise Telegram

5.2.16.1 Rationale: Eurobalise telegram information (e.g., balise header) is needed to consider passed balise telegram information in the fusion logic of the absolute position determination along with respective map data (by retrieving geo-coordinates of the Track Edge Point representing the balise passed).

5.2.16.2 Data properties: Following a list of identified data properties that are seen useful as part of the function's output.

5.2.16.2.1 Balise group id. Identity number of a balise group within the country or region defined (NID_BG [SS026]).

5.2.16.2.2 Region id. Identity number of the country or region the balise group is located (NID_C [SS026]).

5.2.16.2.3 Position in group. Defines the position of the balise in the balise group (N_PIG [SS026]).

5.2.16.2.4 Validity timestamp. Time of balise passage, i.e., the time the balise reader is over the centre of the balise.

5.2.17 LOC-OB_SF-108: Acquire Last Relevant Balise Group (LRBG)

5.2.17.1 Rationale: Reference point in the representation of an LRBG is needed to refer a determined position by LOC-OB to the LRBG (reference point id) and estimated distance (e.g., used for LOC-OB_SF-001).

If LRBGs are replaced by generic map-based reference points in the future, this function could be declared as optional.

5.2.17.2 Data properties: Following a list of identified data properties that are seen useful as part of the function’s output.

5.2.17.2.1 LRBG id. Identity of last relevant balise group (NID_LRBG [SS026]).

5.2.17.2.2 Balise passing orientation. Nominal (ascending order of position of the balise within the balise group) or reverse.

5.2.17.2.3 Validity timestamp. Time of balise group passage, i.e., the time the balise reader is over the centre of the reference balise of the balise group.

5.2.18 LOC-OB_SF-109: Acquire Cold Movement

5.2.18.1 Rationale: Information about whether (and potentially how far) an engine/train has moved or not during ETCS’ “no power”-mode to consider the information as part of the initialisation of the localisation system. Sometimes, slight movements can occur, for example during coupling. Therefore, information about the moved distances is needed, to evaluate if the moved distances are neglectable or can be even used for localisation correction.

5.2.18.2 Data properties: Following a list of identified data properties that are seen useful as part of the function’s output.

5.2.18.2.1 Movement flag. Indicates, if a movement took place in general.

5.2.18.2.2 Moved distance. Indicates, the distance moved during “no power”-mode along with the indication of direction (tbd).

5.2.19 LOC-OB_SF-201: Control Time

5.2.19.1 Rationale: Accurate time information is used to timestamp localisation information (position, speed, etc.) to know exactly where a train/vehicle has been at a certain point in time. Localisation information with accurate time information

a) is beneficial in dense-traffic areas to optimise train scheduling (TMS plan optimisations/extrapolation) in near real-time.

b) simplifies error and event analysis as events are logged with accurate time information

c) allows to reject information in case of outdated data (e.g., message overhauls)

This is a bi-directional function. Besides using time information by LOC-OB trough this function, LOC-OB may provide time information to this function, e.g., if collected directly through its sensors (e.g., GNSS).

As time information is used by LOC-OB in safety as well as in non-safety functions, it needs to fulfil both requirements.

5.2.19.2 Data properties: This is a generic function available not only to LOC-OB and needs to be further discussed and specified.

5.2.20 LOC-OB_SF-202: Control Security Access

5.2.20.1 Rationale: Generic function to authenticate and authorise users and technical systems and grant/deny access.

5.2.20.2 Data properties: This is a generic function available not only to LOC-OB and needs to be further discussed and specified.

5.2.21 LOC-OB_SF-203: Control Diagnostic & Maintenance

5.2.21.1 Rationale: This function provides means for system health measurement and fault recovery. The information provided by this function can be used by other functional blocks in CCS-OB to determine the state of the LOC-OB. This function could evaluate the effect of the fault at a system level and execute appropriate recovery manoeuvre. Example: Multiple trains report for the same track sections deviations between the geometric track information provided by the digital map and the integrity measures estimated by sensors of LOC-OB [SR40.Loc.Integrity].

The function also allows to perform maintenance tasks for LOC-OB, e.g., to reboot a specific component, to install software updates, etc.

5.2.21.2 Data properties: This is a generic function available not only to LOC-OB and needs to be further discussed and specified.

5.2.21.2.1 System Status. This information is given out by the system functions to be able to determine the state of LOC-OB. With the system status the functions expecting output from LOC-OB can determine if the output is healthy.

6 System Interfaces

6.1 Interface with the environment

6.1.1.1 In addition to the functional interfaces, the location(s) of the system parts and their interfaces shall not disturb surrounding systems and environment.

6.2 Output

6.2.1 SCI-VL

6.2.1.1 Safe localisation message

6.2.1.1.1 The safe localisation messages contain the outputs provided by functions SF-001, SF-002, SF-003, SF008 and SF009.

6.2.1.1.2 The safe localisation message is sent by a safe protocol.

6.2.1.2 Non-safe localisation message

6.2.1.2.1 The non-safe localisation messages contain the outputs provided by functions SF-004, SF-005, SF-006 and SF-007.

6.2.1.2.2 The non-safe localisation message is sent by a non-safe protocol.

6.3 Input

6.3.1 SCI-DM-OB

6.3.1.1 The DM-OB provides Map Data [RCA.Doc.59] for function LOC-OB_SF-101 through SCI-DM-OB.

6.3.1.2 The DM-OB messages are received by a safe protocol.

6.3.2 SCI-TRI

6.3.2.1 The TRI provides Linear Contiguous Track Area for function LOC-OB_SF-102 through SCI-TRI to the LOC-OB.

6.3.2.2 The TRI message is received by a safe protocol.

6.3.3 SCI-AUG

6.3.3.1 The AUG provides augmentation data for function LOC-OB_SF-103 through SCI-AUG to the LOC-OB.

6.3.3.2 The AUG messages are received when information is available.

6.3.4 SCI-TIS

6.3.4.1 The TIS provides the Train Integrity Status data for function LOC-OB_SF-104 through SCI-TIS to the LOC-OB.

6.3.4.2 The TIS message is received by a safe protocol.

6.3.5 SCI-CDS

6.3.5.1 The CDS provides the configuration data for function LOC-OB_SF-105 through SCI-CDS to the LOC-OB.

6.3.5.2 The CDS message is received by a safe protocol.

6.3.6 SCI-ODS

6.3.6.1 The ODS provides the Operational Data for function LOC-OB_SF-106 through SCI-ODS to the LOC-OB.

6.3.6.2 The ODS message is received by a safe protocol.

6.3.7 SCI-FVA

6.3.7.1 The FVA provides vehicle information for function LOC-OB_SF-106 through SCI-FVA to the LOC-OB.

6.3.7.2 The FVA message is received by a safe protocol.

6.3.8 SCI-PETS

6.3.8.1 The PETS provides the balise information for function LOC-OB_SF-107 through SCI-PETS to the LOC-OB.

6.3.8.2 The balise information are received when PETS is detecting a new balise telegram.

6.3.8.3 The PETS message is sent by a safe protocol.

6.3.9 SCI-VS

6.3.9.1 This interface is optional; however, it is mandatory when reference points based on LRBG are in use.

6.3.9.2 The VS provides the LRBG information for function LOC-OB_SF-108 through SCI-VS to the LOC-OB.

6.3.9.3 The LRBG information is received when VS is determining a new LRBG.

6.3.9.4 The VS message is received by a safe protocol.

6.3.10 SCI-CMD

6.3.10.1 The CMD (Cold Movement Detection) provides the Movement flag and the Moved distance for function LOC-OB_SF-109 through SCI-CMD to the LOC-OB.

6.3.10.2 The CMD message is received by a safe protocol.

6.3.11 PI-VLS

6.3.11.1 This is a non-standardised perception interface between the Vehicle Locator Sensors (VLS) and their environment (ENV) that can, for example, include trackside mounted location tags on catenary poles. This interface is not further described/specified but listed for the purpose of architectural completeness.

6.4 Input/Output

6.4.1 SCI-TS-OB

6.4.1.1 The TS-OB provides onboard time information (common time of CCS-OB) for function LOC-OB_SF-201 through SCI-TS-OB to the LOC-OB.

6.4.1.2 If required, LOC-OB may send to TS-OB the UTC time received by the GNSS.

6.4.1.3 The time information (safe and non-safe) is received through the TS-OB time protocol.

6.4.1.4 The TS-OB message is received by a safe protocol and non-safe protocol.

6.4.2 SAI-OB

6.4.2.1 The IAM-OB provides access management information for function LOC-OB_SF-202 through SAI-OB to the LOC-OB.

6.4.2.2 The IAM-OB receives identity information through SAI-OB from the LOC-OB.

6.4.2.3 The IAM-OB messages are received by a non-safe protocol.

6.4.3 SCI-MDCM-OB

6.4.3.1 The LOC-OB provides system status and maintenance information (details sensors information, details fusion algorithm results) for function LOC-OB_SF-203 through SCI-MDCM-OB to the MDCM-OB.

6.4.3.2 The LOC-OB receives software updates (incl. security patches) through SCI-MDCM-OB from the MDCM-OB

6.4.3.3 This is a bi-directional interface between the MDCM-OB and the LOC-OB.

6.4.3.4 The exchange of information is controlled by a non-safe protocol.

7 Operational Context

7.1 Consumers Needs

7.1.1.1 LOC-OB shall provide train position information (and additional dynamic parameters) continuously to consumers having different requirements in terms of integrity (confidence associated to the uncertainty), accuracy (uncertainty) and respond time.

Rationale:

The kind of data and their format have to be defined starting from an analysis to be performed at system level to fulfil the requirements of the different consumers and having in mind the overall functionalities envisaged. Possible examples (list to be considered nor mandatory neither exhaustive) of consumers of LOC-OB output are:

- *Automatic Train Protection On-Board (ATP-OB)*
- *Traffic Management System (TMS)*
- *Passenger Information System (PIS)*
- *Automatic train operation (ATO)*

7.1.1.2 The LOC-OB shall be operational at train speeds from 0 km/h up to 500 km/h.

7.1.1.3 The LOC-OB shall fulfil operational scenarios defined in the track occupancy concept document [RCA.Doc.68].

7.2 System Life-Time Considerations

7.2.1.1 The life cycle costs must be equal or lower than today's localisation systems that are mainly based on balises (infrastructure costs) and on-board odometry technology.

7.2.1.2 The system must be standardised as per the defined standard communication interfaces with regard to their functions not least to offer product choices of different suppliers.

7.2.1.3 The system must have a modular structure so that it is flexible for potential future adjustments. Due to the modular architecture, individual sensor components can be exchanged more easily.

7.3 Performance Requirements

7.3.1 Introduction

7.3.1.1 As LOC-OB is assumed to have more degrees of freedom in terms of used inputs and provided outputs, the current terminology of the ERTMS localisation is updated with some new terms. The sections 7.3.2 to 7.3.4 provide complementary definitions of the ETCS localisation principle [SS026, chapter 3] in order to define the availability criteria of the LOC-OB.

7.3.1.2 The confidence interval for position, speed and acceleration influences the operational performance of a line.

7.3.1.3 The operational performance of the line and the definition of the timetable are based on operational boundaries of the confidence interval for position, speed and acceleration. The following chapters 7.3.2, 7.3.3 and 7.3.4 describe the definition of these boundaries.

7.3.1.4 Track occupancy concept defines operational scenarios with headway and accuracy requirements. The position confidence interval boundaries MAPO/MAPU and position accuracy are derived from these requirements.

7.3.2 Position

7.3.2.1 The accuracy of the estimated train front end position is the difference between the estimated train front end position and the true ground train position.

7.3.2.2 The quality of the estimated train front end position accuracy shall be defined with a probability level.

7.3.2.3 The Max Accepted Position Underestimation (MAPU) is used to bound the underestimation of the estimated train front end position.

7.3.2.4 If the underestimation of the estimated distance (as per chapter 5.2.2.2.6) exceeds the MAPU then the system is regarded as unavailable, i.e., the difference between the max safe front end and the estimated train front end position is greater than the MAPU.

7.3.2.5 If the underestimation of the estimated distance (as per chapter 5.2.2.2.6) exceeds the MAPU then the operational performance may be impacted (e.g., large underestimated distance will have an impact on the speed profile of the train), leading to a reduction of the capacity of the line. Therefore, the LOC-OB is considered unavailable when the underestimation of the confidence interval exceeds the MAPU.

7.3.2.6 If the underestimation of the estimated distance (as per chapter 5.2.2.2.6) exceeds the MAPU then the safety of the LOC-OB output is not affected.

7.3.2.7 As it cannot be assumed that the MAPU is never exceeded, there will be an availability requirement, i.e., the amount of time the MAPU may be exceeded within a specific time interval.

7.3.2.8 The Max Accepted Position Overestimation (MAPO) is used to bound the overestimation of the estimated train front end position.

7.3.2.9 If the overestimation of the estimated distance (as per chapter 5.2.2.2.7) exceeds the MAPO then the system is regarded as unavailable, i.e., the difference between the estimated train front end position and the min safe front end is greater than the MAPO.

7.3.2.10 If the overestimation of the estimated distance (as per chapter 5.2.2.2.7) exceeds the MAPO then the operational performance may be impacted (e.g., large overestimated distance will have an impact on the speed profile of the following train, on the clearance of a switch area), leading to a reduction of the capacity of the line. Therefore, the LOC-OB is considered unavailable when the overestimation of the confidence interval exceeds the MAPO.

7.3.2.11 If the overestimation of the estimated distance (as per chapter 5.2.2.2.7) exceeds the MAPO then the safety of the LOC-OB output is not affected.

7.3.2.12 As it cannot be assumed that the MAPO is never exceeded, there will be an availability requirement, i.e., the amount of time the MAPO may be exceeded within a specific time interval.

7.3.2.13 The Max Accepted Position Confidence Interval (MAPCI) is the sum of the MAPU and MAPO. It is only used for explanations and clarifications, to get a better understanding about the position inaccuracy. It is not used for specifying a requirement.

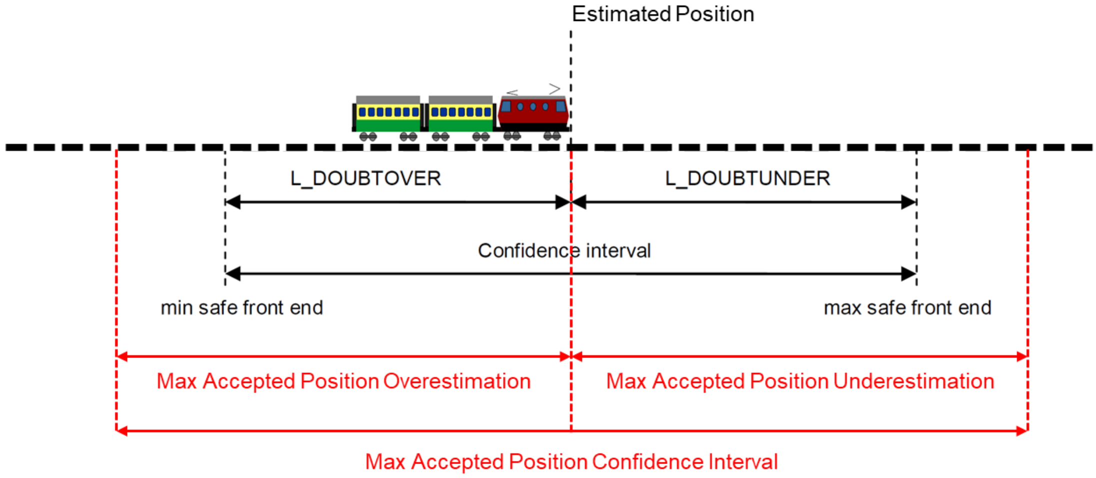

Figure 8: Visualisation of newly introduced terms, considering train position. The black terms describe estimated values by the train [SS026]. The red values describe the required performance values (new introduced terms).

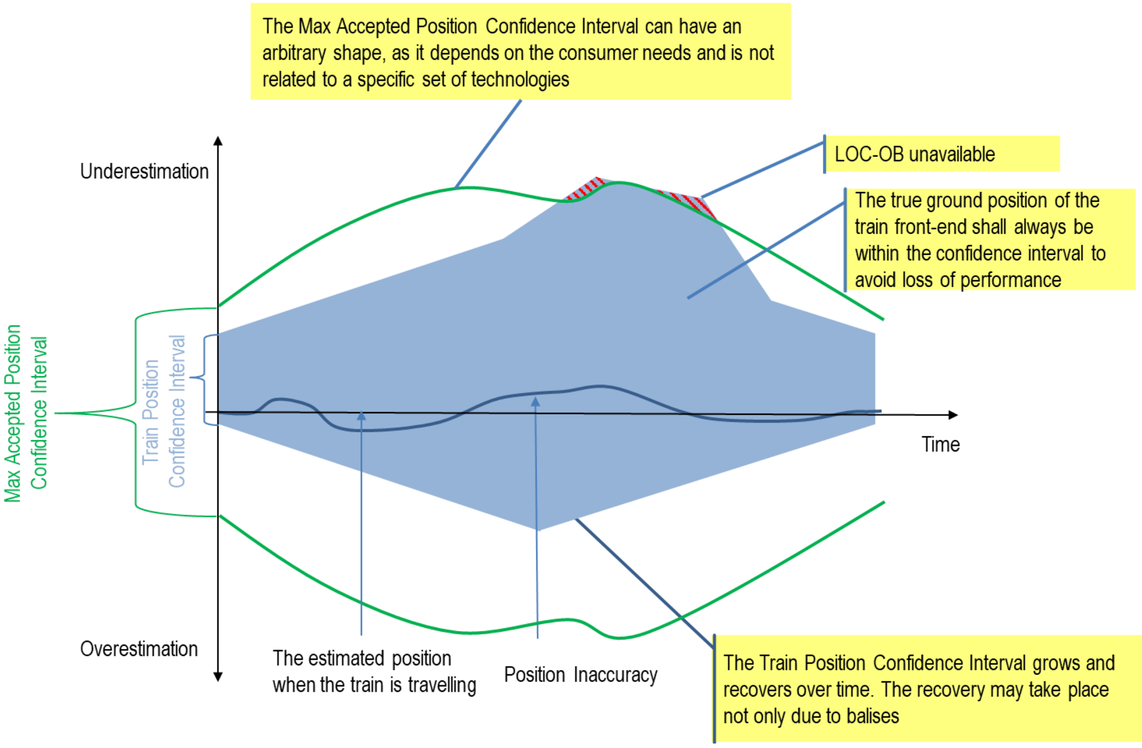

Figure 9: Visualisation of the MAPCI, CI, Unavailability.

7.3.3 Speed

7.3.3.1 The accuracy of the estimated train speed is the difference between the estimated train speed and the true ground train speed.

7.3.3.2 The quality of the estimated train speed accuracy shall be defined with a probability level.

7.3.3.3 The Max Accepted Speed Underestimation (MASU) is used to bound the underestimation of the estimated train speed.

7.3.3.4 If the underestimation of the estimated train speed (as per chapter 5.2.3.2.2) exceeds the MASU then the system is regarded as unavailable, i.e., the difference between the maximum safe speed and the estimated train speed is greater than the MASU.

7.3.3.5 If the underestimation of the estimated train speed (as per chapter 5.2.3.2.2) exceeds the MASU then the operational performance may be impacted (e.g., large underestimated train speed will have an impact on the speed profile of the train), leading to a reduction of the capacity of the line. Therefore, the LOC-OB is considered unavailable when the underestimation of the confidence interval exceeds the MASU.

7.3.3.6 If the underestimation of the estimated train speed (as per chapter 5.2.3.2.2) exceeds the MASU then the safety of the LOC-OB output is not affected.

7.3.3.7 As it cannot be assumed that the MASU is never exceeded, there will be an availability requirement, i.e., the amount of time the MASU may be exceeded within a specific time interval.

7.3.3.8 The Max Accepted Speed Overestimation (MASO) is used to bound the overestimation of the estimated train speed.

7.3.3.9 If the overestimation of the estimated train speed (as per chapter 5.2.3.2.3) exceeds the MASO then the system is regarded as unavailable, i.e., the difference between the estimated train speed and the minimum safe speed is greater than the MASO.

7.3.3.10 If the overestimation of the estimated train speed (as per chapter 5.2.3.2.3) exceeds the MASO then the operational performance may be impacted (e.g., large overestimated train speed will have an impact on the speed profile of the train), leading to a reduction of the capacity of the line. Therefore, the LOC-OB is considered unavailable when the overestimation of the confidence interval exceeds the MASO.

7.3.3.11 If the overestimation of the estimated train speed (as per chapter 5.2.3.2.3) exceeds the MASO then the safety of the LOC-OB output is not affected.

7.3.3.12 As it cannot be assumed that the MASO is never exceeded, there will be an availability requirement, i.e., the amount of time the MASO may be exceeded within a specific time interval.

7.3.3.13 The Max Accepted Speed Confidence Interval (MASCI) is the sum of the MASU and MASO. It is only used for explanations and clarifications, to get a better understanding about the speed inaccuracy. It is not used for specifying a requirement.

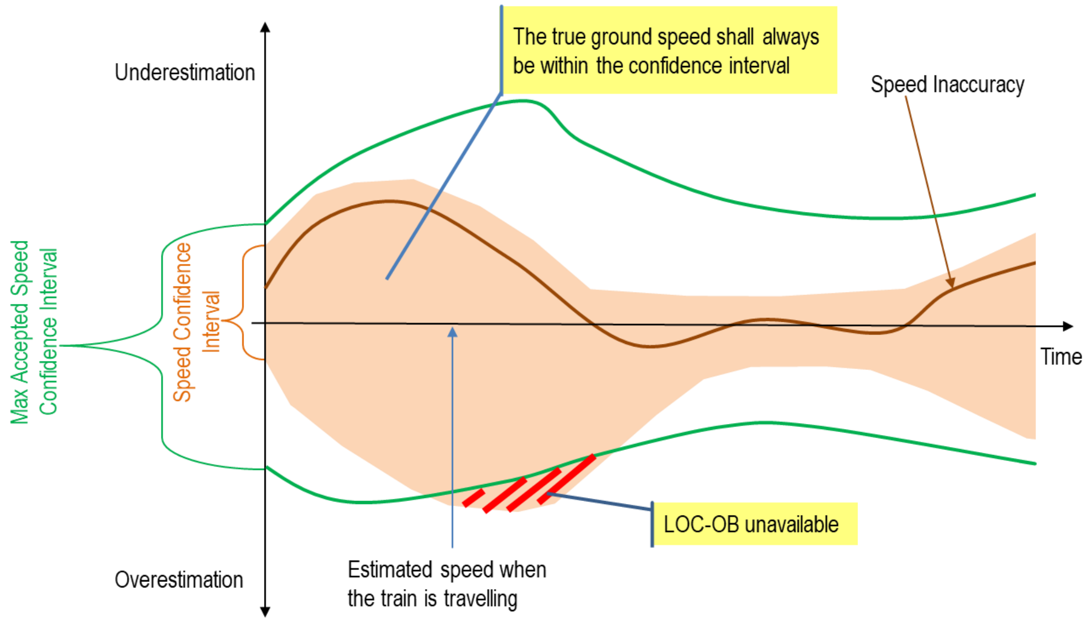

Figure 10: Visualisation of the estimated and Max Accepted Speed Confidence Interval.

7.3.4 Acceleration

7.3.4.1 The accuracy of the estimated train acceleration is the difference between the estimated train acceleration and the true ground train acceleration.

7.3.4.2 The quality of the estimated train acceleration accuracy shall be defined with a probability level.

7.3.4.3 The Max Accepted Acceleration Underestimation (MAAU) is used to bound the underestimation of the estimated train acceleration.

7.3.4.4 If the underestimation of the estimated train acceleration (as per chapter 5.2.4.2.2) exceeds the MAAU then the system is regarded as unavailable, i.e., the difference between the maximum safe acceleration and the estimated train acceleration is greater than the MAAU.

7.3.4.5 If the underestimation of the estimated train acceleration (as per chapter 5.2.4.2.2) exceeds the MAAU then the operational performance may be impacted (e.g., large underestimated train acceleration will have an impact on the distance between the foots of the EBD and SBI curves), leading to a reduction of the capacity of the line or potentially to a trip of the train. Therefore, the LOC-OB is considered unavailable when the underestimation of the confidence interval exceeds the MAAU.

7.3.4.6 If the underestimation of the estimated train acceleration (as per chapter 5.2.4.2.2) exceeds the MAAU then the safety of the LOC-OB output is not affected.

7.3.4.7 As it cannot be assumed that the MAAU is never exceeded, there will be an availability requirement, i.e., the amount of time the MAAU may be exceeded within a specific time interval.

7.3.4.8 The Max Accepted Acceleration Overestimation (MAAO) is used to bound the overestimation of the estimated train acceleration.

7.3.4.9 If the overestimation of the estimated train acceleration (as per chapter 5.2.4.2.3) exceeds the MAAO then the system is regarded as unavailable, i.e., the difference between the estimated train acceleration and the minimum safe acceleration is greater than the MAAO.

7.3.4.10 If the overestimation of the estimated train acceleration (as per chapter 5.2.4.2.3) exceeds the MAAO then the operational performance may be impacted, (e.g., large overestimated train acceleration will have an impact on the braking curve) leading to a reduction of the capacity of the line. Therefore, the LOC-OB is considered unavailable when the overestimation of the confidence interval exceeds the MAAO.

7.3.4.11 If the overestimation of the estimated train acceleration (as per chapter 5.2.4.2.3) exceeds the MAAO then the safety of the LOC-OB output is not affected.

7.3.4.12 As it cannot be assumed that the MAAO is never exceeded, there will be an availability requirement, i.e., the amount of time the MAAO may be exceeded within a specific time interval.

7.3.4.13 The Max Accepted Acceleration Confidence Interval (MAACI) is the sum of the MAAU and MAAO. It is only used for explanations and clarifications, to get a better understanding about the acceleration inaccuracy. It is not used for specifying a requirement.

7.3.5 Capacity Constraints and Confidence Interval Performances

7.3.5.1 The max accepted confidence interval with regard to the estimated position or the estimated speed of the train influences the capacity of the line.

7.3.5.2 The impact of the actual confidence interval on the transportation plan of the line depends on the operational buffer and the traffic constraints, e.g., split of traffic, releasing of switch.

7.3.5.3 The confidence interval influences the safe braking distance and the time to release a part of the track. Thus, the minimal theoretical headway between trains is impacted by the confidence interval.

7.3.5.4 The operational context (capacity of the line, bottleneck, high density of the traffic, station area, type of train, etc.) derived from the transportation plan and the mission profiles allows to classify track areas by headway and position confidence interval constraints.

7.3.5.5 To cope with critical operational points having an impact on the performance of the line, four specific areas are defined:

a) **Mainline**: There is no critical point with regards the operational headway in this area. Train is travelling usually at the track operational speed, the capacity of the line does not require a small train position confidence interval.

b) **Dense traffic line**: Train is travelling at the track operational speed (e.g., when entering big city networks). The capacity of the line is high, spacing between train is short, the area is requiring a small train position confidence interval.

c) **Train traffic node**: A train traffic node is represented by a switch area, where often the train traffic is split or converged. When a train is approaching a train traffic node critical for the capacity of the line, the train position confidence interval is critical for the determination of the beginning of the braking curve (e.g., to gain the maximum line capacity, in this context the train shall not start braking). The train position confidence interval is also critical for clearing the switch area.

d) **Precise positioning area**: The topology of the network in this area is often complex with many switches. Train position needs to be accurate. Example: Train is entering or travelling in a station or in a shunting yard.

7.3.5.6 The confidence interval performances are defined based on the area type constraints.

7.3.6 Function Performance

7.3.6.1 The function performance derives from mission profiles, operational and consumer requirements.

7.3.6.2 The details of function performances will be provided in the LOC-OB system requirement document (see [OCORA-TWS01-101]).

7.3.7 Initialisation Requirement

7.3.7.1 LOC-OB shall initialise itself at power-on and fulfil operational capability thereafter.

7.4 RAMSS Requirements, Strategy and Conditions

7.4.1 Methodology

7.4.1.1 The methodology to define and to demonstrate the RAMS requirements of the LOC-OB shall follow the [EN 50126] standard.

7.4.2 Reliability

7.4.2.1 The hardware failure occurrence of LOC-OB impacting the operation shall be less than $4*10^{-6}$h.

7.4.2.2 A software reliability estimation shall be performed utilising metrics and forms [96S126].

7.4.2.3 Software failures include (list not exhaustive):

a) erroneous warning (no fault found)

b) temporary malfunctioning

c) erroneous diagnostic

d) errors or shut down resulting as "retest OK"

7.4.2.4 Software failures with an impact on operation (implying brake intervention or delay) shall not exceed 40% of the hardware failures target.

7.4.2.5 Software failures with no impact on operation shall not exceed 60% of the hardware failures target.

7.4.2.6 The occurrence of loss of LOC-OB localisation information by a safety relevant consumer due to the lack of valid data (e.g., lack of message, ageing of the data is too old…) shall be less than $2*10^{-5}$/h. The data ageing time is 1s.

7.4.2.7 The occurrence of LOC-OB not operational (major failure, LOC-OB is not providing any output) shall be less than 1 event every 10 years.

7.4.3 Availability

7.4.3.1 In reference to performance requirements stated in chapters 7.3.2, 7.3.3 and 7.3.4, when compared to the current ERTMS localisation as jointly performed by balises and odometry, the LOC-OB shall bring significant improvements in availability.

7.4.3.2 The LOC-OB shall provide services with a high rate of availability to avoid any impact on train operation.

7.4.3.3 The LOC-OB is considered as available if it provides localisation information to consumers and if the confidence intervals are within the MAPCI (position), MASCI (speed) and MAACI (acceleration).

7.4.3.4 If the confidence intervals are outside of MAPCI (position), MASCI (speed) or MAACI (acceleration) for 60 seconds (or more) during 2 hours, the time is accounted in the overall unavailability.

7.4.3.5 If the LOC-OB is not providing data at the defined rate, the LOC-OB is considered as unavailable during this time.

7.4.3.6 The LOC-OB shall have an overall availability of 99,998%. The justification for this figure is given in chapter 9 (Appendix B LOC-OB Availability Target Justification).

7.4.3.7 The LOC-OB shall have a rugged design. The failure of one sensor or one component shall not lead to an outage of the LOC-OB outputs.

7.4.3.8 The LOC-OB shall be available and achieve full performances under all type of train behaviour, operation (e.g., train slip/slide, train coupling, train splitting…).

7.4.4 Maintainability

7.4.4.1 Maintenance costs can negatively affect life cycle costs. For this reason, the system must be designed in such a way that maintenance work is minimal.

7.4.4.2 The railway operator must be able to carry out the maintenance himself or it must be possible for the railway operator to outsource the maintenance work to another company that is officially certified by public authorities to carry out maintenance work.

7.4.4.3 The long-term maintenance strategy shall include damage-dependent (past) and preventive (forward-looking) measures.

7.4.4.4 To detect systematic malfunctions early and to carry out preventive maintenance, the system must record relevant diagnostic and maintenance information and share the same, if available, with a diagnostic and maintenance system (e.g. MDCM-OB). This will increase the overall system availability.

7.4.4.5 Maintenance measures must be carried out in such a way that the system can be operated within the defined RAMS requirements for the entire system life cycle.

7.4.4.6 LOC-OB shall be able to self-diagnose.

Rationale:

self-diagnostic capability is necessary to minimise maintenance activities and consequences the failure of accuracy targets would have on LOC-OB consumers.

7.4.4.7 The results of the self-diagnose shall be able to determine the replaceable unit to be replaced.

7.4.4.8 The Mean Repair Time (MRT) shall be less than 15 minutes as per [EN 50126].

7.4.4.9 The LOC-OB's design and maintenance concept shall meet a Mean Time To Restore (MTTR) ≤ 1h. The Mean Time to Restore (MTTR) is defined in [EN 50126]. The administrative delay (MAD), Logistic Delay (MLD) shall not be considered. The time elapsed to restore starts when the failure occurs and ends when the LOC-OB is ready for service.

7.4.5 Safety

7.4.5.1 The safety of the LOC-OB shall be ensured and demonstrated according to the Common Safety Methods [ERA_CSM] and the [EN 50126] standard.

7.4.5.2 The safety level of the LOC-OB output data shall be determined according to the safety relevance of consumers (e.g., SIL4 for ATP-OB).

7.4.5.3 The LOC-OB input information shall comply with the safety requirement constraints.

7.4.5.4 The failure of one sensor or component of the LOC-OB shall not jeopardise the safety of the LOC-OB.

7.4.5.5 The LOC-OB shall comply to the requirements for transmission systems in [EN 50159] to provide safety-related communication between safety related equipment.

7.4.5.6 The true ground position of the train front-end shall be within the position confidence interval.

7.4.5.7 The true ground position of the train front-end outside the confidence interval leads to safety issues.

7.4.5.8 The true ground speed of the train shall be within the speed confidence interval.

7.4.5.9 The true ground speed of the train outside the confidence interval leads to safety issues.

7.4.5.10 The true ground acceleration of the train shall be within the acceleration confidence interval.

7.4.5.11 The true ground acceleration of the train outside the confidence interval leads to safety issue.

7.4.6 Security

7.4.6.1 The LOC-OB shall fulfil requirements and recommendations for cybersecurity as specified in [CLC/TS 50701:2021] with the purpose to demonstrate that the system is up to date from a cybersecurity perspective and that it meets and maintains the target level of security for the entire system life cycle.

7.4.6.2 The LOC-OB security shall be ensured by using means and technologies in accordance with OCORA security plan.

7.4.6.3 If the LOC-OB is using GNSS, jamming or spoofing of GNSS signals has to be considered. Appropriate detection measures of such conditions and mitigation measure to counter such attacks shall be addressed to keep the integrity of the LOC-OB.

7.4.6.4 The LOC-OB security shall use services provided by the onboard security services (OSS OCORA component [OCORA-TWS01-030]). For information the list of services provided by OSS is:

a) System-wide time service

b) Central logging

c) Identity and Access Management

d) Backup

e) Asset inventory

f) Intrusion detection / continuous security monitoring

g) Public Key Infrastructure

h) Domain Name Service

7.4.6.5 Only authorised personnel shall have access to the LOC-OB

7.4.6.6 The LOC-OB shall be installed in a secure cabinet preventing access to unauthorised people (e.g., passenger and public).

7.5 Operating Strategy, Conditions and Constraints

7.5.1 Operating Strategy

7.5.1.1 The LOC-OB shall be operational in ETCS L0, L1, L2, L3 and NTC.

7.5.1.2 When compared to the current ERTMS localisation as jointly performed by repositioning balises and odometry, the LOC-OB shall bring significant improvements in accuracy and availability.

7.5.1.3 When compared to the current ERTMS line, the same performances shall be achieved by LOC-OB using a reduced number of balises.

7.5.1.4 In mainline area with no critical point the minimum distance between repositioning balises shall be 30 km.

7.5.1.5 If required, additional repositioning balises may be installed at critical points (e.g., switch area, station, tunnel…) independent of the distance specified in 7.5.1.4.

7.5.1.6 The LOC-OB shall achieve the full operational capability and performances in ETCS level 2 and level 3 (train equipped with LOC-OB running on new lines).

7.5.1.7 The LOC-OB shall achieve backward compatibility (e.g., a train equipped with the LOC-OB shall be operated on the existing ETCS line with or without Digital Map or augmentation data).

7.5.1.8 The LOC-OB operation shall be seamless (no human intervention).

7.5.1.9 The LOC-OB must be designed for an operational use with a life cycle of at least 20 years for individual components and at least 30 years for the entire system.

7.5.1.10 It must be possible to provide new compatible LOC-OB after the system's life cycle has expired.

7.5.2 Mode of Operations / Implementation Variants

7.5.2.1 The LOC-OB shall be used under various operational configurations.

7.5.2.2 Train equipped with the LOC-OB may run on tracks not equipped with a data radio communication system. In this case lower performances are acceptable that will be further specified (see 7.5.1.3).

7.5.2.3 Train equipped with the LOC-OB may run on tracks with no Digital Map available. In this case lower performances are acceptable that will be further specified (see 7.5.1.3). Without Map Data, LOC-OB (in combination with trackside assets, e.g., balises) must achieve at least the performance as specified today in [SS026] and [SS041] for backward compatibility purposes in such a case.

7.5.2.4 Train equipped with the LOC-OB may run on track with no augmentation data available. In this case lower performances are acceptable that will be further specified (see 7.5.1.3). Without augmentation data, LOC-OB (in combination with trackside assets, e.g., balises) must achieve at least the performance as specified today in [SS026] and [SS041] for backward compatibility purposes in such a case.

7.5.2.5 Train equipped with the LOC-OB may not be set with the Train Integrity Status Management (TIS). In this case the LOC-OB shall be installed in the very first (leading) vehicle.

7.5.2.6 Train equipped with the LOC-OB may not receive Train Routing Information. In this case after the system is powered on, it is allowed to move the train to the next balise to confirm the reference point and therefore to determine the track edge id.

7.5.2.7 Train equipped with the LOC-OB may not be set with the Cold Movement Detection.

7.5.3 Environment

7.5.3.1 The LOC-OB system must function under the environmental conditions defined in [97s066] for the following:

a) Temperature
b) Altitude
c) Humidity
d) Air movements
e) Rain, snow, hail, ice and water
f) Solar radiation
g) Pollutants and contaminants
h) Fire
i) Electromagnetic compatibility and power supplies
j) Vibration and Shock
k) Chemicals
l) Ergonomics
m) Track
n) Degraded environments

7.5.3.2 [97s066] describes the operational environmental requirements, guidelines, and test requirements for the operation of ERTMS train mounted equipment like the LOC-OB.

7.5.3.3 As [97s066] was derived from preliminary CENELEC standards, updates made in [EN 50121], [EN 50125], [EN 50155], [IEC 60721], [EN 61373] and [EN 45545] shall be considered.

7.5.4 Logistic Considerations

7.5.4.1 The individual system components must be always ready for use and, if necessary, exchangeable. This assumes that the necessary equipment is in reserve.

7.5.4.2 The presence of the following points must be ensured:

a) spare parts warehouse

b) trained maintenance personnel

c) maintenance tools

d) maintenance manuals

7.5.5 Constraints imposed by existing Infrastructure

7.5.5.1 Train equipped with LOC-OB shall run on existing infrastructures without moving any existing balises.

7.5.5.2 If additional balises need to be installed, the balise installation shall follow Infrastructure Manager (IM) engineering rules (e.g., not over metallic mass etc.).

8 Appendix A LOC-OB Insights

8.1.1.1 Informative preliminary visualisation of LOC-OB insights to better understand the system functions (chapter 5.2) and system interfaces (chapter 6).

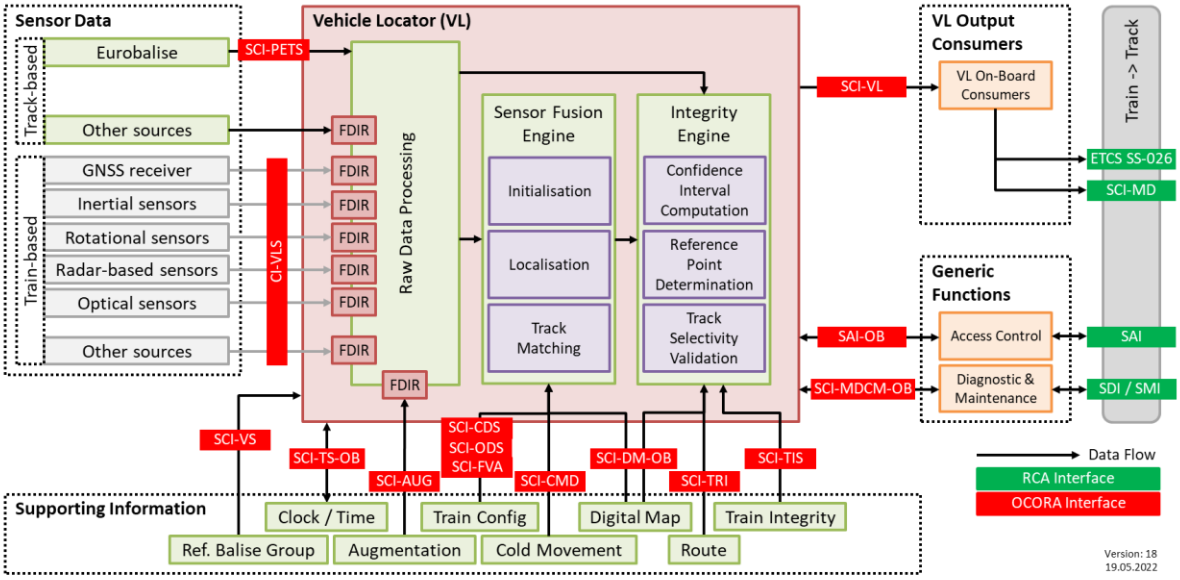

Figure 11: Informative preliminary visualisation of LOC-OB insights

8.1.1.2 In Figure 11, LOC-OB consists of the Vehicle Locator (VL) and the train-based Sensor Data (grey sensor data boxes).

8.1.1.3 Note: RUs and IMs will not define the internal structure, functions, and choice of sensor technology of LOC-OB and leave this decision up to the suppliers.

9 Appendix B LOC-OB Availability Target Justification

9.1.1.1 This appendix provides the justification of the LOC-OB availability target.

9.1.1.2 The availability of the LOC-OB is defined to assess the performance with regard to the value of the confidence interval associated to the estimated position and the estimated speed of the train.

9.1.1.3 The availability is assessed on a monthly period.

9.1.1.4 The method used to define the availability target of the LOC-OB is based on the goal of the overall availability to be achieved at the level of a line. From the overall availability target, at the level of the line, an apportionment is made on the main systems. Finally, the LOC-OB availability target is derived.

9.1.1.5 The overall availability target of a line used in the calculation is 99,9% (which is not so high, in general it is more 99,97%). This availability figure leads to a downtime of 43,2 minutes per month (line is operated 24 hours a day, 30 days per month).

9.1.1.6 The downtime is considered as the loss of time in operation (train delayed) with regard to the transportation plan. It is the time when the system is not performing as it should, causing delays and loss of capacity.

9.1.1.7 The three main systems considered at the level of the line are:

a) Traction power and track

b) Rolling stock

c) Signalling and protection system

9.1.1.8 The following apportionment of the down time is made between these systems

Subsystem	Ratio	Downtime per month
Overall downtime	1	43,2 min
Traction power and track	0,25	10,80 min
Rolling stock	0,25	10,80 min
Signalling and protection system	0,50	21,60 min

Table 4: Allocation of downtime per month by subsystem

9.1.1.9 The signalling and protection system is divided in two main parts of our interest: the on-board localisation system and the others (interlocking, ETCS trackside, ETCS on-board, etc.).

9.1.1.10 The apportionment of the downtime used between these two parts is 1/3 to the onboard localisation system and 2/3 to the other parts. Hence the downtime allocated to the LOC-OB system is 7,2 min.

9.1.1.11 To assess the operating time of the LOC-OB, the analysis is based on a transportation plan (train planning) for main line corridor and high-speed line.

9.1.1.12 The number of trains running per hour in both directions are counted, then a mean of train running per hour can be derived (number of trains per hour during the day/24h).

Therefore, the operating time per month of the LOC-OB in minutes is: Number of trains per hour * 24*60*30.

9.1.1.13 For the main line corridor, an average of 10 trains (both directions) per hour is used leading to an operating time of 432’000 min per month.
For the high-speed line, an average of 15 trains (both directions) per hour is used leading to an operating time of 648’000 min.
Finally, the LOC-OB availability figure is deduced for these two use cases.

Number of trains per hour (mean, both directions)	10	15
LOC-OB operating minutes	432’000 min	648’000 min
Downtime (1/3 signalling and protection system)	7,20 min	7,20 min
LOC-OB availability	**99,9983%**	**99,9989%**

Table 5: LOC-OB availability target based on two use cases (10 and 15 trains per hour)

9.1.1.14 From this study the LOC-OB availability target is set to 99,998%.

10 Appendix C Open Issues

10.1.1.1 It needs to be defined how exceeding MAPU/MAPO, MASU/MASO, MAAU/MAAO can be measured and reported to interested consumers. First idea: thresholds/limits need to be defined in the digital map depending on the type of area as defined in chapter 7.3.5.5. Differences between actual values and thresholds/limits to be reported through existing system functions (LOC-OB_SF-001, LOC-OB_SF-002, LOC-OB_SF-003, LOC-OB_SF-203) or a new system function.

11 List of Figures

12 List of Tables