LOCALISATION WORKING GROUP

VEHICLE LOCATOR

CONCEPT ARCHITECTURE

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VERSIONS & MODIFICATIONS

Version No.	Date of distribution	Comments on the modifications	Responsible for the modifications
0a		First Draft	DC
0b		Inclusion of inputs and outputs	DC
0c		New and consolidated inputs/outputs	DC
0d		Modifications to align the document with the architecture diagram	DC
0e		Modification after LWG21. Interface naming and OCORA/RCA alignment	DC
0f		Rename of interfaces to be coherent with OCORA Delta release	DC
0g		Revision round after LWG22	DC
0h		Comments harmonisation. Clean version	DC
0i		Alignment with OCORA Delta, various structural updates, minor content adjustments	SBB/DC
0J		Odometer function exclusion, final editorial and minor comments review	LWG
1		Version 1.0	LWG

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1. INTRODUCTION

1.1 Scope of the document

1.1.1.1 Purposes of this document are:

- Describe the concept architecture for the Vehicle Locator
- Identify and describe inputs and outputs for the Vehicle Locator
- Identify input and output interfaces to the Vehicle Locator

2. REFERENCE AND ABBREVIATIONS

2.1 Table of references

ID	Reference	Title	Version
1	CR ERTMS00001212	CR1368 Enhanced onboard localisation	
2	RCA_Architecture_Poster_v0.2 (0.B)	RCA Architecture Poster	BL0 R2 (v0.2)
3	OCORA-BWS02-030_Technical-Slide-Deck	OCORA Technical Slide Deck	Delta Release
4	EUG 18E112	Railway Localisation System - High Level Users' Requirements	2
5	OCORA-TWS01-030-System-Architecture	OCORA System Architecture	Delta Release
6	SS026	ERTMS/ETCS System Requirements Specification	3.6.0
7	SS023	ERTMS/ETCS Glossary of Terms and Abbreviations	3.3.0
8	RCA Domain Knowledge	RCA Domain Knowledge	0.3 (0.A)
9	21E057	DIGITAL MAP AND AUGMENTATION EUG-S2R JOINT WORKING GROUP (JWG). Concept Paper	1.0
10	SS035	Specific Transmission Module FFFIS	3.2.0

2.2 Abbreviations

CCS	Control Command and Signalling
CI	Communication Interface (non-standardized)
CMD	Cold Movement Detection
EGNOS	European Geostationary Navigation Overlay Service
ETCS	European Train Control System
FRMCS	Future Railway Mobile Communication System
LGPR	Localizing Ground Penetrating Radar
LiDAR	Laser imaging, Detection and Ranging
LWG	EUG Localisation Working Group

OCORA	Open CCS On-board Reference Architecture
RCA	Reference CCS Architecture
RFID	Radio Frequency Identification
SCI	Standard Communication Interface
TIMS	Train Integrity Monitoring System
VL	Vehicle Locator
WLAN	Wireless Local Area Network

3. DEFINITIONS

3.1.1.1 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.

3.1.1.2 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. [7]

3.1.1.3 Vehicle Locator. The Vehicle Locator (VL) is a safe CCS On-Board 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 an odometry component [5].

3.1.1.4 Reference point. Measured distances are given in relation to this point that is known on-board (although not necessarily geographically) and trackside.

3.1.1.5 Track edge. A TrackEdge is a linear object that connects exactly two TrackNodes. One of these TrackNodes is defined as a Start TrackNode called Side A, the other is defined as an End TrackNode called Side B. TrackEdges are directed. TrackEdges are directed for positioning reasons and to determine the effective direction of a topology related element (e.g. for a light signal). The TrackEdge direction doesn't specify the drivability of a TrackEdge. [8]

Each route path between two adjacent TrackNodes is represented by a TrackEdge.

Figure 1: TrackEdge definition [8]

4. METHODOLOGY

4.1.1.1 The LWG, by means of different dedicated workshops, has derived the following concept architecture for the on-board vehicle locator.

4.1.1.2 The concept is based on a black box approach where only the inputs and outputs have been identified and described.

4.1.1.3 This document will list the inputs and the outputs. The full specification is not included in the document.

4.1.1.4 The internal functions of the vehicle locator will not be defined as part of this document.

5. VEHICLE LOCATOR (VL)

5.1 Concept

5.1.1.1 The VL is the functional block whose main responsibility is to determine and provide the localisation information of the train to other on-board subsystems which in turn pass the localisation information on to trackside subsystems, e.g., as part of position reports.

5.1.1.2 RCA defines the reference CCS architecture and focuses on the trackside mainly. This reference architecture is depicted in Figure 2.

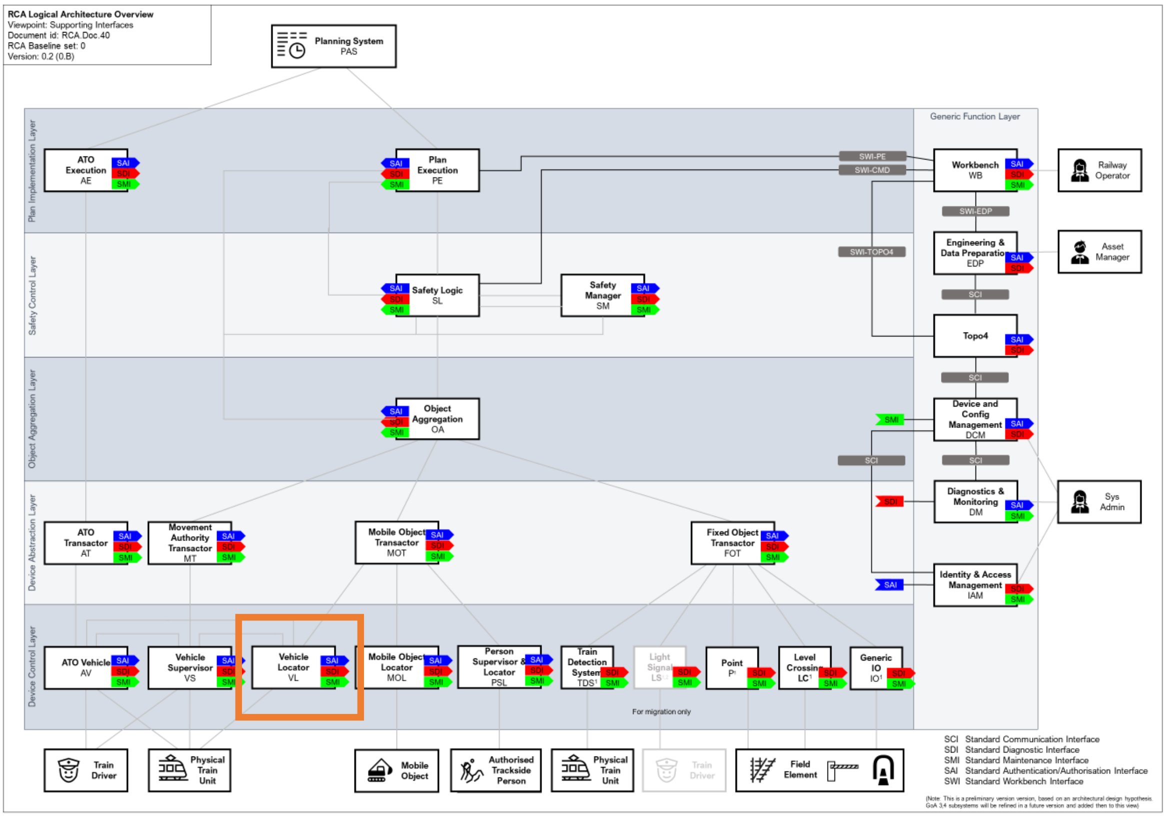

Figure 2: RCA Architecture with the SubSystem VL outlined in orange[2]

5.1.1.3 OCORA defines the reference architecture for the on-board. This reference architecture is depicted in Figure 3.

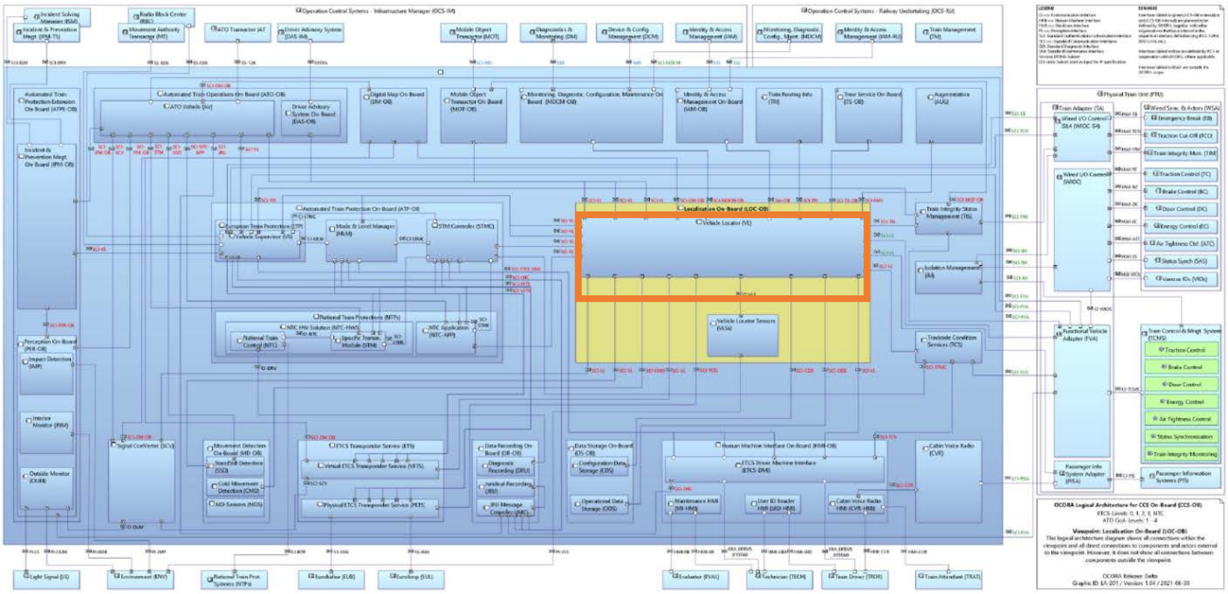

Figure 3: OCORA Logical Architecture with the SubSystem VL outlined in orange [3]

5.1.1.4 The terminology used in this document is aligned with RCA / OCORA [2,3,5]

5.2 General view

5.2.1.1 Architecture view of the on-board vehicle locator is depicted in Figure 4.

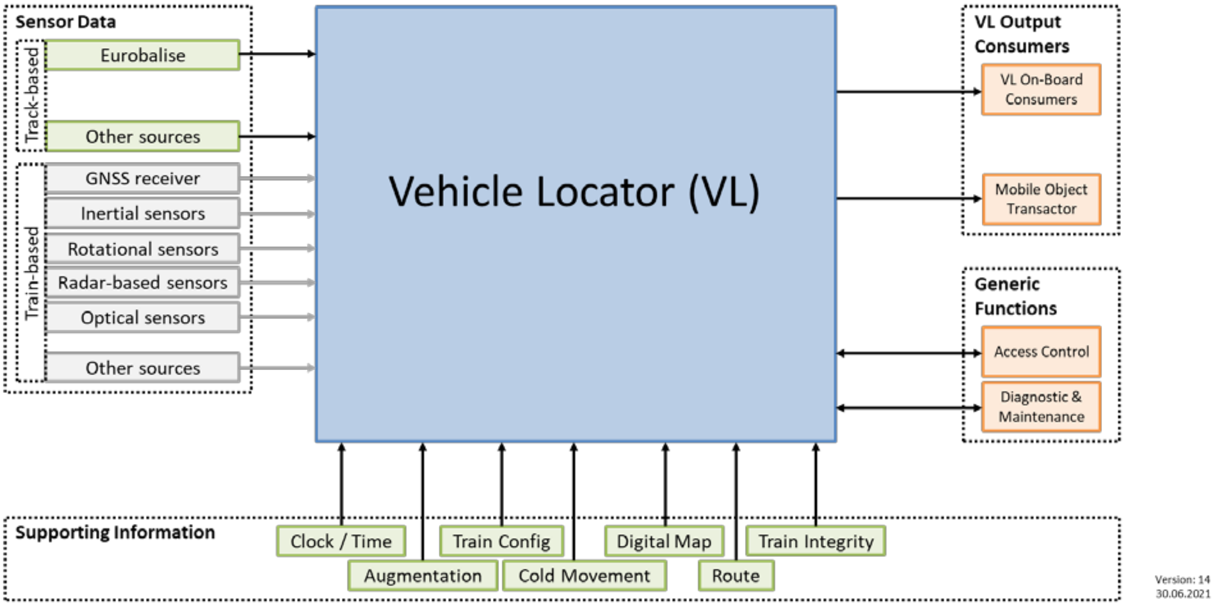

Figure 4: General Localisation Architecture

5.2.1.2 The Vehicle Locator functional box is surrounded by different elements grouped by their influence with the VL:

5.2.1.3 **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.

5.2.1.4 **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.

5.2.1.5 **VL Output Consumers**. Grouping of on-board and trackside consumers of localisation information. Further details on identified consumers can be found in OCORA [5].

5.2.1.6 **Generic Functions**. Generic functions common to every functional box (diagnostic, maintenance and access control) in the context of RCA and OCORA (interfaces in blue, red and green in Figure 2).

5.2.1.7 Several interfaces link the VL with the surrounding elements as depicted in Figure 5 (red and green labels).

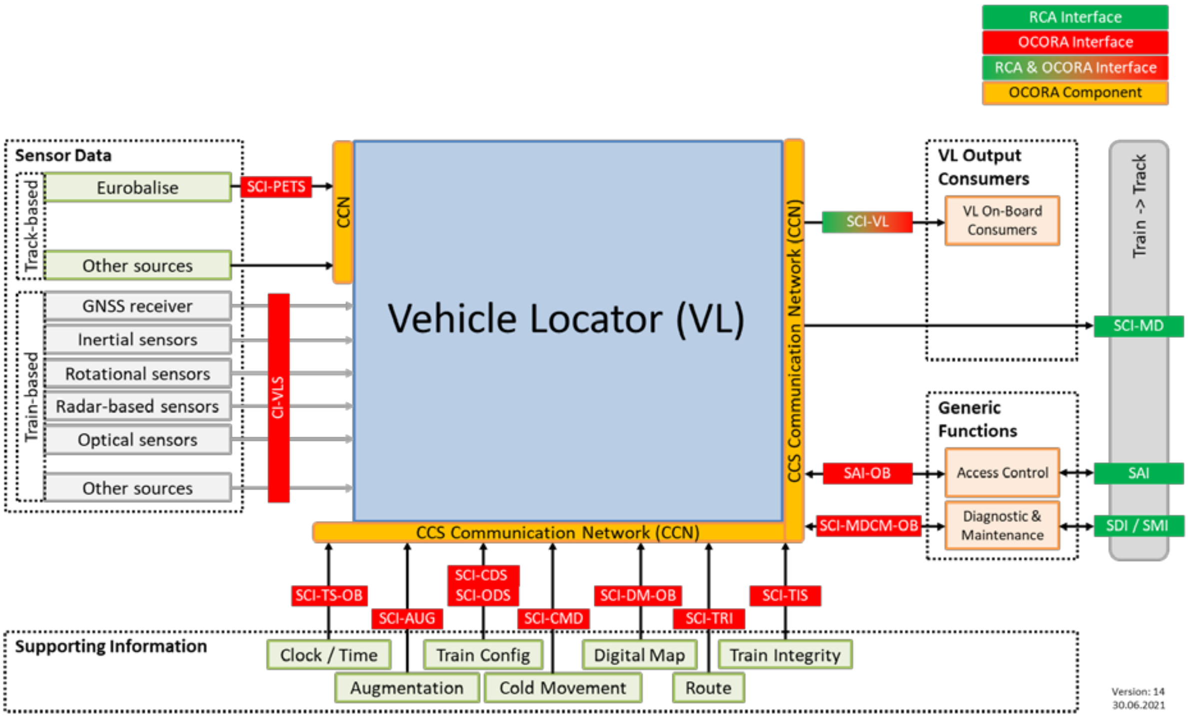

Figure 5 Localisation Concept Architecture Including the interface specification

5.2.1.8 Interface and component/subsystem (without SCI- and CI-prefix) descriptions can be found in [2,5].

5.3 Outputs

5.3.1.1 The VL, processing the different inputs, shall provide the following outputs.

5.3.1.2 Outputs through SCI-VL containing localisation information

a. 1D Position

b. Speed

c. Acceleration

d. 3D Position

e. 3D Orientation

f. 3D Velocity

g. 3D Acceleration

h. Timing

i. Train front end safety property

5.3.1.3 Outputs through interfaces different than SCI-VL

a. Diagnostic information

b. Maintenance information

5.3.2 1D Position group

5.3.2.1 The outputs of the 1D position group are:

5.3.2.2 Reference point Id. Unique identifier of the element from which distance measures are given. Comparable to NID_LRBG but not limited to balise technology [6].

5.3.2.3 Orientation. Orientation of the train in relation to the direction of the reference point. Comparable to Q_DIRLRBG but not limited to balise technology [6].

5.3.2.4 Direction. Direction of train movement in relation to the reference point orientation, i.e., towards or away from the reference point. Comparable to Q_DIRTRAIN but not limited to balise technology [6].

5.3.2.5 Position of the train front end. It tells on which side of the reference point the estimated front end of the train is. Comparable to Q_DLRBG but not limited to balise technology [6].

5.3.2.6 Track edge Id. Identifier of the track edge in which the estimated front end position of the train is.

5.3.2.7 1D distance to the relevant reference point. Distance between the last relevant reference point and the estimated front end of the train. It is expressed as a distance from the last relevant reference point. Comparable to D_LRBG but not limited to balise technology [6].

5.3.2.8 Underestimation of the 1D distance to the relevant reference point. The distance the train may have travelled further than the estimated position. Comparable to L_DOUBTUNDER but not limited to balise technology [6].

5.3.2.9 Overestimation of the 1D distance to the relevant reference point. The distance the train may have travelled shorter than the estimated position. Comparable to L_DOUBTOVER but not limited to balise technology [6].

5.3.3 Speed group

5.3.3.1 The outputs of the speed group are:

5.3.3.2 Train speed. Absolute (1D) estimated speed value along the track, referred to the front end of the train.

5.3.3.3 Underestimation Train Speed. The lower bound of the speed the VL assumes the speed of the front end of the train is.

5.3.3.4 Overestimation Train Speed. The upper bound of the speed the VL assumes the speed of the front end of the train is.

5.3.4 1D Acceleration group

5.3.4.1 The outputs of the acceleration group are:

5.3.4.2 Train acceleration. Absolute (1D) estimated acceleration value along the track, referred to the front end of the train.

5.3.4.3 Underestimation Train Acceleration. The lower bound of the acceleration (1D) the VL assumes the acceleration (1D) of the front end of the train is.

5.3.4.4 Overestimation Train Acceleration. The upper bound of the acceleration (1D) the VL assumes the acceleration (1D) of the front end of the train is.

5.3.5 3D Position group

5.3.5.1 The outputs of the 3D position group are:

5.3.5.2 3D Position. Geographical coordinates for the train front end position. These coordinates will be track constrained.

5.3.5.3 3D Position uncertainty. Covariance matrix of the geographical coordinates.

5.3.6 3D Orientation group

5.3.6.1 The outputs of the 3D orientation group are:

5.3.6.2 Rotational angles. Yaw, pitch, roll of the vehicle where the information providing sensors are installed.

5.3.6.3 Rotational angles uncertainty. Covariance matrix of the value of the different rotational angles.

5.3.7 3D Velocity group

5.3.7.1 The outputs of the 3D velocity group are:

5.3.7.2 3D Velocity. Value related to the position where sensors providing the information are installed given for the different axes in reference to a coordinate system.

5.3.7.3 3D Velocity uncertainty. Covariance matrix of the value of the different velocity values.

5.3.8 3D Acceleration group

5.3.8.1 The outputs of the 3D acceleration group are:

5.3.8.2 3D Acceleration. Value related to the position where sensors providing the information are installed given for the different axes in reference to a coordinate system.

5.3.8.3 3D acceleration uncertainty. Covariance matrix of the value of the different acceleration values.

5.3.9 Timing group

5.3.9.1 The output of the timing group is:

5.3.9.2 Validity Timestamp. Time stamping of the validity of the measures (VL Outputs) using the central on-board Time Service [5], i.e., the time when the localisation information was valid.

5.3.10 Train front end safety property group (Under discussion output, to be confirmed)

5.3.10.1 Front end safety property: This output, considering the train integrity and the train composition definition data, will determine if the localisation information (See 1D Position group 5.3.2 and 3D Position Group 5.3.5) that is being provided (and usually consumed) in a safety-relevant context can be considered safe or non-safe.

(1) Localisation Information is safe when the VL is installed at the front end of the train (without need of TIMS info).

(2) Localisation Information is safe when the VL is NOT installed at the front end of the train and TIMS info is available and integrity is confirmed.

(3) Localisation Information CANNOT be guaranteed to be safe when the VL is NOT installed at the front end of the train and TIMS provides info “integrity loss” or “no information” when TIMS is installed on the train, or there is no TIMS installed.

VL Location at the front end of the train	**TIMS available**	**Integrity status**	**Front end safety property**
Y	N	N/A	Safe
Y	Y	N/A	Safe
N	Y	Confirmed	Safe
N	Y	Integrity loss/No information	Not Safe

N	N	N/A	Not Safe

Table 1: Front end safety property depending on the train configuration

5.3.11 Diagnostic & Maintenance Information group

5.3.11.1 Diagnostic & Maintenance Information about the status (health) of the VL and its components (the definition of the precise diagnostic information the VL needs to provide is out of scope).

5.4 Inputs

5.4.1.1 The identified primary inputs to the VL come from the Sensors Data and the Supporting Information.

5.4.1.2 This document lists all possible primary inputs. The choice of which inputs will be used in the specific product development is up to the designer.

5.4.2 Sensor Data (Track-based)

5.4.2.1 Eurobalise. Eurobalise Data Telegram as specified in ERTMS/ETCS [6, chapter 8] to identify the balise as an absolute reference point, e.g., NID_C, NID_BG, N_PIG, Q_LINK, along with time of balise passage. This information is useful to validate the determined position by the VL against the physical reference position matching.

5.4.2.2 Other sources. Other not explicitly identified sources in conjunction with trackside elements that may provide useful input information to the VL. For example, RFID tags to improve the localisation at low speed in shunting yards or stations, or fiducially markers (e.g., AprilTag) to detect catenary masts. This input has been added to allow flexibility and future developments.

5.4.3 Sensor Data (Train-based)

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

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

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

5.4.3.4 Radar-based sensors. Distance and speed measurements, e.g., doppler radar, LiDAR, LGPR.

5.4.3.5 Optical sensors. Sensors based on image acquisition and analysis to recognise known elements from trackside that may be referenced, e.g., visual odometry, object recognition.

5.4.3.6 Other sources. Other not explicitly identified sources gathered/measured on-board that may provide useful input information to the VL (e.g. radio-based technologies like FRMCS, WLAN, Ultra-Wideband).

5.4.4 Supporting Information

5.4.4.1 Digital Map is a set of functionalities providing track and trackside infrastructure information in the form of structured map data, including quality criteria for the map data. In addition, it also ensures map management functionalities like management of consistency (map versioning), and data transfer (download of map data)[9].

5.4.4.2 Augmentation Information (not from Signal in Space). Augmentation of a positioning system is a method of improving – “augmenting” - the positioning system's performances, such as integrity and/or accuracy thanks to the use of external information. It also ensures management functionalities like management of consistency (versioning) and data transfer from trackside to on-board. EGNOS has to be considered as the starting basis for the standardisation of augmentation of the positioning system.

5.4.4.3 Route Information. An interlocked (safe) train path uniquely assigned to a train/vehicle. This information is seen useful to validate the determined position by the vehicle locator against track selectivity.

5.4.4.4 Train Integrity (Unstable, to be aligned with 5.3.10). Status of the completeness of the train composition. In case the VL is not located in the front of the train, train integrity status will determine the safety property of the output (e.g., engine in the middle scenario).

5.4.4.5 Cold Movement Detector. Information about whether (and potentially how far) an engine/train has moved or not during ETCS’ “no power”-mode to speed up the initialisation of the localisation system.

5.4.4.6 Train Configuration. Configuration data containing disposition information, such as, the sensor/antenna/VL installation location. This information is needed to determine the estimated train front end position and its estimated speed.

5.4.4.7 Clock / Time. Master clock information from the central on-board Time Service [5] that allows all CCS on-board components to have their time synchronised with each other and synchronised with trackside systems. This information will be used to timestamp the output of the VL with the validity time of the information provided.

5.5 Positioning Functions NOT allocated to the Vehicle Locator

5.5.1.1 The following ETCS positioning functions are not in the responsibility of the VL:

a. Generation and transmission of the Train Position Report [6, chapter 8.6.4]

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 SS035 odometer function information for STM system [10]