



CLUG Demonstration of Readiness for Rail – CLUG 2.0

D6.6 - PROPOSED LOCALISATION ON-BOARD SYSTEM REQUIREMENTS AND GAP ANALYSIS

Due date of deliverable: 31/01/2025

Actual submission date: 24/04/2025

Leader of this Deliverable: Adrien GHARIOS, SNCF

Reviewed: Y

Document status		
Revision	Date	Description
0.1	01/08/2024	Initialisation of the document
0.2	04/10/2024	Update with ADS contribution
0.3	08/01/2024	Update with Partners contribution
0.4	13/02/2024	Update after TMT review
1.0	24/02/2025	Final approved version after quality check
1.1	21/03/2025	Update after external review
2.0	24/04/2025	Final version officially submitted to EUSPA

Project funded from the European Union’s Horizon 2020 research and innovation programme		
Dissemination Level		
PU	Public	X
SEN	Sensitive, limited under the conditions of the Grant Agreement	
Classified R-UE/EU-R	EU RESTRICTED under the Commission Decision No2015/444	
Classified C-UE/EU-C	EU CONFIDENTIAL under the Commission Decision No2015/444	
Classified S-UE/EU-S	EU SECRET under the Commission Decision No2015/444	

Start date of project: 01/02/2023

Duration: 30 months

REPORT CONTRIBUTORS

NAME	COMPANY	DETAILS OF CONTRIBUTION
Adrien GHARIOS	SNCF	Author
Said EL FASSI	SNCF	Contributor
Anas DARWICH	SNCF	Contributor
Arnault SFEIR	ADS	Contributor
Roman EHRLER	SBB	Contributor
Iban LOPETEGI ZINKUNEGI	CAF	Contributor
Bernhard STAMM	SMO	Contributor
Zoltan ABRAM	DB	Contributor
Lena-Alexandra TILLEMANN	DB	Contributor
Valentin BARREAU	SNCF	Reviewer
Mariya Kayalova	RINA-C	Quality check
Jose Bertolin	UNIFE	Final check and submission to reviewers and EUSPA
Denis Dusso		External review

EXECUTIVE SUMMARY

CLUG 2.0 is going a step forward through the improvement of the safe functional architecture (LOC-OB System) prototyped in WP4/WP5, mainly through post processing and partly in live demonstration.

The LOC-OB System is reviewed, consolidated and tested 1) using as a basis the high-level user need and subsequently the system requirements including RAMS, 2) and putting a focus on relevant functions such as Data Fault Detection and Exclusion, Track Selectivity, Integrity, and Initialisation.

This document, “D6.6: *Proposed Localisation On-Board System Requirements and Gap Analysis*” proposes a review of the requirements defined in D2.4 considering the feedback of all the work packages. It also provides a gap analysis on the ERTMS documents identifying the modifications to be done with the introduction of the LOC-OB into the ERTMS CCS-OB.

It is important to remember that WP2 proposed a set of requirements anticipating a future standardised equipment and not a set of requirements to be fulfilled by the development done within the project. Due to this agreed strategy, the demonstrator shall not cover all the requirements defined in D2.4 [2] if no limitation is identified.

To summarise:

- WP2 defined the desired requirements for the standardised LOC-OB.
- WP4 defined a functional architecture then developed a prototype focusing on critical functions or on technical uncertainties derived from the requirements.
- WP5 defined the validation strategy formulated in a test plan, developed a test environment and tools to perform tests and analyse data, and performed test activities and data analysis to conclude on the feasibility of the defined requirements.
- WP3 carried out safety activities.

It has to be noted that the overall CCS-OB architecture is still under discussion and no agreement is foreseen before the end of the CLUG 2.0 project. The CLUG 2.0 demonstrator aims to showcase the use of GNSS and EGNOS in railways. While topics related to the CCS-OB architecture agreement are identified in this document, they are neither discussed nor commented on.

The conclusions of this gap analysis can be summarised as:

- The set of requirements defined in D2.4 [2] cannot be considered as mature enough and needs to be refined in the scope of future projects. This is mainly due to its dependency on and the missing agreement on an overall CCS-OB architecture and the lack of a clear functional allocation that cannot be solved or defined in the scope of CLUG 2.0.
- The introduction of the LOC-OB will have a significant impact on the ERTMS system, and several subsets will need to be updated impacting other ETCS components.

No part of this work may be reproduced or used in any form or by any means (graphic, electronic, or mechanical including photocopying, recording, taping, or information storage and retrieval systems) without the written permission of the copyright owner(s) in accordance with the terms of the CLUG Consortium Agreement (EC Grant Agreement 101082624).

LIST OF ACRONYMS

ACRONYM	CONCEPTS
BTM	Balise Transmission Module
CMD	Cold Movement Detector
CCN	CCS Communication Network
CCS	Command, Control and Signalling
CCS-OB	Command, Control and Signalling Onboard
EGNOS	European Geostationary Navigation Overlay Service
ETCS	European Train Control System
ERTMS	European Rail Traffic Management System
FFFIS	Fit, Form and Functional Interface Specification
GNSS	Global Navigation Satellite System
LOC-OB	Localisation Onboard
RAMS	Reliability, Availability, Maintainability, Safety
TSI	Technical Specification of Interoperability
WP	Work Package



CONTENTS

Applicable Documents.....	7
1 Introduction	7
2 Re-evaluation of the system requirements.....	8
2.1 Methodology	8
2.2 Requirements classification and analysis.....	8
2.3 Results of the requirements analysis.....	8
2.3.1 Requirement not covered by CLUG 2.0 demonstration purpose.....	8
2.3.1.1 Reference frame divergence.....	8
2.3.1.2 Requirements related to the interaction with other CCS-OB components.	9
2.3.1.3 Industrialisation requirements.....	10
2.3.2 Design anomaly : LOC-OB cannot provide any data if the track is not determined.....	11
2.3.3 The system requirement need to be updated.	12
2.3.4 The system requirement is not relevant and needs to be deleted.	13
2.3.5 The system requirement is subject to discussion.	13
2.3.6 Potential performance non-achievement	13
2.4 Missing LOC-OB requirements and clarifications	14
2.5 Specific case of the safety requirements and the safety demonstration	15
3 ETCS Gap Analysis.....	16
3.1 Interfaces to be standardised.....	16
3.1.1 Case of subset 147 and CCS Consist Network.....	17
3.1.2 Identification of the interfaces and impacts on ETCS.....	18
3.2 Functional and non-functional modifications foreseen.....	23
3.2.1 Introduction of the digital map and other localisation references	23
3.2.2 Introduction of the track edge ID.....	23
3.2.3 Performance objectives Subset-041.....	24
3.2.4 Impact of changing the model of accuracy.....	26



3.2.5	Balises	28
3.2.5.1	Engineering rules update	28
3.2.5.2	Impact on the RAMS analysis	29
3.2.5.3	Impact on Linking	29
3.2.5.4	Balises not related to localisation	29
3.2.6	Virtual reference location conceptor track node	29
3.2.7	Orientation of Virtual Refence Frame	29
3.2.8	Start of mission procedures following power on	30
3.3	Interaction between the subsets and the introduction of LOC-OB	30
4	Overall gap analysis table.....	32
5	Conclusion.....	35
Appendix A: References.....		37

Table of Figures

Figure 1	: Extract from Subset-026 BL4 § 2.....	16
Figure 2	: LOC-OB identified interfaces.	17
Figure 3	: Subset 41 extract	24
Figure 4	: SS41 vs CLUG 2.0 model of accuracy.....	27

List of Tables

Table 1	: Interaction between the subsets and the introduction of LOC-OB	31
Table 2	: Overall gap analysis.....	34

Applicable Documents

The following documents define the contractual requirements that all project partners are required to comply with:

- Grant Agreement N°101082624 (which includes Description of Work, Grant Preparation Forms and annexes): This is the contract with the European Commission which defines what must be done, how and the relevant efforts.
- Consortium Agreement: This defines our obligations towards each other.

Each of these documents were established at the start of the project, and copies were supplied to each partner. Where changes have been made to these documents during the duration of the project, the latest formal issued version shall apply.

In the event of a conflict between this document and any of the contractual documents referenced above, the contractual document(s) shall take precedence.

1 Introduction

This document, “D6.6: *Proposed Localisation On-Board System Requirements and Gap Analysis*” proposes a review of the requirements defined in D2.4 considering the feedback of all the work packages. It also provides a gap analysis on the ERTMS documents identifying the modifications to be done with the introduction of the LOC-OB into the ERTMS CCS-OB.

It will be divided in three main sections:

- Re-evaluation of the system requirements defined in WP2 considering the feedback of WP3, WP4 and WP5.
- ETCS gap analysis (based on TSI 2023 and any subsequent CRs already identified for future TSIs) to identify the impacts on the ETCS documentation with the introduction of LOC-OB. This includes the evolution of the system both on the trackside (CCS) and on-board side (LOC & PAS).
- Overall Gap analysis also considering the state of the demonstrations.

2 Re-evaluation of the system requirements

2.1 Methodology

The re-evaluation of the system requirements is performed in two steps:

- A classification of each requirement based on the applicability or inapplicability resulting of the outcomes of WP3, WP4 and WP5 is carried out. An update proposal of D2.4 will be provided accordingly.
- A qualitative approach, where some topics are highlighted, and missing requirements are identified.

2.2 Requirements classification and analysis

The requirement classification and analysis is available in a matrix format. In this analysis, requirements are reviewed by each Work Package.

2.3 Results of the requirements analysis

From the gap analysis on the requirements, it is possible to identify 5 types of discrepancies:

- 1) The CLUG 2.0 demonstrator does not consider the requirement because it is not relevant for demonstration purposes. Note: The demonstrator focuses on the technical and functional aspects related to the usage of GNSS and EGNOS in a railway environment.
- 2) The CLUG 2.0 demonstration does not cover the requirement because of technical limitations or non-conforming design.
- 3) The system requirement is misleading and needs to be updated.
- 4) The system requirement is not relevant and needs to be deleted.
- 5) The system requirement is subject to discussion (no agreement found or missing reliable information as the functional allocation on the CCS-OB). Since CLUG 2.0 focuses on the technical aspects related to the usage of GNSS and EGNOS in the railways, topics related to railway sector non-agreement are identified in this document but not discussed nor commented.

2.3.1 Requirement not covered by CLUG 2.0 demonstration purpose.

2.3.1.1 Reference frame divergence.

The set of requirements defined in D2.4 [2] specifies that the LOC-OB shall provide the train front end position and provide information in reference to the train front end as train orientation or the track edge ID.

The train front end is related to the train configuration (active cab for example), the demonstrator would need to have access to extra information to derive the train front end position from its local

position. The LOC-OB demonstrator developed in WP4 outputs the position at boggie pin as it is easier for the performance analysis purpose. Since this translation from the LOC-OB local position to the train front end is not considered necessary for the CLUG2.0 project, this limitation is considered accepted.

Note that some other localisation projects, as R2DATO [18], request that the Localisation On-board Unit provides only its local position. Each user is expected to convert / adapt the local position information provided by the LOC-OB into a format suited to their specific needs.

The reference frame issue can also be considered as a subject to discussion (no agreement found or missing reliable information as the functional allocation on the CCS-OB). it is not a major technical issue but rather a question of agreement.

2.3.1.2 Requirements related to the interaction with other CCS-OB components.

Since CLUG 2.0 is not tested in a real CCS-OB environment, all requirements related to interfaces cannot be implemented or tested. These requirements are reminded there after:

SpecSysReq[034]	LOC-OB shall embed a safe and secure mechanism to detect delays and time incoherencies within the most constraining user exported THR.
SpecSysReq[035]	LOC-OB, user equipment and provider equipment shall use data exchange mechanisms in accordance with the safety, security and interoperability requirements.
SpecSysReq[036]	LOC-OB shall provide its dataset in compliance with the future TSI through the SCI - Vehicle Locator (SCI-VL) interface.
SpecSysReq[037]	If needed, LOC-OB shall acquire the Digital Map in accordance with the future TSI through the SCI - Map Repository On-Board (SCI-REP-OB) interface.
SpecSysReq[039]	If available and needed, LOC-OB shall comply with the future TSI concerning the use the Augmentation Data (definition of the dataset and exchange mechanism) through the SCI - Augmentation (SCI-AUG) interface.
SpecSysReq[041]	If existing, LOC-OB shall acquire the train static configuration from the common on-board Configuration Data Storage (CDS) component through the SCI - Configuration Data Storage (SCI-CDS) interface. Otherwise, specific static configuration information shall be managed as an internal component of LOC-OB.
SpecSysReq[044]	If needed, LOC-OB shall use the LRBG reference provided by ETCS through the SCI - Vehicle Supervisor (SCI-VS) interface.
SpecSysReq[045]	If needed, LOC-OB shall use the reference points defined in the Digital Map through the SCI-VS interface.
SpecSysReq[046]	If available and needed, LOC-OB shall comply with the future TSI concerning the use of Cold Movement information. (Definition of the dataset and exchange mechanism).

2.3.1.3 Industrialisation requirements.

Several requirements are dedicated to the industrialised product and are not considered by the demonstrator. These requirements are reminded there after:

SpecSysReq[047]	The LOC-OB hardware shall comply with the overall CCS-OB reliability as defined in EEIG 92S126 Chapter 2. Minor failure: $\lambda < 1,25 \cdot 10^{-4}/h$. Reduced service failure: $\lambda < 3,3 \cdot 10^{-6}/h$. Immobility failure: $\lambda < 3,7 \cdot 10^{-7}/h$.
SpecSysReq[050]	LOC-OB shall manage useful data toward maintenance in an internal log memory and through the SCI - Monitoring, Diagnostic, Configuration, Maintenance On-Board (SCI-MDCM-OB) interface.
SpecSysReq[067]	LOC-OB shall log overall availability issues and specific relevant events as timestamped events.
SpecSysReq[051]	LOC-OB shall be designed as a generic application (cf. EN 50126-1:2017 and EN 50126-2:2017).
SpecSysReq[052]	LOC-OB shall be designed to ease software updates (including security patches) by avoiding complex workshop procedures requiring bench testing.
SpecSysReq[054]	The LOC-OB's design and maintenance concept shall meet a Mean Time To Restore (MTTR) $\leq 1h$.
SpecSysReq[055]	Preventive maintenance or periodic sensor calibration period of the overall LOC-OB shall exceed 2 years.
SpecSysReq[056]	The safety of the LOC-OB shall be ensured and demonstrated according to the Common Safety Methods (cf. Ref [34]) and the EN 50126 standard (cf. Ref [5] and Ref [6]).
SpecSysReq[057]	If needed, calibration procedure(s) shall fulfil with the safety requirement.
SpecSysReq[066]	If LOC-OB cannot guarantee safe operation due to internal safety process faults (for ex: safe computer failure): LOC-OB shall not provide any information to the users.
SpecSysReq[068]	If LOC-OB is unable to produce a data within the awaited THR due to insufficient information to guarantee safe results (one or several sensor failure or unavailability), LOC-OB shall provide a default invalid value for the data concerned and shall provide all other data as specified.
SpecSysReq[058]	LOC-OB shall fulfil requirements and recommendations for cybersecurity as specified in CLC/TS 50701 (cf. Ref [36]) 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.
SpecSysReq[059]	LOC-OB components shall comply with applicable environmental standards.

SpecSysReq[060]	LOC-OB components shall comply with the Ref [42] standard: Railway applications - Fire protection on railway vehicles. The latest edition shall apply.
SpecSysReq[061]	LOC-OB components shall comply with the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and RoHS2 directives. The latest edition shall apply.

2.3.2 Design anomaly : LOC-OB cannot provide any data if the track is not determined

This limitation is identified on the demonstrator algorithms. It is not considered as problematic for the CLUG 2.0 project, and no blocking point is identified to modify the demonstrator to fulfil SpecSysReq[031] (not done in the scope of CLUG 2.0).

Reminder of the limitation:

The LOC-OB algorithms developed for the CLUG2.0 project cannot generate any data without knowing the track on which the train is (track selectivity). This is not an issue for the demonstration but need to be corrected for an industrial LOC-OB to solve the case of an initialisation without a known initial position. In this case, the LOC-OB does not have any initial position, and the train may need to run in Staff Responsible mode to determine an initial position (Balise detection, access to open sky etc). To run a train in Staff Responsible, speed and travelled distance are mandatory.

SpecSysReq[028] SpecSysReq[031] are still considered relevant even if not implemented nor tested in the scope of the CLUG 2.0 project.

SpecSysReq[028]	After being powered up and its initialisation stage ended, LOC-OB shall provide data continuously.
SpecSysReq[031]	In case the LOC-OB cannot reach full operational capability after the system is powered on (e.g., Unknown track segment / track edge), estimated speed and travelled distance since the LOC-OB is powered on shall always be provided.

2.3.3 The system requirement need to be updated.

Two requirements have been identified:

SpecSysReq[025]	<p>Only if safety is not to be compromised, LOC-OB shall not provide a sudden variation of the position and the speed confidence intervals that leads to brake intervention or trip (TR) mode. The increase of the confidence interval shall allow the train to adapt its behaviour to avoid emergency braking.</p>	<p><u>Upgrade proposal:</u> Only if safety is granted (fulfilment to the safety requirements), the occurrence of sudden variation (e.g., sudden increase of the confidence interval while the train is following a braking curve) or loss of LOC-OB localisation information by a safety relevant consumer due to the lack of valid data (e.g., lack of message, data is too old, etc.) leading to a brake intervention (service brake or emergency brake) shall be less than $2 \cdot 10^{-6}/h$ (one brake intervention per year for a fleet of 10 trains operated during 14 hours per day).</p>
------------------------	---	---

[Rationale]: Three use cases are identified:

- In the case the sudden increase of the train front end position confidence interval is greater than the distance travelled, the train minimum safe rear end can be seen as going backwards. Therefore, in moving block area, the following train can then trigger brake intervention or trip mode if the two trains are close to each other.
- In the case the sudden increase of the train front end position underestimation is larger than the distance to a target (EOA, speed decrease ...), the train can trigger brake intervention.
- In the case the sudden increase of the speed underestimation is larger than the margin to the speed curve, the train can trigger brake intervention or trip mode instead of adapting its speed.

The confidence interval increase can be counterbalanced by slowing down the train (lower traction or service braking).

<p>SpecSysReq[030]</p>	<p>After the LOC-OB is powered-on, it shall fulfil entire operational capability in less than 10 minutes when initial position is not valid under any of the following conditions:</p> <ol style="list-style-type: none"> 1. Initial position is unknown (e.g., last known position is not saved before LOC-OB is switched-off). 2. Track edge id is unknown (e.g., last track edge id is not saved before LOC-OB is switched-off). 3. CMD indicates a train movement during the train is powered off. 	<p><u>Upgrade proposal:</u> After the LOC-OB is powered-on, if the initial position is not valid under any of the following conditions:</p> <ol style="list-style-type: none"> 1. Initial position is unknown (e.g., last known position is not saved before LOC-OB is switched-off). 2. Track edge id is unknown (e.g., last track edge id is not saved before LOC-OB is switched-off). 3. CMD indicates a train movement during the train is powered off. <p>The LOC-OB shall be able to generate an initial position while the train move in unsupervised position mode (for example shunting mode or staff responsible mode) .</p>
-------------------------------	---	---

2.3.4 The system requirement is not relevant and needs to be deleted.

In the frame of Clug 2.0, no requirement to be purely deleted has been identified. To be noticed that several requirements are still under discussion and could be deleted in the frame of other projects taking over and using CLUG 2.0 results.

2.3.5 The system requirement is subject to discussion.

Most but not all of the system requirements subject to discussion are related to the reference frame definition. (refer to §2.3.1.1).

2.3.6 Potential performance non-achievement

The demonstrator performances will be analysed in the performance analysis report (D5.3[19]) delivered by Task 5.5.

2.4 Missing LOC-OB requirements and clarifications

Time synchronization, or rail localization system time reference: cf D4.1[4] §3.5, there is no requirement in D2.4 [2] defining an absolute time reference nor the need of a relative time stamping. This situation brings that the “validity timestamp”, requested in the datasets as a time reference can’t be used by the LOC-OB users as they are no common time reference.

This situation is related to the assumption that future CCS-OB will need to define a common reference time strategy (absolute or relative) for all the components and formalised in the following requirements:

Req ID	SpecSysReq[034]
Requirement	LOC-OB shall embed a safe and secure mechanism to detect delays and time incoherencies within the most constraining user exported THR.
Additional information	Undetected offsets or clock drift on interfaces can lead to safety issues.
Category / classification	RAMSS
Traceability	UR[007]; SF-002
Acceptance Method	Analysis; Test
Safety assumption	Related to safety

Req ID	SpecSysReq[035]
Requirement	LOC-OB, user equipment and provider equipment shall use data exchange mechanisms in accordance with the safety, security and interoperability requirements.
Additional information	Most of the interfaces between LOC-OB and provider/user will be defined in future relevant standards. Supplier specific mechanisms shall be avoided. If data is transferred through a communication interface, EN50159 shall apply. To be noticed that Subset 147 will define the standard for the network technology being used for the on-board CCS subsystem.
Category / classification	RAMSS
Traceability	UR[015]
Acceptance Method	Analysis; Test
Safety assumption	Related to safety



Track edge ID output required strategy: cf D4.1[4] §3.6, the strategy or the functional concept for the LOC-OB to output the current track edge ID when the LOC-OB defined it at the integrity risk probability is not specified in D2.4 [2] . In WP4, it was assumed the track edge ID can be output only when under and over CI does not include the node when the track edge ID are changing. Indeed, this position CI is the interval to ensure the real train position inside at the same integrity risk probability requested to the track edge ID. This deduction and the strategy for the LOC-OB to output the track edge ID should be clarified in terms of what are the safe user needs with regard to track edge ID. Potentially, as per demonstrator objective, the track edge ID is output even when the associated integrity risk does reach the specified one (i.e. SIL4 THR) with an associated safe confidence status. This could be another strategy offering more information to the safe users for specific operations accepting less stringent safety level.

The track edge ID strategy is not agreed and is currently being discussed as part of other projects.

2.5 Specific case of the safety requirements and the safety demonstration

A gap analysis focusing on the safety requirements is performed in the scope of WP3.

The results are available in D3.7 [3]§ 2.2.

To be reminded that from RAMSS perspective, the CLUG 2.0 demonstrator does not demonstrate any safety compliance with a SIL4 process or objective and focusses on the achievement of performance requirements.

3 ETCS Gap Analysis

3.1 Interfaces to be standardised.

In opposition to TSI 2023, where odometry is part of the ETCS onboard unit with internal, supplier-specific functionality and interfaces, LOC-OB is intended to become CCS-OB interoperability constituent, to which various interfaces, as well as a defined functionality, related test specifications etc. need to be standardised.

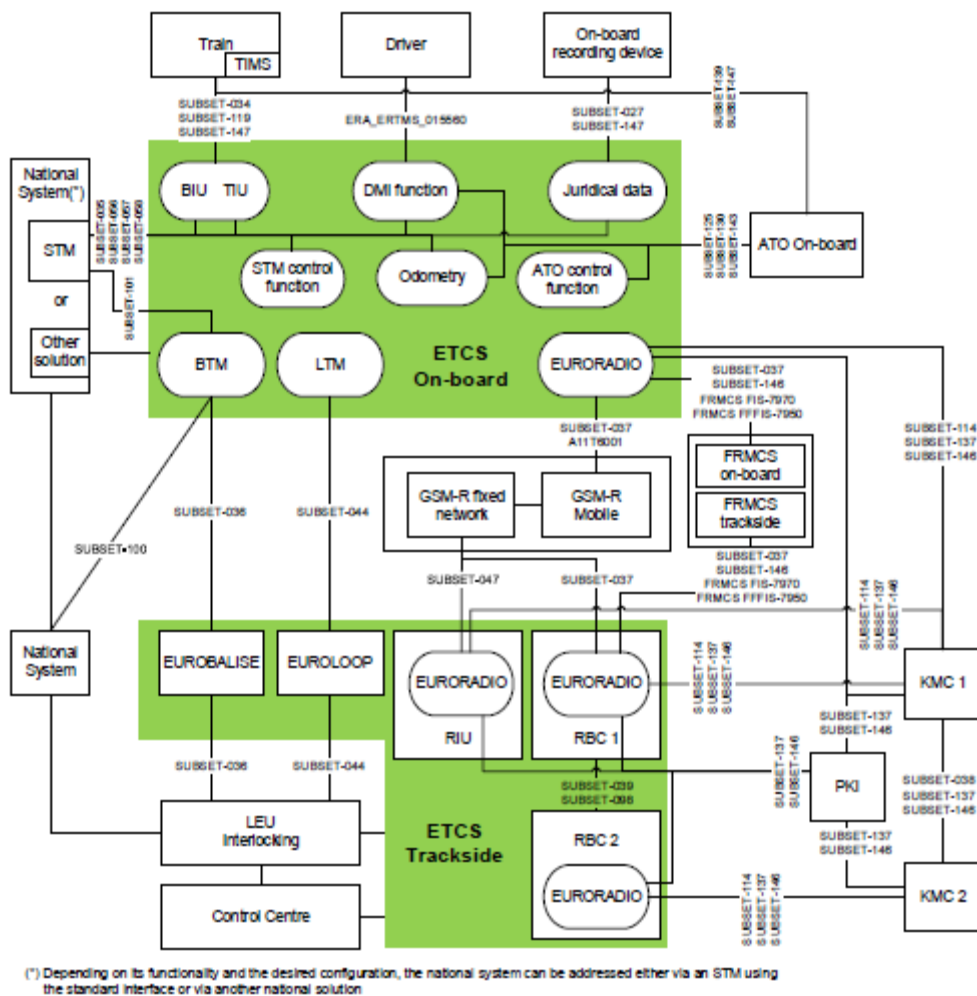


Figure 1 : Extract from Subset-026 BL4 § 2.

In the scope of CLUG2.0, D2.3 [1] §4 provides assumptions toward the LOC-OB interfaces.

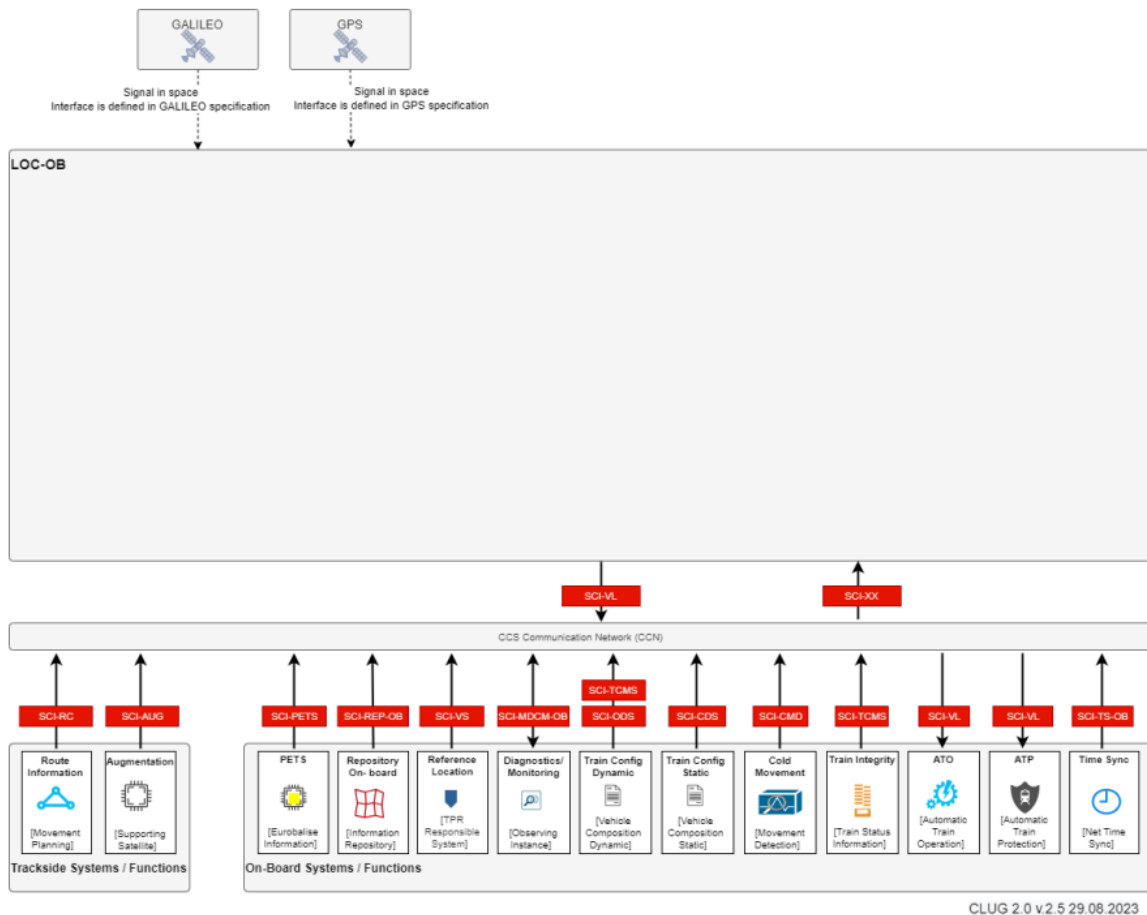


Figure 2 : LOC-OB identified interfaces.

D6.6 takes the hypothesis that all the interfaces identified in D2.3 [1] will be needed and therefore must be standardised. It is however possible that, with the work in progress in some other initiatives in EU-RAIL, several interfaces will be kept supplier specific or even deleted.

3.1.1 Case of subset 147 and CCS Consist Network

D2.3 [1] and D2.4 [2] do not explicitly define how the LOC-OB will be connected to the ETCS onboard system, and possibly other systems which require position and odometry information.

According to the SS147 a CCS Consist Network is defined which is based on IP technology, and the LOC-OB must comply with its requirements. No technical challenges are anticipated for the LOC-OB to operate on this network.

SS147 will also define a safe protocol to ensure secure and safe data transmission, capable of supporting safety integrity levels up to SIL4. Although this protocol has not yet been defined, it is not considered a technical obstacle, as there are several SIL4-certifiable safe protocols readily available on the market.

3.1.2 Identification of the interfaces and impacts on ETCS

The following table lists the interfaces identified in D2.3[1], classifies them in regard to the need for standardisation, and identifies the status of work.

Interface Name	Description	Related requirement (D2.4[2])	Defined in an existing subset? current situation	Conditions to be met when introducing the LOC-OB
SCI-VL	<p>The SCI-VL interface is the central and unique output interface of LOC-OB. It delivers all desired computed information to the CCS-OB components such as autonomous train operation (ATO) and the train protection (ATP, national train protection) systems.</p> <p>Note: All LOC-OB output is distributed through the SCI-VL interface via the CCN.</p>	SpecSysReq[036] LOC-OB shall provide its dataset in compliance with the future TSI through the SCI - Vehicle Locator (SCI-VL) interface.	<p>Not defined in any existing subset.</p> <p>Some equivalent interfaces may exist but are supplier specific.</p>	The interface needs to be defined in a subset.
SCI-REP-OB	The SCI-REP-OB provides Map Data from the Repository On-Board (REP-OB) to the LOC-OB unit by the CCN.	SpecSysReq[037] If needed, LOC-OB shall acquire the Digital Map in accordance with the future TSI through the SCI - Map Repository On-Board (SCI-REP-OB) interface.	<p>Not defined in any existing subset.</p> <p>Presently, no map is embedded onboard.</p>	<p>The interface needs to be defined in a subset.</p> <p>Map data is a key data shared between several onboard constituents.</p>
SCI-PETS	SCI-PETS provides Balise information from the Physical ETCS Transponder Service (PETS) component of the	SpecSysReq[043] If needed and available, LOC-OB shall acquire the EUB Telegram in accordance with	<p>Not defined in any existing subset.</p> <p>Presently, some equivalent interfaces may exist but are supplier specific.</p>	The interface needs to be defined in a subset.

Interface Name	Description	Related requirement (D2.4[2])	Defined in an existing subset? current situation	Conditions to be met when introducing the LOC-OB
	European Train Protection - On-Board (ETPOB) building block to LOC-OB through the CCN.	the future TSI. through the SCI - Physical ETCS Transponder Service (SCI-PETS) interface.		
SCI-VS	The SCI-VS interface provides the information of the Vehicle Supervisor (VS) which reference location should be used (e.g., LRBG).	<p>SpecSysReq[044] If needed, LOC-OB shall use the LRBG reference provided by ETCS through the SCI - Vehicle Supervisor (SCI-VS) interface.</p> <p>SpecSysReq[045] If needed, LOC-OB shall use the reference points defined in the Digital Map through the SCI-VS interface.</p>	<p>Not defined in any existing subset.</p> <p>Presently, some equivalent interfaces may exist but are supplier specific.</p>	<p>The interface needs to be defined in a subset but depends on the CCS-OB architecture. Also, depending on the functional allocation of the CCS-OB, this interface may not be needed by LOC-OB.</p>
SCI-RC	<p>The SCI-RC interface provides the information of an interlocked and safe train path uniquely assigned to a train/vehicle. Note: This interface is not yet defined and needs a safety study first. Depending on the outcome of this safety study, this interface might be obsolete. See also discussion on Appendix A in Ref [2] regarding the main open questions and concerns with</p>	<p>SpecSysReq[038] If available and needed by LOC-OB, LOC-OB shall acquire the train routing information (Movement authority, journey profile or switch information etc) in accordance to the future TSI through the SCI – Route Control (SCI-RC) interface.</p>	<p>Not defined in any existing subset.</p> <p>Presently, some equivalent interfaces may exist but are supplier specific.</p>	<p>The interface needs to be defined in a subset but depend on the CCS-OB architecture. Also, this data can be provided via the SCI-RC or through ETCS-OB.</p>

Interface Name	Description	Related requirement (D2.4[2])	Defined in an existing subset? current situation	Conditions to be met when introducing the LOC-OB
	regards to the use of route information as LOC-OB input.			
SCI-AUG	The SCI-AUG interface provides Augmentation Data (supporting information such as GNSS augmentation or the knowledge of temporary conditions) from trackside that can enhance sensor measurements for real-time information in severe conditions (i.e., tunnel, leaves on rails, etc.). Note: EGNOS information can also be received by a GNSS receiver from the signal in space. This acquisition is in the responsibility of the supplier selecting the set of sensors.	SpecSysReq[039] If available and needed, LOC-OB shall comply with the future TSI concerning the use the Augmentation Data (definition of the dataset and exchange mechanism) through the SCI - Augmentation (SCI-AUG) interface.	Not defined in any existing subset. Presently, some specific augmentation data as track conditions are available onboard but not used by odometry.	The interface needs to be defined in a subset. EGNOS data, as show in CLUG 2.0, need to be provided by the trackside. It is highly probable that EGNOS will be provided via FRMCS.
GPS / GALILEO	GPS / GALILEO signals are transmitted over space from the satellites towards the LOC-OB sensors. The interface is defined in GPS / GALILEO specifications.	Not identified in D2.4.	Not defined in any existing subset.	No need to define this interface in a subset is identified nor to create a dedicated standard for the railway. GPS / GALILEO sensors are component of the shelf based on GPS/GALILEO specifications.

Interface Name	Description	Related requirement (D2.4[2])	Defined in an existing subset? current situation	Conditions to be met when introducing the LOC-OB
SCI-TCMS	SCI-TCMS	SpecSysReq[040] If available and needed by LOC-OB, LOC-OB shall comply with the future TSI concerning the use of Train integrity status. (Definition of the dataset and exchange mechanism) through the SCI - Train Control Management System (SCI-TCMS) interface.	Not defined in any existing subset.	The interface needs to be defined in a subset.
SCI-ODS	The SCI-ODS interface provides dynamic train configuration such as train length, cab status, and a representation of the current dynamic train configuration.	SpecSysReq[042] If needed, LOC-OB shall acquire the dynamic train configuration, as active cab, train length, rigid definition of the primary moving direction, or definition of trains front end from Train Control Management System (TCMS) through the SCI - Operational Data Storage (SCI-ODS) interface.	Not defined in any existing subset. Presently, some equivalent interfaces may exist but are supplier specific.	The interface needs to be defined in a subset. Also, depending on the functional allocation of the CCS-OB, this interface may not be needed by LOC-OB.
SCI-CMD	The SCI-CMD (Cold Movement Detection) interface delivers information on whether the train moved while LOC-	SpecSysReq[046] If available and needed, LOC-OB shall comply with the future TSI concerning the use of Cold Movement	Not defined in any existing subset. Presently, some equivalent interfaces may exist but are supplier specific.	The interface needs to be defined in a subset.

Interface Name	Description	Related requirement (D2.4[2])	Defined in an existing subset? current situation	Conditions to be met when introducing the LOC-OB
	<p>OB was off or not in operation. Note: We assume that the data delivered is the minimal information whether the vehicle got moved or not while LOC-OB was inactive. Additional information like distance moved etc. could be available, but this cannot be verified since the implementation state is “planned”.</p>	<p>information. (Definition of the dataset and exchange mechanism).</p>		
<p>SCI-MDCM-OB</p>	<p>The Monitoring, Diagnostics, Configuration and Maintenance On-Board (MDCM-OB) building block provides on-board monitoring and diagnostics information through the SCI-MDCM-OB interface. LOC-OB sends its diagnostic information to the MDCM-OB for a system-wide inspection and supervision.</p>	<p>SpecSysReq[050] LOC-OB shall manage useful data toward maintenance in an internal log memory and through the SCI - Monitoring, Diagnostic, Configuration, Maintenance On-Board (SCI-MDCM-OB) interface.</p>	<p>Not defined in any existing subset. Presently, some equivalent interfaces may exist but are supplier specific.</p>	<p>LOC-OB will use the standard interface if defined, otherwise, this interface can be kept specific.</p>

3.2 Functional and non-functional modifications foreseen.

3.2.1 Introduction of the digital map and other localisation references

ETCS (all baselines) uses physical Eurobalises groups as a reference location and the train position is defined as the travelled distance from that reference.

A position report based on distance from Eurobalises groups is track selective due to the physical nature of the Eurobalise transmission system, but the track selectivity is lost when passing a facing point. In these cases, only the trackside system can determine a track selective position, as the onboard system has no information on the track layout, as well as the location and dynamic position of points.

With the introduction of GNSS + EGNOS based positioning, and the possible reduction of the number of Eurobalises in the track, virtual reference location shall be used as a reference position. These reference points shall permit reporting a track selective position also after passing facing points. For these reasons, a digital track map is required onboard the train, which is accessible by the ASTP system. The introduction of a digital map will not only require new functionality and interfaces to provide the map, but also impact several of the existing ETCS principles:

- The introduction of virtual reference location that can be any position on the map.
- The positioning error (supposedly equal to zero) of the virtual reference location that is today defined as the Q_LOCACC for physical balises, will need to be agreed and clarified.
- The management of virtual reference location and physical reference location needs to be agreed and clarified.
- The handling of physical balise position (position + inaccuracy available in the map vs timestamped telegram + Q-LOCACC provided by the BTM) needs to be agreed and clarified.
- The linked balise verification will need to be redefined. Physical balise verification can then be done comparing map data and time-stamped balise telegram instead of the linked balise verification.
- Mechanisms are required to ensure that the onboard track map is always up to date and valid.

3.2.2 Introduction of the track edge ID

CLUG 2.0 introduces the track edge ID which shall be provided by the LOC-OB as part of the reported position.

The track edge ID is not identified, defined nor currently used in ETCS.

Track selectivity, formalised by the track edge ID, is a piece of important information used by the LOC-OB internal algorithm to generate the 1D position.

When drafting D2.4 [2], no clear use of the track edge ID was identified but it was decided to keep the track edge ID in the datasets generated by LOC-OB because:

- The track edge ID is anyhow generated by the LOC-OB algorithms.
- The track edge ID can be a piece of important information for future applications as perception.

The introduction of the track edge ID will impact at least Subset-026, Subset-088 and 091, Subset-041 and possibly other Subsets.

3.2.3 Performance objectives Subset-041

Subset-041[9] will be significantly impacted since the model of accuracy and the performance objectives are different.

In the current Subset-041[9], performance is defined with respect to the technology used in ETCS (Odometry + Balises), therefore Confidence Interval is specified in % of travelled distance (respectively speed) + 5 m (related to the balise detection). CLUG 2.0 D2.4 [2] defines performance objectives on the Confidence Interval with absolute value depending on the operational needs, not the technology used.

CLUG 2.0, accuracy is defined as: The statistical error between true and estimated values of parameter (such as position).

The confidence interval is defined as: The position, speed, acceleration interval within which the LOC-OB guarantees the true train position, speed, acceleration is, with a defined THR.

D2.4[2] does not use the term accuracy to define the Confidence Interval performance objectives.

For example, Subset-041[9] defines:

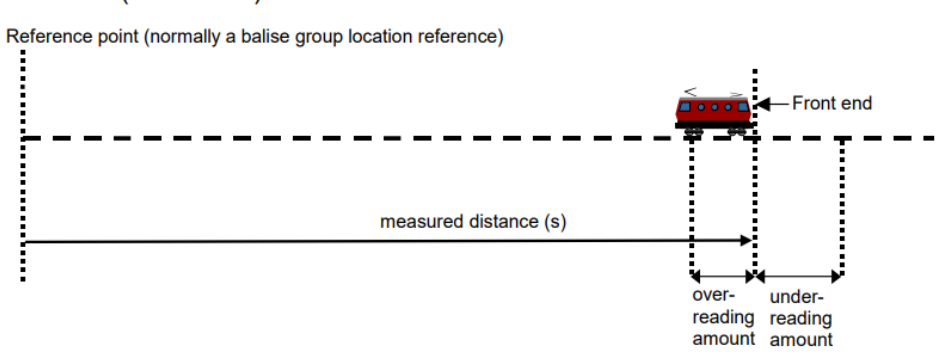
Description	Accuracy of distances measured on-board
Start Event	not applicable
Stop Event	not applicable
Value	<p>for every measured distance s the accuracy shall be better or equal to $\pm (5m + 5\% s)$, i.e. the over reading amount and the under reading amount shall be equal to or lower than $(5m +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

Figure 3 : Subset 41 extract.

With the introduction of the LOC-OB, this requirement would be replaced by requirements inspired the following requirements:

<u>Req ID</u>	SpecSysReq[003]
<u>Requirement</u>	The absolute value of the Overestimation related to the estimated distance and the absolute value of the Underestimation related to the estimated distance shall be lower than ten meters. surrounding: - An operational stop or speed limitation. - A stop in train station. Surrounding shall be interpreted as +/- 500m of a stopping point.
<u>Additional information</u>	Refer to Section 3.6.3.2. $ \text{Max Accepted Position Overestimation} = \text{Max Accepted Position Underestimation} = 10\text{m}$. The values are results from capacity studies as presented in appendix A of Ref [1].
<u>Category / classification</u>	Capacity; Performance
<u>Traceability</u>	UR[006]; UR[011]; Appendix A of Ref [1]
<u>Acceptance Method</u>	Analysis; Lab test; field test
<u>Safety assumption</u>	Not related to safety

<u>Req ID</u>	SpecSysReq[004]
<u>Requirement</u>	The absolute value of the Overestimation related to the estimated distance and the absolute value of the Underestimation related to the estimated distance shall be lower than sixty meters anywhere the SpecSysReq[003] requirement is not requested.
<u>Additional information</u>	Refer to Section 3.6.3.2. The values are results from capacity studies as presented in appendix A of Ref [1].
<u>Category / classification</u>	Capacity; Performance
<u>Traceability</u>	UR[006] ;UR[011]; Appendix A of Ref [1]
<u>Acceptance Method</u>	Lab test; field test
<u>Safety assumption</u>	Not related to safety.

<u>Req ID</u>	SpecSysReq[005]
<u>Requirement</u>	The absolute error of the estimated distance to the reference location shall not exceed 1.25m, for at least 95% of the cases, surrounding: - An operational stop or speed limitation - A stop in train station. Surrounding shall be interpreted as +- 500m of a stopping point.
<u>Additional information</u>	Refer to Section 3.6.3.2. 2 sigma accuracy may be used for gaussian algorithms.
<u>Category / classification</u>	Performance
<u>Traceability</u>	UR[006]
<u>Acceptance Method</u>	Lab test; field test
<u>Safety assumption</u>	Not related to safety

<u>Req ID</u>	SpecSysReq[006]
<u>Requirement</u>	The absolute error of the estimated distance calculated by LOC-OB shall not exceed 4m (for at least 95% of the cases), anywhere the SpecSysReq[005] requirement is not requested.
<u>Additional information</u>	Refer to Section 3.6.3.2. 2 sigma accuracy may be used for gaussian algorithms.
<u>Category / classification</u>	Performance
<u>Traceability</u>	UR[006]
<u>Acceptance Method</u>	Lab test; field test
<u>Safety assumption</u>	Not related to safety

3.2.4 Impact of changing the model of accuracy

The model of accuracy proposed in D2.4[2] is different from the one defined in the Subset 41[9] and used in the Subset 26 [6]. The “sawtooth model” is inherited from the tachometry-based odometry and Eurobalise mechanism.

Even if this transition may be handled without major technical issues, this modification will have major impacts on the subsets.

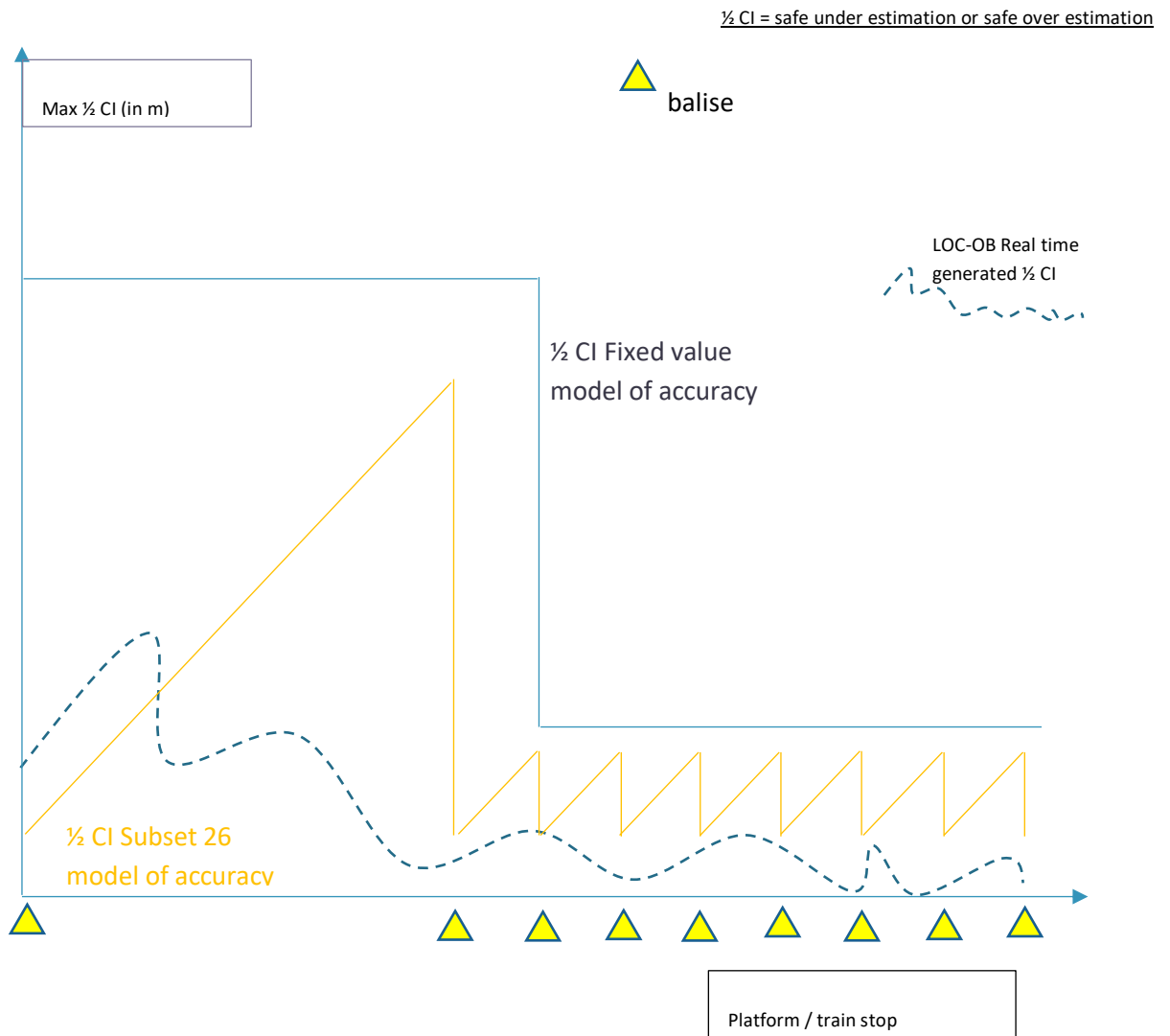


Figure 4 : SS41 vs CLUG 2.0 model of accuracy.

One of the potential issues identified is that the confidence interval size can increase and decrease continuously in opposition of the current model of accuracy, where the Confidence Interval can only shrink when a balise group is detected.

The impact on ETCS, especially on the braking curves and on the information displayed to the driver through the DMI, is not clear and needs to be analysed in detail.

3.2.5 Balises

The introduction of LOC-OB might enable the reduction of the number of Eurobalises needed.

Reducing the number of balises will have significant impacts on the hypothesis defined by the subsets as engineering rules or safety demonstrations.

3.2.5.1 Engineering rules update

Engineering rules will need to be updated.

For example, the Subset-088[10] Part 3 Annex A 6.6.1.2 defines a recommended maximum distance between balise groups lower than 2500m. This has been introduced as the safety analysis assumed a certain probability of an undetected failure of the balise reader, so the balise reader needs to be checked at certain intervals.

10.2.1.14	Maximum distances between Balise groups	2.5 km	2.5 km
-----------	---	--------	--------

Considering that removing balises is one of the main advantages of using LOC-OB, keeping this recommendation is antagonist to the introduction of LOC-OB.

An in-depth analysis of the subsets as well as the supplier solution safety case will be required to confirm that requirement 10.2.1.14 can be updated.

Another example are the specific Swiss engineering rules ([17]). The Swiss engineering rules give constraints on where an Eurobalise group needs to be placed in chapter 5.3:

- The maximal distance before an ETCS marker should always be smaller than 100m.
- The maximal allowed distance between Eurobalise groups (not close to an ETCS marker) should always be smaller than 1500m.

Also, the new engineering rules will need to consider new constraints related the usage of GNSS, which will require installing Eurobalises in areas where the GNSS reception is limited (tunnels, urban canyons etc). These rules need to be integrated in a future update of the Subset-040[8].

The introduction of new technologies with their own limitations will require additional engineering rules.

It is also important to notice that the Q_LOCACC value is not always only related to the inaccuracy of the Eurobalise installation but can be increased by choice for operational reasons. The impact of this type of “optimisation” needs to be clarified.

These new constraints will consider the results of the demonstrations and the agreement of the sector on common exported constrains.

3.2.5.2 Impact on the RAMS analysis

It is highly probable that the Balise reading function safety cases consider that Eurobalises are seen regularly. Removing most of the Eurobalises will impact this assumption with a risk of redesigning existing Balise reading functions.

Also, the feared events related to balises identified in Subset-088[10] and Subset-091[11] may need to be updated and can impact the onboard and trackside safety analysis.

3.2.5.3 Impact on Linking

Linking is considered as optional. If linking verifications is active, ETCS continuously supervise the Eurobalise layout thanks to the linked balises principle and the verification of the D_LINK data. This principle may be impacted by the introduction of LOC-OB due to potential balise removal, the potential use of virtual reference location but also by using the Digital Map data that identifies the physical balise location.

3.2.5.4 Balises not related to localisation

ETCS can use balises to send specific messages to the train as level transitions, RBC handover, etc.

With the introduction of LOC-OB, these messages may be virtualised and provided to ETCS thanks to the absolute position generated by LOC-OB and relevant map data, only if all leading vehicles are equipped. To be noticed that some of these messages must be sent by balises for safety reasons, such as level transitions and national values.

3.2.6 Virtual reference location concept track node

Subset 26[6] introduce the concept of Single On-board Localisation Reference (SOLR).

The SOLR is the Eurobalise group used by ERTMS/ETCS on-board as a unique reference location to supervise all location items against the train position.

The introduction of LOC-OB, of the map data and the reduction of the number of Eurobalises, will request the usage of virtual reference locations or track nodes as a SOLR. Today, no concept exists on how to use virtual reference locations.

3.2.7 Orientation of Virtual Refence Frame

In subset 26[6], the orientation of LRBG is defined by the numbering of several balises representing the balise group. An incrementation of the Eurobalises IDs is considered as nominal, a descent of the Eurobalises IDs is considered as reverse. For single Eurobalise, it is inherited from the previous BG.

Considering virtual reference locations, this principle cannot be used. LOC-OB shall deduce the orientation of the virtual reference location from the map data. A principle must be defined and agreed by the sector.

3.2.8 Start of mission procedures following power on

In subset26 [6] (§3.15.8 & §4.11), one functionality of the ETCS-OB is to save and handle the train position, depending on the information provided by the CMD, during the Start of Mission procedure following a power on.

With the introduction of LOC-OB, this functionality needs to be transferred from ETCS to LOC-OB. LOC-OB will provide an absolute position thanks to saved data, saved context and the information provided by the CMD after powering on the train.

3.3 Interaction between the subsets and the introduction of LOC-OB

The following table identify the impacts on the subsets by introducing LOC-OB but also the subsets to be considered during the design phase of LOC-OB. Major impacts are highlighted in red.

SUBSET	Impacted by the LOC-OB introduction	Impacting LOC-OB
Subset 026: System requirement specification (V4.0.0)	Major impact, general description and mechanisms, modification of the model of accuracy, extension of Balise Group to any type of reference location.	
Subset 034: Train interface FIS (V4.0.0)	Introduction of LOC-OB to train interface.	LOC-OB shall comply with future updates of this subset.
Subset 040: Dimensioning and Engineering rules (V4.0.0)	Major impact related to the balise removal and the introduction of new rules related to areas where GNSS may struggle.	
Subset 041: Performance requirements for interoperability (V4.0.0)	Major impact related to the model of accuracy and performances.	
Subset 088: ETCS Application Levels 1 & 2 - Safety Analysis (V3.7.0)	Major impact related to the balise removal.	
Subset 091: Safety Requirements for the Technical Interoperability of ETCS in Levels 1 & 2 (V4.0.0)	Major impact related to the balise removal.	

SUBSET	Impacted by the LOC-OB introduction	Impacting LOC-OB
Subset 119: Train Interface FFFIS (V4.0.0)	Introduction of LOC-OB to train interface.	LOC-OB shall comply with future updates of this subset.
Subset 125: ERTMS/ATO: System Requirements Specification (V1.0.0)	ATO receive the train localisation through ETCS. The introduction of LOC-OB can impact this principle.	
Subset 146: ERTMS End-to-End Security (V4.0.0)		LOC-OB shall comply with future updates of this subset.
Subset 147: FFFIS part: CCS Consist Network Communication Layers (V1.0.0)		LOC-OB shall comply with future updates of this subset.
Subset 149: Online Monitoring System (V1.2.0)		LOC-OB shall comply with future updates of this subset.

Table 1 : Interaction between the subsets and the introduction of LOC-OB

4 Overall gap analysis table

The following table propose to compare the current situation with the conditions to be met when deploying the LOC-OB in trains. It can be considered as an overall gap analysis completing the impact analysis provided in §3.3.

Topic	Current situation	Conditions to be met when introducing the LOC-OB	Comments
Overall CCS-OB architecture and functional allocation	Odometry is part of the monolithic EVC.	A clear CCS-OB architecture is defined with a clear functional allocation. Standardised interfaces are agreed and defined.	The architecture and functional allocation of the CCS-OB is one of the main difficulties encountered when specifying the LOC-OB.
LOC-OB specifications: Functional Requirements	Functional requirements are defined but uncertainties remain.	Functional requirements without any uncertainties or ambiguities.	Most of the uncertainties are related to the CCS-OB architecture and functional allocation.
LOC-OB specifications: Performance Requirements	Performance requirements are defined but need to be compared with the test results.	Performance requirements are agreed by the sector and consider all user needs. Achievement of these performance requirements is demonstrated with the appropriate level of safety.	Some user needs are still unclear (ATO and perception). The impact of increasing safety on overall performance is not negligible (The demonstrator does not embed all safety mechanisms).
LOC-OB specifications: RAM Requirements	RAM requirements are defined.	RAM requirements are defined and are agreed by the sector.	
LOC-OB specifications: Safety Requirements	Safety requirements are defined.	Safety requirements are defined and are agreed by the sector. Achievement of these safety requirements is demonstrated.	The CLUG2.0 project does not provide sufficient evidence of the feasibility of the

Topic	Current situation	Conditions to be met when introducing the LOC-OB	Comments
			safety requirements.
LOC-OB specifications: Environmental Requirements	High level environmental requirements are defined.	Environmental requirements are defined. are agreed by the sector. Ideally, a common environmental test procedure is defined as a subset.	Environmental test cases need to consider the sensor set which makes it difficult to define a set of tests common to all suppliers.
LOC-OB Design: railway standards compliance	Clug2.0 project does not consider any of the railway standards as EN50155 , EN50126, EN50129, EN50716, EN50159.	LOC-OB is compliant to railway standards as (and not limited to): EN50155 , EN50126, EN50129, EN50716, EN50159.	Compliance to railway standards can be challenging especially when using complex algorithms.
Technology readiness to initiate a Change request procedure	The technology readiness has not been proven.	The state of readiness of the technology has been proven in terms of performance and safety.	
Balise layout and engineering rules	<p>Balise layout and engineering rules are governed by strict rules linked to odo/balise technology.</p> <p>These rules severely limit the benefits of absolute localisation technology.</p>	Balise layout are relaxed and engineering rules consider the LOC-OB exported constraints to trackside.	It is important to highlight that backward compatibility is impossible if engineering rules evolve and if no evolution is planned, the benefits of absolute localisation technology is questionable.
Virtual reference location concept	ETCS only refer to balise groups as reference location.	Virtual reference location concept is specified in the subsets.	Virtual reference concept is only useful if the balise layout is relaxed. The introduction of SLOR can be seen as a first step towards the introduction of

Topic	Current situation	Conditions to be met when introducing the LOC-OB	Comments
			reference locations other than balise groups.
Model of accuracy	Saw-tooth model.	Fixed value model.	
Supporting information	The odo/balise principle does not request any supporting information.	Supporting information are defined (content, quality, safety, and interfaces), standardised and agreed by the sector.	
Map handling	The odo/balise principle does not request any map data.	Operational rules will be defined to cover map handling as version verification and updates.	

Table 2 : Overall gap analysis

5 Conclusion

The GAP analysis highlighted three main topics:

- Maturity of the LOC-OB specification
- Maturity of the technology readiness
- Gap between present day ETCS and LOC-OB compatible ETCS

At the time being, each topics contains open issues than needs to be investigated. Eventually, several activities still need to be undertaken to trigger TSI change requests.

The LOC-OB specification is deeply linked to the overall CCS-OB definition and derived functional allocation. An agreement at sector level on the overall CCS-OB architecture with a clear functional allocation and clear performance targets is mandatory to finalise the LOC-OB specifications. These issues cannot be resolved within a project only focusing on localisation.

Figure 5 presents the European roadmap related to Localisation. CLUG 2.0 consortium does not have the mandate to provide full specification. These specifications need to be agreed and validated at rail sector level. The maturity of the CCS-OB architecture as well as the associated set of requirements will be matured in the frame of the ERJU System and Innovation Pillars. And when mature, it will then be specified for the TSI.

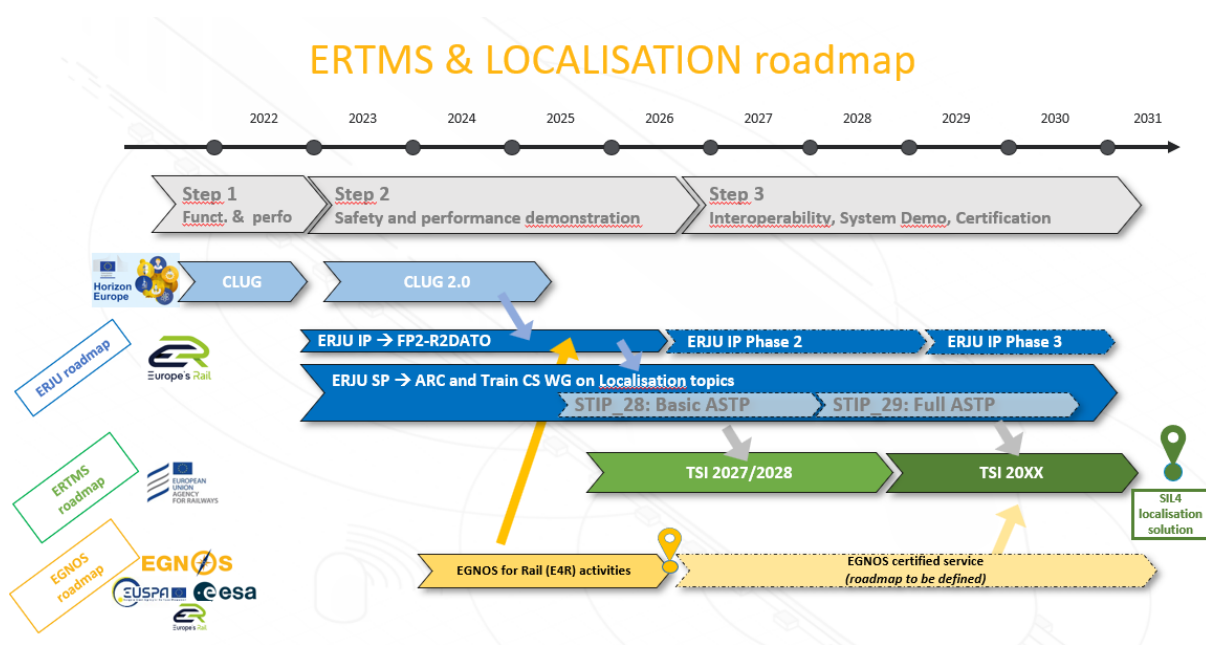


Figure 5: ERTMS & ERJU roadmap for Localisation.

Concerning the technology readiness, the main remaining activities are related to complementary safety demonstration (see CLUG 2.0 D3.7[3]) and the compliance with railway standards. Indeed, the safety analysis made in the frame of CLUG 2.0 concluded that the proposed architecture can reach the safety targets, but more analysis remains to be done when supplementary information regarding the FDE functions will be available.



The results of CLUG 2.0 are not sufficient to prove that the specified safety objectives may be met in the future.

Introducing LOC-OB in the TSI will have a significant impact on ETCS. Backward compatibility between trackside (balise layering) and onboards (train equipped with LOC-OB or not) will be an important factor in decision-making. On one hand, keeping the balise layout as today will significantly reduce the gain of introducing absolute positioning, on the other hand, reducing the number of balises may prevent the circulation / use of (old) trains not equipped with LOC-OB. The strategy still needs to be clarified at sector level.

It is important to note that many of the open issues cannot be resolved without strong involvement from the industry.

Appendix A: References

REF	Document/Sou rce	Title/WEBSITE	Versio n	Date
[1]	CLUG 2.0 D2.3	LOC-OB System Definition and Operational Context	1.0	30/11 /2023
[2]	CLUG 2.0 D2.4	LOC-OB System Requirements	1.0	30/11 /2023
[3]	CLUG 2.0 D3.7	LOC-OB Evaluation report	0.2	29/11 /2024
[4]	CLUG 2.0 D4.1	LOC-OB Functional Architecture	0.2	25/03 /2024
[5]	CLUG 2.0 D6.5	Architecture Trade-off Analysis and Proposed Localisation On-Board System	0.4	29.11. 2024
[6]	Subset-026	Subset 026 System requirement specification	V4.0.0	
[7]	Subset-034	Train interface FIS	V4.0.0	
[8]	Subset-040	Dimensioning and Engineering rules	V4.0.0	
[9]	Subset-041	Performance requirements for interoperability	V4.0.0	
[10]	Subset-088	ETCS Application Levels 1 & 2 - Safety Analysis	V3.7.0	
[11]	Subset-091	Safety Requirements for the Technical Interoperability of ETCS in Levels 1 & 2	V4.0.0	
[12]	Subset-119	Train Interface FFFIS	V4.0.0	
[13]	Subset-125	ERTMS/ATO: System Requirements Specification	V1.0.0	
[14]	Subset-146	ERTMS End-to-End Security	V4.0.0	
[15]	Subset-147	FFFIS part: CCS Consist Network Communication Layers	V1.0.0	
[16]	Subset-149	Online Monitoring System	V1.2.0	
[17]	Swiss engineering rules	https://www.bav.admin.ch/dam/bav/fr/dokumente/themen/zugbeeinflussung/102_etcs12kgb_projektierungsregelnv15.pdf.download.pdf/_102_etcs12kgb_projektierungsregelnv15.pdf		
[18]	R2DATO	https://projects.rail-research.europa.eu/eurail-fp2/		
[19]	CLUG 2.0 D5.3	Analysis report	N/A	N/A
[20]	D6.6 Req analysis	D6.6 requirement analysis	V0.3	



CLUG 2.0 has received funding from the European Union's Horizon research and innovation programme under grant agreement No 101082624