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LOCALISATION WORKING GROUP (LWG)

Railways Localisation System
Localisation Performance Requirements
from use cases

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Modification history

Version	Date	Modification / Description	Editor
0A	12/06/2019	Internal review of LWG	LWG
1a	14/06/2019	Draft for discussion with specific supporting group of X2R2 WP3	LWG
1b	01/07/2019	Addressed comments from Future Localisation Meeting on June	LWG
1c	12/07/2019	Working version	LWG
1d	18/07/2019	Including remarks on chapters 3, 4 and 5 after EUG meeting of 17/7/2019	GR
1e	29/07/2019	Including remarks on chapters 2 and 6 after EUG meeting of 17/7/2019	SK, DS, GR
1f	31/07/2019	Including remarks after EUG meeting of 31/7/2019	GR
2	02/08/2019	Delivery for discussion with specific supporting group of X2R2 WP3	LWG
2 a, b	24/10/2019	Input from X2R-2 WP3	DC, GR
2d	22/11/2019	After discussion in LWG Meeting of 2019/11, homogenise terminology with LSL document and localisation CR. Distinguish between positioning performance model (technology-driven and solution-dependent) and maximum confidence interval for operations (operational need). Use “Train position confidence interval” on the drawings as defined in SS023. Removed the “reference point” which is not used in specifying operational needs. Exchanged “principles” with “terminology” because we sometimes introduce new terms, not necessarily new principles.	SK
2e	02/12/19	Editorial clean up. Clarification about “nominal” condition in chapter 5.	GR
3	10/12/2019	Version 3. Aligned with [HLR]	LWG

Table of Contents

1 List of References and Acronyms

References

HLR	18E112 Railways Localisation System High Level Users' Requirements
RCA	RCA Beta - Architecture Overview
Stanford Diagram	Navipedia page on Integrity (https://gssc.esa.int/navipedia/index.php/Integrity)
SS023	ERTMS/ETCS Subset-023 Glossary of Terms and Abbreviations
SS026	ERTMS/ETCS Subset-026 System Requirements Specification
SS041	ERTMS/ETCS Subset-041 Performance Requirements for Interoperability
EN50155	EN50155 2007 Railways applications – Electronic equipment used on rolling stock

Acronyms

ATO	Automatic Train Operation
APS OA	Advanced Protection System Object Aggregator
MCI	Maximum Confidence Interval for operations
EoA	End of Authority
ERTMS	European Rail Traffic Management System
EUG	ERTMS Users Group
HHPLOC	High Safety High Impact on Operations and Precise Location
HHSD	High Safety High Impact on Operations and Speed Dependent
HL	High Safety Low Impact on Operations
L2/3	ERTMS Level 2/3
LH	Low Safety High Impact on Operations
LL	Low Safety Low Impact on Operations
LLPLOC	Low Safety Low Impact on Operations and Precise Location
LHPLOC	Low Safety High Impact on Operations and Precise Location
LWG	Localisation Working Group
MCI	Maximum Confidence Interval for operations
MOT	Mobile Object Transactor
MP	Mission Profile
PeLS	Persons Localisation System

PP	Performance Profile
RCA	Reference CCS Architecture
RP	Reference Point
SD	Standard Deviation
SoM	Start of Mission
TLS	Train Localisation System
VL	Vehicle Locator

2 Glossary and definitions

2.1 Localisation principles according to current ERTMS standards

2.1.1.1 Figure 1 describes the localisation principles used by ERTMS according to chapter 3 of [SS026].

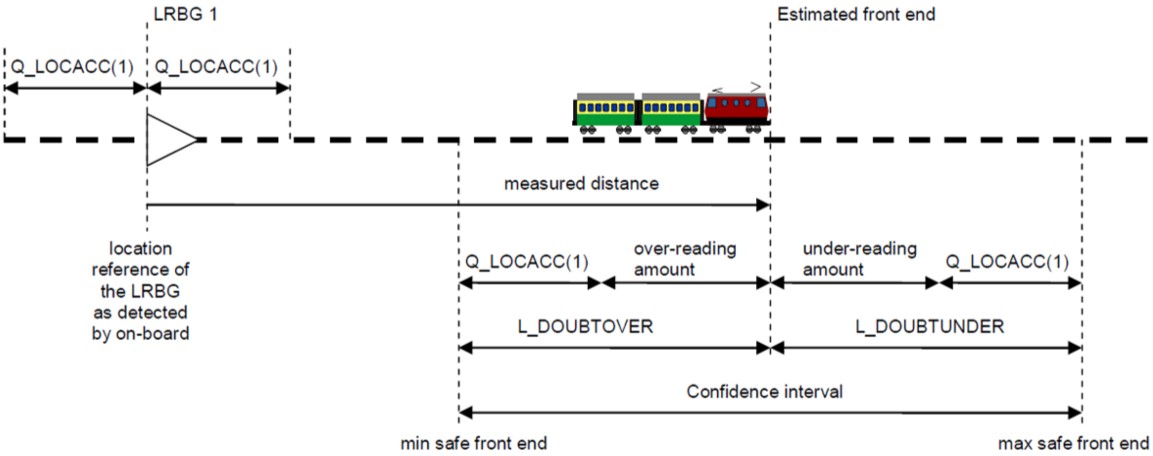

Figure 1: Train Localisation based on ERTMS Subset 026

2.1.1.2 Figure 2 describes the evolution in travelled distance of the maximum expected confidence interval according to the localisation principles used by ERTMS. The positioning performance model described in [SS041] is inspired by the balise and odometry technologies. The positioning performance needed for fluent operations is not known explicitly but careful engineering ensures that it is achieved.

2.1.1.3 Note: according to some current and future need (e.g. high-density applications), the fulfilment of the accuracy target of distances measured on-board (see [SS041]) does not always ensure a satisfactory operational behavior.

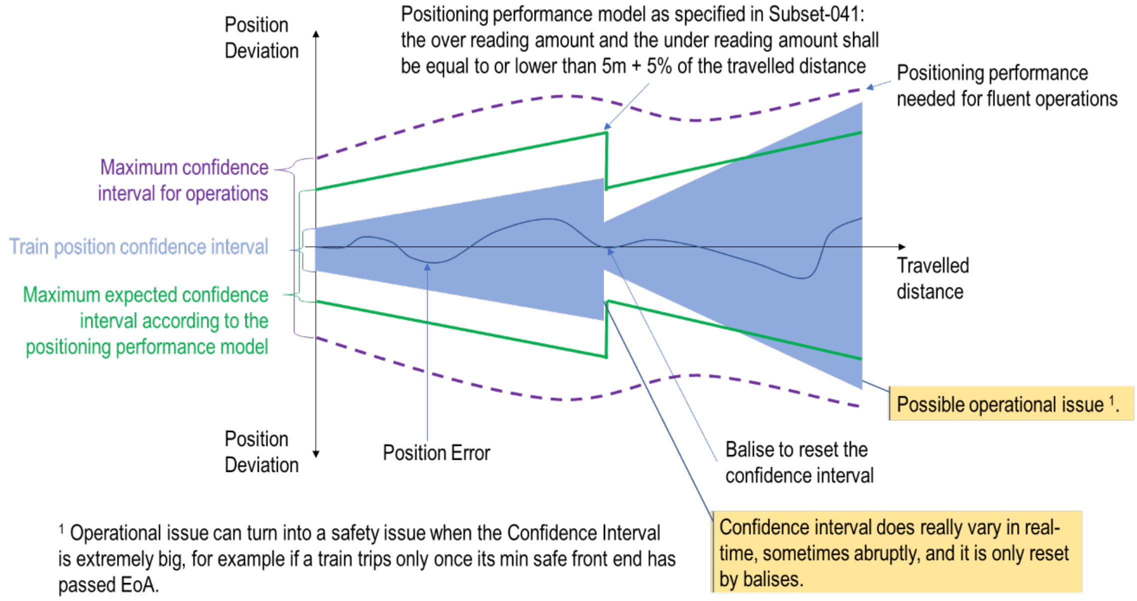

Figure 2: positioning performance model based on balise and odometry technology

2.1.1.4 With reference to Figure 1 and Figure 2, the relevant terminology is defined in [SS026] and [SS023]; for the definition of the maximum confidence interval for operation see § 2.2.

2.2 Localisation terminology used in this document

2.2.1.1 Figure 3 describes the localisation terminology used in this document and derived from the ERTMS one.

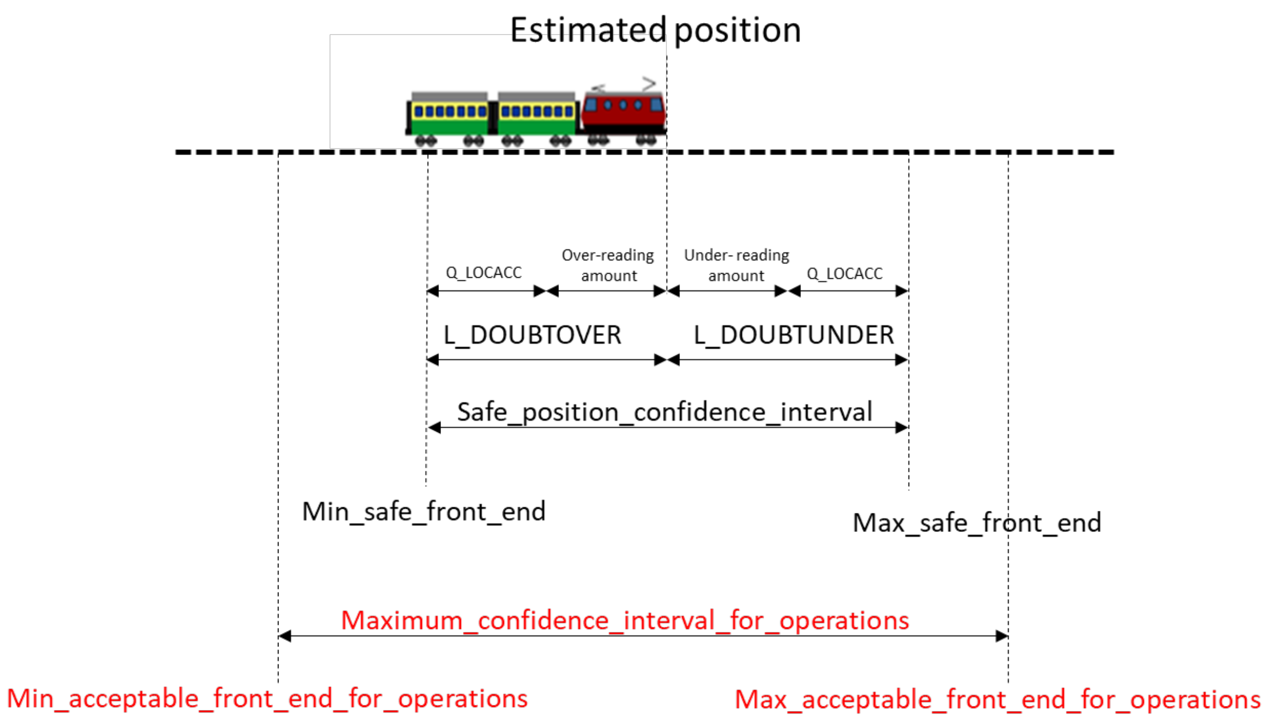

Figure 3: localization terminology used in this document

2.2.1.2 Figure 4 describes the evolution with the travelled distance of the maximum confidence interval for operations which is further described in this document.

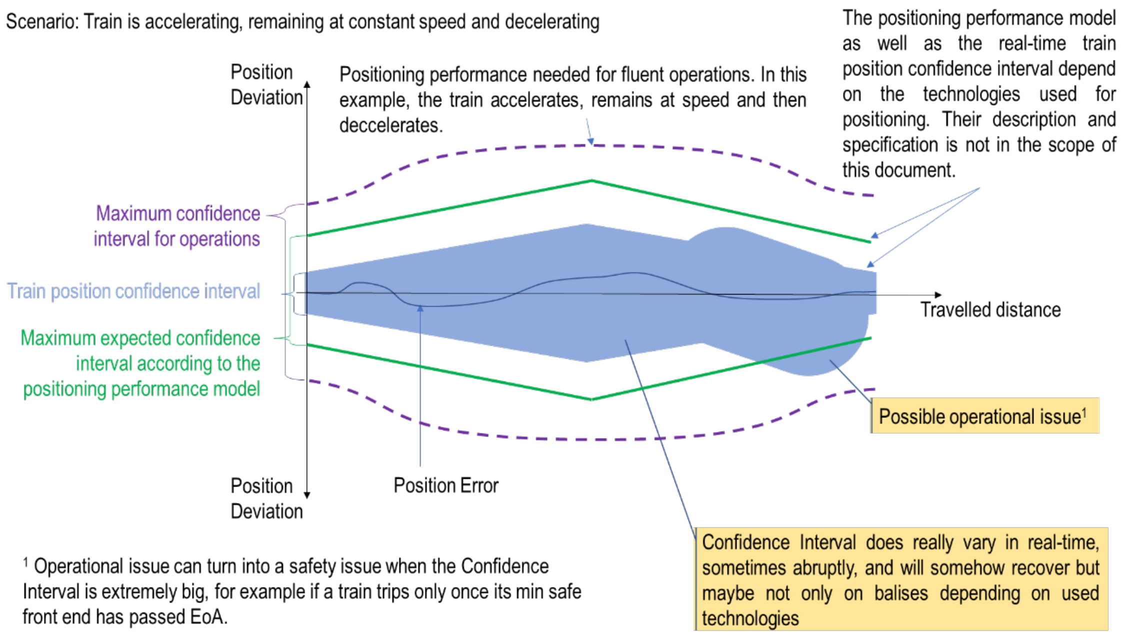

Figure 4: Evolution of the maximum confidence interval for operations

2.2.1.3 Note: The positioning performance model describing the expected behavior of positioning solutions is given here as an example. Its description and specification are out of the scope of this document. Only the specification of the Maximum Confidence Interval for operations is addressed in this document.

2.2.1.4 With reference to Figure 3 and Figure 4, the same terms used by ERTMS (e.g. confidence interval, Max/Min_safe_front_end) do not change their meaning.

2.2.1.5 The <u>max_acceptable_front_end_for_operations</u> and <u>min_acceptable_front_end_for_operaitons</u> are defined to bound the accuracy requirement able to fulfil operational needs.

2.2.1.6 Note: for the sake of simplicity, the rest of this document considers min_ and max_ acceptable_front_end_for_operations to be symmetrically distributed on both sides of the estimated position. This assumption may be challenged in future revisions.

2.2.1.7 The interval bounded by <u>max_acceptable_front_end_for_operations</u> and <u>min_acceptable_front_end_for_operaitons</u> is called maximum_confidence_interval_for_operations (MCI).

2.2.1.8 When the confidence_interval is exceeding the maximum_confidence_interval_for_operations, the punctuality of operation is not guaranteed anymore.

2.2.1.9 The ratio of time when the confidence_interval is not exceeding the maximum_confidence_interval_for_operations to the mission time is called the operational availability. In some scenarios, the operational availability is not affected even if the confidence interval exceeds the MCI however over engineering must be avoided.

2.2.1.10 The term "Mission critical" is related to the operational availability and it indicates how vastly the mission of the train and the capacity/operation of the network, or part of it, is affected in terms of delays in case the Train Localisation system is not able to fulfil the performance requirements.

2.2.1.11 The term "Safety critical" indicates that providing the Train Localisation system a wrong train location[1], without being detected, has a potential impact on trains safe operation.

2.2.1.12 In the performance profiles (see § 4 for the definition) described in § 6, different indicators are used to express accuracy requirements:

- for safety critical profiles, during operations, the confidence interval will be used to trigger safety reactions possibly impacting operations. Thus, the behaviour of the confidence interval is specified using MCI.
- for non-safety critical profiles, during operations, the estimated position will possibly be used without considering the confidence interval. Thus, it is sufficient and more flexible to specify the behaviour of the estimated position in a statistical manner using the standard deviation[2] (SD) of the error multiplied by a K factor between the estimated value (e.g location) and the real value (i.e the ground truth).

2.2.1.13 For any additional definition found in this document, § 1 and [SS023] makes reference.

3 Scope of the document

3.1.1.1 The Rail Localisation system is the set of functional blocks able to provide "objects" (e.g. trains, coaches, maintenance rolling stock, workers) positioning information along\around the track (see also [HLR]).

3.1.1.2 Within the Rail Localisation system, the Train Localisation system (TLS) is the subset of functional blocks able to provide "trains" positioning information along the track.

3.1.1.3 With reference to [RCA], the Train Localisation system includes the onboard functional block VL and trackside functional blocks MOT and APS OA (aggregating information also coming from possible trackside occupancy detection devices).

3.1.1.4 The purpose of the document is to identify the localisation performance requirements of the TLS starting from current and future needs derived from use cases (railways operational scenarios).

[1] With reference to ERTMS specification it is the case where real train position is outside the train confidence interval calculated by the onboard.

[2] Standard deviation: let X be a random variable with mean value μ, the standard deviation σ (sigma) is the square root of the variance of X; i.e., it is the square root of the average value of $(X - \mu)^2$.

3.1.1.5 Localisation performance requirements are to be intended to deal with accuracy, availability and safety; the impact on safety and on operation (availability) has been evaluated in a qualitative way.

3.1.1.6 According to top-down approach, the current document intends to further develop the accuracy, safety and availability targets provided for TLS by the High Level Users' Requirements document [HLR] which represent an input to the current document.

3.1.1.7 The localisation of "objects" along the track different from trains is not in the scope of this document however it is possible that some requirement could be applicable for odometry enhancement, MOLS and PeLS as well (see [HLR]).

3.1.1.8 Some environmental requirement is included in § 5 as well.

3.1.1.9 The evaluation of the impact of failures preventing the system from fulfilling the identified performance requirement and the definition of relevant quantitative RAMS requirements of the train localisation system are out of the scope of this document. This will be done in a future step.

3.1.1.10 The allocation of the identified requirements to the onboard and/or trackside functional block of the Train Localisation system is out of scope of this document.

3.1.1.11 The onboard VL shall not necessary fulfil all (nor the most stringent) identified requirements however the allocation of localisation requirements to the onboard VL (minimum predictable performances under defined circumstances) is necessary to ensure interoperability and allow IM to put in place possible additional measures to achieve the expected performances requirements in case the VL is not able to achieve them by itself. Allocation of requirements to the onboard VL will be made after feasibility study of possible technological solutions and the technical and economical evaluation coming from research projects (proof of concepts).

3.1.1.12 The documents aim at defining requirements to be fulfilled in ERTMS/ETCS L2 and L3.

4 Methodology

4.1.1.1 The first step consisted in identifying different use cases in which the localisation of the train is necessary or desired. For this purpose, operational units in different administrations were consulted, deriving different operational scenarios.

4.1.1.2 Specific use cases were provided by different experts. These use cases targeted the rail current and future operational scenarios in which localisation is needed. The list of use cases was shared and discussed among EUG Localisation Working Group members.

4.1.1.3 These use cases were analysed and specific localisation requirements were allocated to each of them. Performance requirements for each of the use cases were assigned by different experts and recorded in a spreadsheet.

4.1.1.4 When the same use case had different performance requirements in different organisations, the most restrictive target was selected.

4.1.1.5 The analysis of use cases included the safety and operational criticality impact evaluation from a qualitative point of view.

4.1.1.6 To express localisation performance requirements, the definitions recorded in § 2 are used.

4.1.1.7 Uses cases were clustered in different performance profiles (PP) targeting similar performance localisation requirements and similar safety/operational criticalities. The figures associated to each PP were taken from use cases addressing common necessities in terms of performance.

4.1.1.8 Note: the following example is provided to make the methodology clearer. For train running on a high-speed line some administrations set target figures based on the distance travelled within a unit of time, others based it on absolute distance depending on speed intervals. These values are used when calculating the capacity of the line. After discussions, it was agreed that the necessity of the absolute distance is more important at low speeds. Then an agreement on the use case performance target was reached. This use case was also commonly catalogued as mission and safety critical. The use case was then clustered with other similar use cases to create the performance profiles.

4.1.1.9 The resulting PP are shown and explained § 6.

5 Assumptions and environmental constraints

5.1.1.1 The identified performance requirements shall be met on every European rail physical environment including (the list does not have to be considered exhaustive) tunnels, forests, mountains, underground stations, presence of metal masses around rail.

5.1.1.2 The identified performance requirements shall be met on every reasonably European rail meteorological environment including (the list does not have to be considered exhaustive) high rail temperature and low adherence conditions such as the presence of ice, snow, leaves; for what it concerns, EN50155 applies.

5.1.1.3 The identified performance requirements shall be met considering, as nominal, all the operating condition where a train is allowed to run and the absence of sensor's hardware failure.

5.1.1.4 Note: only a sensor's hardware failure can be considered as a "malfunctioning" to justify the lack of fulfilment of the performance requirements; the possible vehicle slide/slip protection device shall contribute to fulfil the requirements.

5.1.1.5 Track selectivity is mandatory for all performance profiles, understanding track selectivity as the TLS ability to discern in which track the train is located.

5.1.1.6 The localisation performance requirements are independent of any technical solution used. Combinations of different measurement technologies is expected to reach them.

6 Train Localisation Performance requirements associated to performance profiles

6.1.1 HHSD

6.1.1.1 Front

HHSD Front	
Description	Provide train front position and train speed (including direction) for track occupancy notification and for speed supervision.
Safety Critical	Yes
Mission critical	Yes
½ MCI	10 m for speed lower that 40 km/h then the distance run in 1 s at higher speed
Speed ½ MCI	2 km/h for speed lower than 30 km/h, then increasing linearly up to 12 km/h at 500 km/h.
Operational Examples	Train control while running, speed supervision, train control in ATO.

6.1.1.2 Rear

HHSD Rear	
Description	Provide train rear position for track occupancy notification.
Safety Critical	Yes
Mission critical	Yes
½ MCI	10 m for speed lower that 40 km/h then the distance run in 1 s at higher speed
Operational Examples	Track occupancy notification in L3

6.1.1.3 Note: profile 6.1.1.1 serves for speed supervision in L2. Supporting profile 6.1.1.2 enables running L3 high density applications.

6.1.1.4 Note: the HHSD performance profile covers most of the operational situations, they can be considered as fundamental.

6.1.1.5 Note: profile 6.1.1.1 also covers non-mission critical use cases where train front position and speed are necessary for external warning systems aiming to warn from incoming trains (e.g. devices to alert workers along the track).

6.1.1.6 Justification: accuracy expectations reflect capacity planning in dense traffic areas where releasing points within seconds is required. The specification of speed-dependent performance profiles is an attempt to avoid over-specifying at high speeds.

6.1.1.7 Justification, SoM in profile 6.1.1.1: minimise the travelled distance without supervision (Movement Authority).

6.1.1.8 Note: the expectations stated in 6.1.1.2 are notoriously challenging for freight trains. The considerations of 3.1.1.11 apply. The accuracy target may be relaxed according to feasibility and cost benefit analysis.

6.1.1.9 Note: no hint is made as to the method used to fulfill 6.1.1.2. Using safe length and integrity information is a possibility.

6.1.2 HHPLOC

6.1.2.1 Front

HHPLOC Front	
Description	Provide train front position and train speed (including direction) for track occupancy notification and for speed supervision in missions that require high accuracy at low speed.
Safety Critical	Yes
Mission critical	Yes
Front Position ½ MCI	1m
Speed ½ MCI	2 km/h for speed lower than 30 km/h
Operational Examples	Train control in parking areas, stopping, coupling.

6.1.2.2 Rear

HHPLOC Rear	
Description	Provide train rear position for track occupancy notification at low speed and high accuracy
Safety Critical	Yes
Mission critical	Yes
Rear Position ½ MCI	1m
Operational Examples	Train control in parking areas, stopping, coupling, parking different trains in the same track.

6.1.2.3 Note: the expectations stated in 6.1.2.1 and in 6.1.2.2 are clearly challenging. The considerations of 3.1.1.11 apply. The opportunity of using track-side or onboard localisation techniques shall depend on feasibility and cost benefit analysis.

6.1.2.4 Note: concerning standstill detection, the possible interactions between Localisation and Roll Away Protection, Reverse Movement Protection and Standstill Supervision have not been investigated yet (anyway this document does not intend to relax requirements of [SS026] on D_NVROLL).

6.1.2.5 Justification, parking: on short parking tracks, train buffers may lie within a few meters of danger points. Moreover, if several trains are parked on the same track, it is often necessary to park them very close together.

6.1.2.6 Justification, coupling: minimise the distance without full supervision. Speed constraints can be required.

6.1.2.7 Justification, stopping: covers cases ranging from virtualisation of stopping indicators to precise EoA in tight places.

6.1.3 LHPLOC

6.1.3.1 Front

LHPLOC Front	
Description	Provide train front position, train speed (including direction), train acceleration for ATO while the train is stopping at a platform.
Safety Critical	No
Mission critical	Yes
Front Position 3 * SD	0.5 m
Speed SD	2 km/h
Acceleration SD	To be defined
Operational Examples	Parking in ATO, stopping in ATO, Guidance and control of the ATO

6.1.3.2 Rear

LHPLOC Rear	
Description	Provide train rear position for ATO while the train is stopping.
Safety Critical	No
Mission critical	Yes
Rear Position SD	Under analysis, TBD
Operational Examples	parking, stopping in ATO

6.1.3.3 Note: profile 6.1.3.1 also covers non-mission critical use cases where train front position and speed is necessary for monitoring or civil engineering purposes (e.g. track monitoring/surveying, spraying trains monitoring).

6.1.3.4 Note: Safe parking/stopping conditions shall be defined to avoid overengineering in certain areas.

6.1.3.5 Justification for 6.1.3.1: accurate regulation of speed and acceleration and stopping at platforms under ATO.

6.1.3.6 Justification for 6.1.3.2: the control loop of the ATO for freight train could need information from rear to adapt the traction power during the starting phase. A freight train is like a chain. Before providing full power, the driver shall add tension to this chain, wagon by wagon. Today it is up to the driver to adjust power traction accordingly. For an automatic system, it could be useful to know when the tension of this chain is optimal.

6.1.4 LH

6.1.4.1 Front

LH Front	
Description	Provide train front position, and train speed (including direction) for TMS, passenger information and location-based services
Safety Critical	No
Mission critical	Yes
Front Position SD	10 m up to 40 km/h, distance run in 1 s at higher speed
Speed SD	2 km/h for speed lower than 30 km/h, then increasing linearly up to ± 12 km/h at 500 km/h.
Operational Examples	Location for passenger information system, input for the train management system, information for fleet management

6.1.4.2 Rear

LH Rear	
Description	Provide train end position for TMS, passenger information and location-based services.
Safety Critical	No
Mission critical	Yes
Rear Position SD	10 m up to 40 km/h, distance run in 1 s at higher speed
Operational Examples	Location for passenger information system, input for the train management system, information for fleet management

6.1.4.3 Note: these performance profiles are automatically fulfilled if HHSD performance requirements (see 6.1.1) are. Though, in case a safe localisation information cannot be delivered, an unsafe localisation information is still useful for TMS and passenger information.

6.1.4.4 Justification: feed the customer information and TMS trackside databases to inform customers and take the decision for the operation officer. Speed will be used to predict the future position of the train to avoid conflict at the cross section (e.g. switch) or to detect automatically a potential problem.

6.1.4.5 Justification: this information could be used for onboard passenger information as well.

6.1.4.6 Note: the size of the train or the rear position is mandatory to optimise TMS performances since the train is not a point but a segment (e.g. it is important to manage traffic in degraded situations with permissive blocking system).