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LOCALISATION WORKING GROUP (LWG)
Technical Note on ASTP odometry accuracy
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0a	2025-02-20	First draft	EUG LWG
0b	2025-04-28	Second draft	EUG LWG
0c	2025-06-04	Third draft including speed performance	EUG LWG
0d		Internal review	EUG LWG
0e	2026-07-17	Forth draft adding EuroSpec requirements	EUG LWG
0f	2026-09-24	Update following TL4EU feedback	EUG LWG
1	2026-09-29	Official release	EUG LWG

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1 List of references and acronyms

1.1 References

- [1] UNISIG, "UNISIG position on ASTP v11," 2024-12-16.
- [2] Blue Arches, "Economic Analysis - ASTP," 2024-12-10.
- [3] R2DATO WP23, "D23.4 – Proposal on TSI202x, SS147 Release 03," 2025-02-01.
- [4] R2DATO WP21, "D21.1 - Operational needs and system capabilities of an ASTP system (Use Cases), Revision 17," 2025-05-15.
- [5] R2DATO WP21, "D21.2 – System requirements of ASTP system, Revision 9," 2024-12-11.

Unless otherwise stated, all references to ETCS subsets and specifications in this document refer to the latest applicable version included in Appendix A of the CCS TSI (Baseline 4 Release 1).

1.2 Acronyms

ASTP	Advanced Safe Train Positioning
ATO	Automatic Train Operation
BG	Balise Group
CCS	Control Command and Signalling
CI	Confidence Interval
DMI	Driver Machine Interface
EoA	End of Authority
ERJU	Europe's Rail Joint Undertaking
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
EU	European Union
EUG	ERTMS Users Group
EVC	European Vital Computer (core of on-board ETCS)
FP2	Flagship Project 2 (in the context of IP)
GNSS	Global Navigation Satalite System
HTTPS	Hypertext Transfer Protocol Secure

IMU	Intertial Measurement Unit
IP	Innovation Pillar
MAPO/MAPU	Max acceptable position overreading/underreading
MASO/MASU	Max acceptable speed overreading/underreading
LRBG	Last Relevant Balise Group
MAPCI	Max Accepted Position Confidence Interval
MD	Message Data
MDBF	Mean Distance Between Failures
MDBI	Mean Distance Between Incidents
PD	Process Data
R2DATO	Rail to Digital Automated Train Operation (Name of Flagship Project Nr. 2 of Innovation Pillar)
RPC	Remote Procedure Call
RU	Railway Undertaking
SLAM	Simultaneous Localization and Mapping
SP	System Pillar
STIP	Standardisation and TSI Input Plan
TRDP	Train Real-Time Protocol
TSI	Technical Specification for Interoperability
WP	Work Package

2 Scope of the document

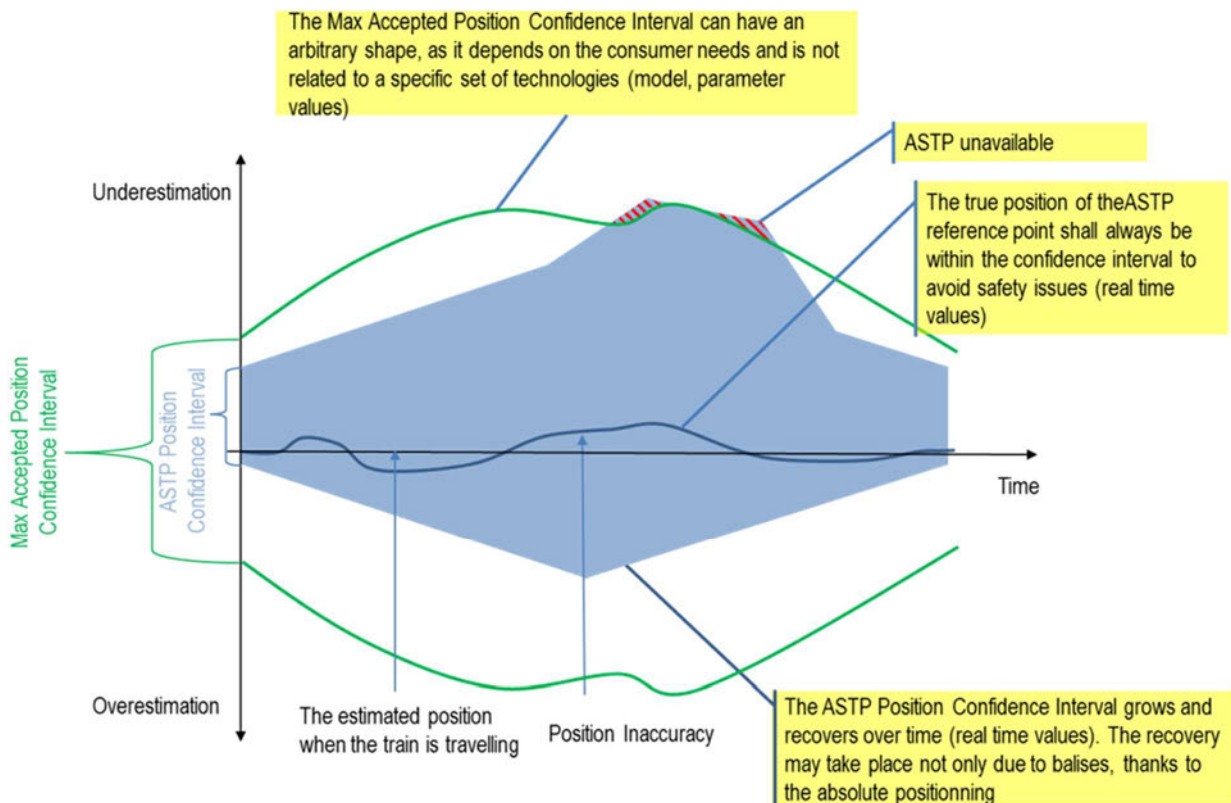
- 2.1.1.1 In the STIP, which outlines the ERJU plan for the evolution of the ETCS system, ASTP is introduced in two steps with basic ASTP¹ (see Robustness CR ERTMS00001691, Performance CR ERTMS00001712 and Localisation Interface CR ERTMS00001714) (STIP_29) in the time frame of 2027 and full ASTP (see CR1368) (STIP_30) in the timeframe of 2032.
- 2.1.1.2 According to the decision of TrainCS domain of System Pillar, in the first step the odometry function will remain embedded into the EVC consequently it would be more appropriate to use the term “enhanced odometry” rather than basic ASTP (which implies a constituent independent from the EVC). However, in conformity with STIP, in this document the term “basic ASTP” will continue to be used to indicate the first objective “enhanced odometry”.
- 2.1.1.3 The improvement of odometry performance is already considered into the scope of basic ASTP and it will be also addressed within the scope of full ASTP.
- 2.1.1.4 This document intends to clarify the meaning of “(operational) train position accuracy” and “odometry performance” in the scope of both basic and full ASTP, considering only the ETCS as the consumer.
- 2.1.1.5 This document also intends to suggest how the ETCS specification should evolve following the 2 steps approach of ASTP.
- 2.1.1.6 To do this, the document starts by presenting background concepts, namely the current definition of the accuracy target into ETCS specifications and the work done in the context of IP FP2 WP21 and EuroSpec².
- 2.1.1.7 Finally, the objectives intended to be achieved for both basic and full ASTP are summarised.
- 2.1.1.8 The performance related to position, speed and acceleration of the train are considered in the scope of this document.
- 2.1.1.9 It is not in the scope of this document to evaluate the “availability” (robustness) of the odometry performance.

¹ In this document the name basic ASTP is kept in consistency with the STIP even if it would be more correct to name it “enhanced odometry” since in the first step the ASTP IC will not be present

² The EuroSpec initiative is composed of six European organisations with wide knowledge on writing specifications for the procurement of rolling stock based on operations and tender experiences, i.e. Nederlandse Spoorwegen (NS), Deutsche Bahn (DB), SNCF Voyageurs (SNCF), Österreichische Bundesbahnen (ÖBB), Schweizerische Bundesbahnen (SBB) and the Railway Delivery Group (RDG). It started in 2011: <https://eurospec.eu/>

3 Train position accuracy and Odometry performance

- 3.1.1.1 In this document, the term “(operational) train position accuracy” refers to the operational user needs, derived with a technological agnostic approach, and it is independent on its apportionment to on-board and trackside.
- 3.1.1.2 In this document, the term “odometry performance” has to be meant as the technical performance requirements which is linked to the “accuracy” of the location/speed function of the ERTMS on-board equipment (see SS-041). Also, acceleration is considered despite no performance requirement are allocated to it by ETCS specification.
- 3.1.1.3 According to SS-023, the following definitions apply:
- ODOMETRY ACCURACY: The extent to which the odometer might make underestimation/overestimation in measuring the movement of the train
 - TRAIN POSITION CONFIDENCE INTERVAL: The distance interval within which the ERTMS/ETCS on-board assumes the actual train position is, with a defined probability. It comprises the odometer over-reading and under-reading amounts, including the error to detect the center of the BG, plus twice the location accuracy of the reference BG.
- 3.1.1.4 In the context of IP FP2 WP21, the Accuracy is defined as the difference between true and estimated values with a defined probability. The inaccuracy limits related to performance needs are also defined together with the availability of ASTP (the capability of ASTP to provide output within the inaccuracy limits).
- 3.1.1.5 In the context of IP FP2 WP21, the inaccuracy limits for the CI are defined as follows:
- Max Accepted Position/Speed Underestimation (MAPU, MASU)
 - Max Accepted Position/Speed Overestimation (MAPO, MASO)
- 3.1.1.6 The following figure from WP21.1 v17 illustrates the definitions in §3.1.1.4 and §3.1.1.5.



- The dark blue line represents the position inaccuracy of the train (true position of the train = estimated position + position inaccuracy).
- The x-axis represents the estimated position of the train over time (estimated by the on-board odometry). There will always be a difference between the estimated position (x-axis) and the true position which cannot be determined by the ASTP. Nevertheless, accuracy limits have been defined in §4.1.3.3 requirement 038.
- The blue area represents the CI which is determined by the ASTP: It varies along the journey of the train, depending on slip/slide events, doppler radar errors and other events which affect the odometry readings from the sensors.
- The Green line represents the threshold which the CI shall not be outside of. If it is outside of this threshold, the CI will still be utilised (i.e. no impact on safety), but ASTP is not fulfilling the accuracy limits for the CI. This threshold is the pre-defined MAPU and MAPO, see §4.1.3.3 requirement 036 and 037.

4 Existing requirements

4.1 Position and travelled distance

4.1.1.1 In this chapter it is reported how position and travelled distance accuracy target is defined in:

- The current ETCS specification
- The context of the IP FP2,
- The context of EuroSpec

and how these targets are apportioned to on-board and trackside.

4.1.2 Current ETCS specifications (B4R1)

4.1.2.1 According to SS-026 §3.6.4.1, train position accuracy is related to the train position CI defined as:

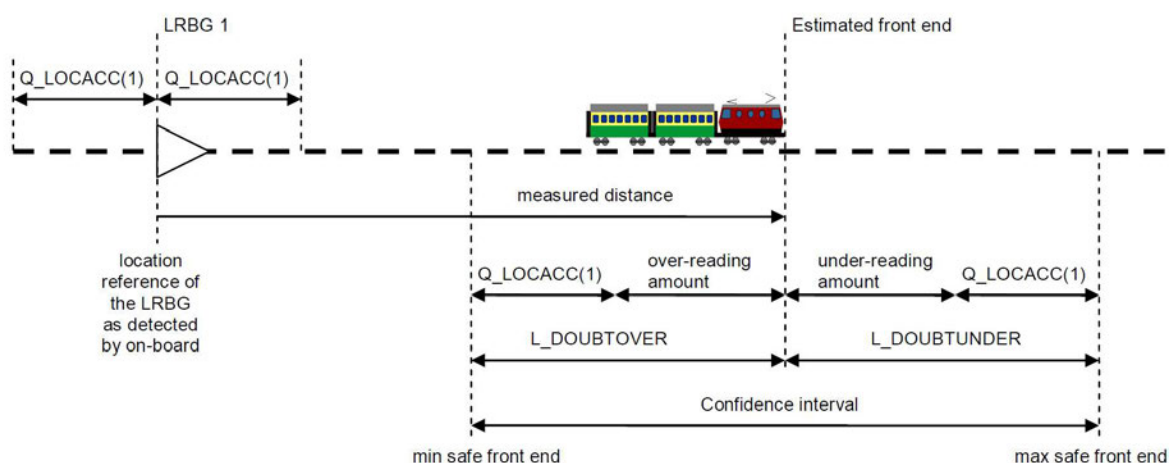
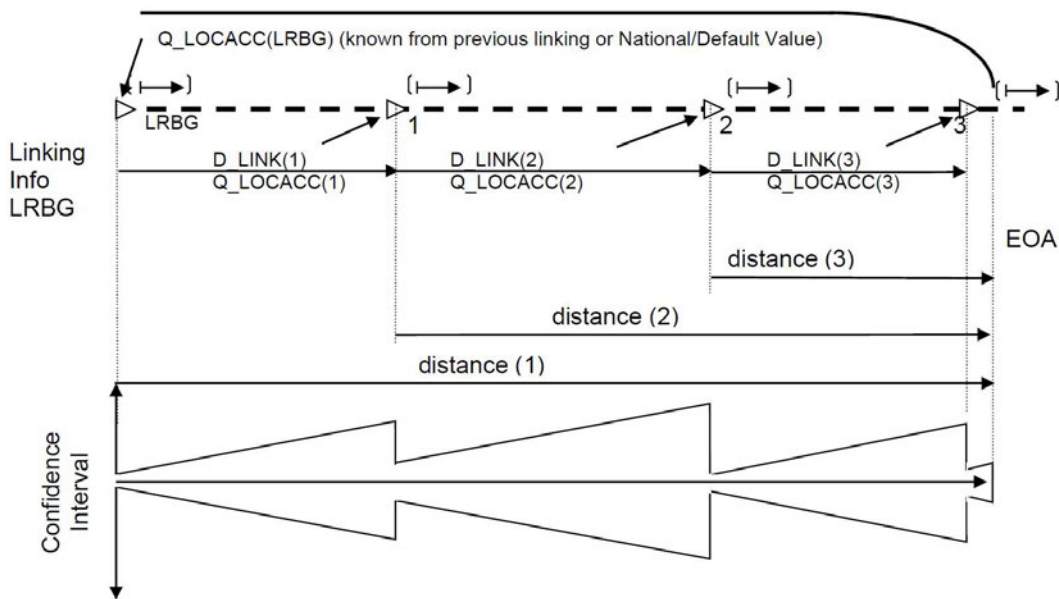


Figure 13a: Train confidence interval and train front end position in reference to LRBG

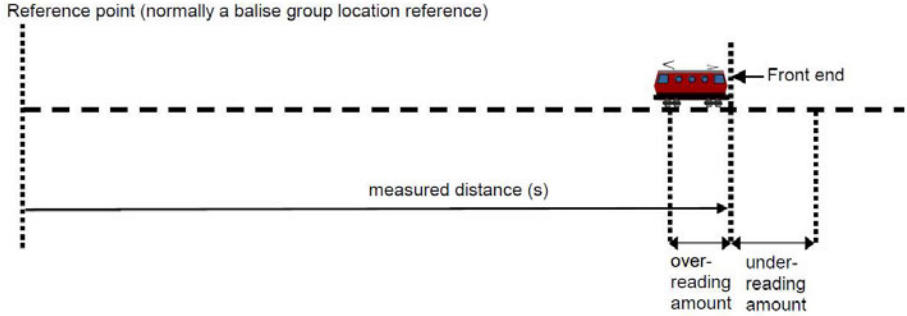
To be noted that the over-reading amount and under-reading amount does includes odometry errors but also error related to reading Eurobalises (refer to 5.3.1.1).

4.1.2.2 According to SS-026 §3.6.4.2, the size of train position CI also depends on the principle of relocation based on the position of linked BGs (reference position) as described in the following picture:



- 4.1.2.3 ETCS trackside engineering rules for the placement of the reference position are included into Subset 40 (they refer, until a certain extent, to clause 4.1.1.13).
- 4.1.2.4 According to Subset 040, clause 4.1.1.13, the balise installation relative to mission profile must be respected with regards to
- Number of Unlinked Balise groups (marked as unlinked): *1 in 1000 for high speed rail and 4 in 1000 for conventional rail.*
 - Maximum distance between Balise groups: *2.5 km for both conventional and high speed rail*
- The *values* originate from Subset 091, chapter 10.2 "The Reference Infrastructure". The maximum distance of 2.5 km is specified to detect BTM antenna errors.
- 4.1.2.5 According to Subset 036, clause 4.2.10.2, the location accuracy for vital purposes shall be within +/- 1 m of each balise, when a balise has been passed. This value of +/- 1 m is included in the value of 5m + 5% s for the accuracy of distance measured on-board (Subset 041, clause 5.3.1.1).
- 4.1.2.6 Q_LOCACC must be considered for the overall system performance for positioning. However, Q_LOCACC is purely a trackside engineering consideration and is not relevant to the performance of the odometry function: the IM must decide how precise Q_LOCACC shall be, depending on which balise placement accuracy can be achieved (0-63 m) considering installation and maintenance risks.
- 4.1.2.7 ETCS on-board distance accuracy target (on-board over/under reading amount) is included into SS-041 (it refers to the on-board performances - §Fel! Hittar inte referensskälla.).
- 4.1.2.8 Subset 41 defines the over/under reading error of on-board to measure the travelled distance as linearly increasing, starting at 5m (error for the detection of the balise), with a fixed slope according to the distance as reported hereafter:

5.3.1.1 Accuracy of distances measured on-board

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

4.1.2.9 To be noted that SS-041 allows to equalise the over/under reading amount to a maximum fixed value even if the calculated ones are lower.

4.1.2.10 In summary, in the context of ETCS, the “operational train position accuracy” is apportioned to on-board through the:

- distance measurement accuracy requirements defined in SS-041 §5.3.1.1
- on-board accuracy to detect the reference position requirement (e.g. the centre of the balise group) defined in SS-036 §4.2.10.2

and to trackside through the:

- trackside engineering rules for the placement of the reference position (e.g. accuracy and frequency of the placement of balise groups) defined in SS-40.

4.1.3 IP FP2 WP21 specifications

4.1.3.1 FP2 WP21 defines performance objectives on train position Max Accepted Position Confidence Interval (MAPCI) with absolute value depending on the operational needs, not the technology used (“operational train position accuracy”).

4.1.3.2 FP2 WP21 defines the user needs including all sources of errors, without allocation of the target between onboard and trackside with a technological agnostic approach with the definition of areas with constraints where the train need to stop accurately. These areas can be stations or area surrounding signals.

4.1.3.3 The WP21 requirements are reminded thereafter.

[REQ: FP2-ASTP-SRS-036]: ASTP computed confidence interval toward the estimated ASTP position performance

[category]: NFR-PERFO.

[Requirement]: The computed $\frac{1}{2}$ confidence interval (Underestimation of the estimated distance and Overestimation of the estimated distance) toward the ASTP reference position provided by ASTP shall not exceed (absolute value):

- 60m in areas with negligible constraints whatever is the train operation (cruising, accelerating, standstill etc).
- 60m in areas with constraints only if the train is not stopping in this area.

[Rationale]: refer to D21.1 § 6.3.3.

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: D21.1 § 6.3.3 / §4.1.1.4.1 / §4.1.1.4.2 / §4.1.1.4.5 / §4.1.2.4.1

[END REQ]

[REQ: FP2-ASTP-SRS-037]: ASTP computed confidence interval, stopping in an area with constraints

[category]: NFR-PERFO.

[Requirement]: The computed $\frac{1}{2}$ confidence interval (Underestimation of the estimated distance and Overestimation of the estimated distance) toward the ASTP reference position provided by ASTP shall not exceed (absolute value):

- 10m in areas with constraints if the train is stopping in this area.

[Rationale]: refer to D21.1 § 6.3.3.

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: D21.1 § 6.3.3 / §4.1.1.4.1 / §4.1.1.4.2 / §4.1.1.4.5 / §4.1.2.4.1

[END REQ]

[REQ: FP2-ASTP-SRS-038]: *ASTP computed estimated position accuracy*

[category]: NFR-PERFO.

[Requirement]: For at least 95% of the cases, the absolute error of the ASTP reference estimated position provided by ASTP shall not exceed:

- ± 5.0 m in areas with negligible constraints.
- ± 5.0 m in areas with constraints.

[Rationale]: Refer to D21.1 § 6.3.3. To be noticed that these values are subject to evolution especially considering the results of the demonstrations done in the scope of WP22.

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: D21.1 §4.4 / § 6.3.3.

[END REQ]

- 4.1.3.4 Fulfilling the needs defined in FP2 WP21 depends on the onboard odometry accuracy model of the technical solution chosen and then how the target is allocated to trackside and onboard.
- 4.1.3.5 Figure 1 represents together the FP2 WP21 operational accuracy profile (blue) and how this can be fulfilled by the ETCS train position accuracy model (orange).

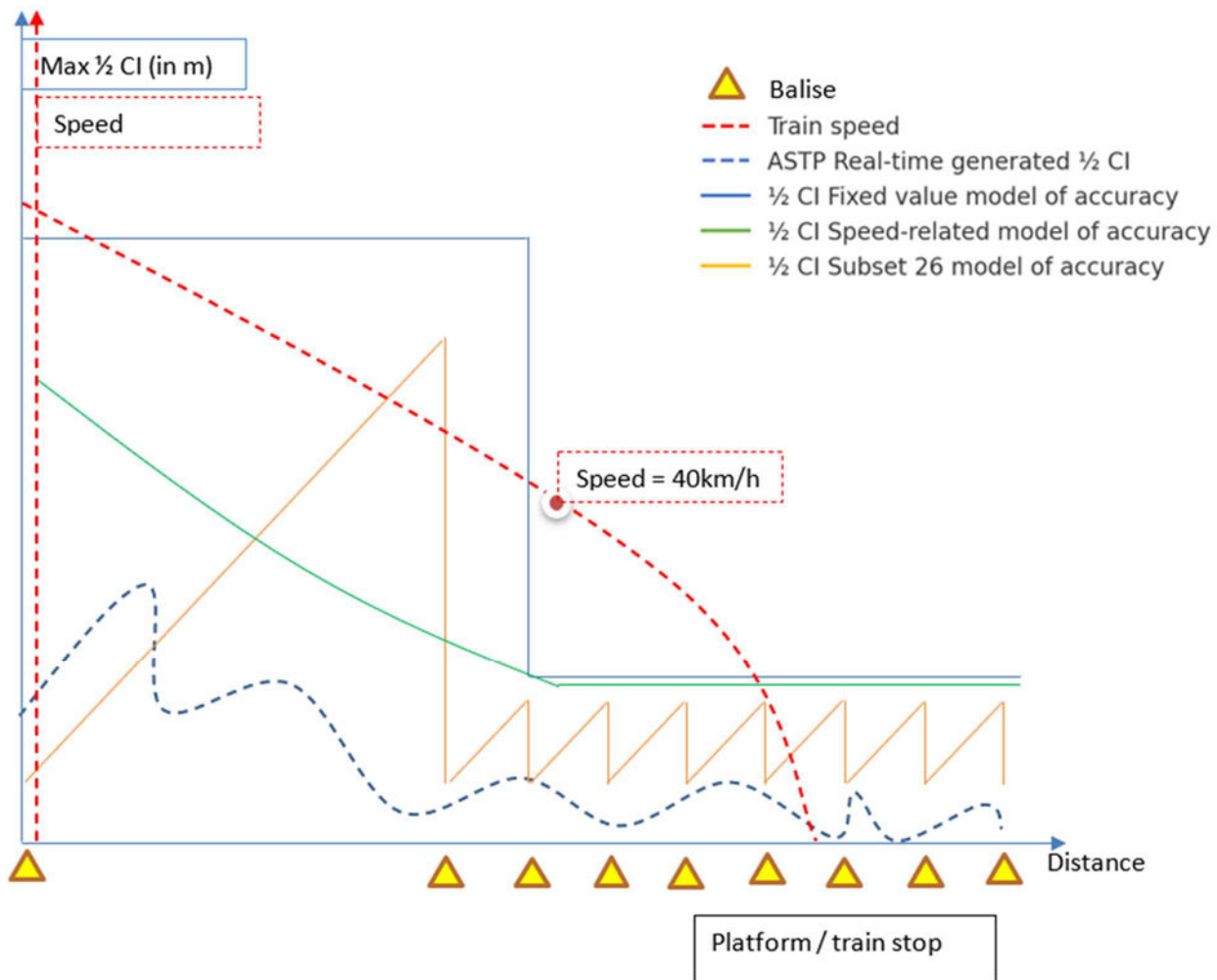


Figure 1 : models of accuracy vs FP2 WP21 requirements

Figure 1 highlight that the requirements defined in WP21 based on user needs can be fulfilled by different technical solutions including present day odometry + balise principle.

4.1.4 EuroSpec requirements

4.1.4.1 The purpose of the EuroSpec requirements is to minimise the impact of CR1389.

4.1.4.2 Odometry - Degradation exceeding 5%

- To minimize the negative impact of the odometry inaccuracy on the line capacity,
- and to minimize the number of warnings shown to the driver, i.e., to avoid too defensive driving due to the constant warnings:

The ETCS OB shall achieve a Mean Distance Between Incidents (MDBI) of at least 30'000 km for incidents triggered by the odometry accuracy monitoring function according to clause 3.6.8.5 of CCS TSI - SUBSET-026-3.

4.1.4.3 Odometry - Degradation exceeding 30%

- To minimize the impact of CR 1389 (mandatory for BL 4 R1) operational availability - this impacts Level1 and Level2 operation:

The ETCS OB shall meet a Mean Distance Between failures (MDBF) of at least 3'000'000 km for system failures triggered by the odometer accuracy-monitoring according to clause 3.6.8.7 of CCS TSI -SUBSET-026-3.

4.1.4.4 Odometry - Distance measurement accuracy

- For ATO readiness - to support a stopping accuracy of up to 1m (depending on the position of the LRBG) for ATO based on the ETCS odometry (see clause 7.3.9.2 of SUBSET-126), hence the accuracy is mainly needed for the braking phase.
- And to avoid a separate odometry dedicated to ATO needs,
- and to minimize the number of required balises to achieve the required stopping accuracy:

The ETCS OB shall estimate the distance travelled since passing the LRBG with an accuracy of $\pm(0.5\text{m} + 2\% \cdot \text{of the real distance since passing the LRBG})$ for at least 95% of the estimates in addition to the accuracy requirement in clause 5.3.1.1 of CCS TSI SUBSET-041. This performance requirement includes the error for the detection of a balise location ($\pm 0.5\text{m}$).

4.1.5 Comparison between models of train position accuracy

4.1.5.1 Figure 2 compares the apportionment of an (operational – top down) train position accuracy target to on-board and trackside (engineering rules) by using the current ETCS train position accuracy model and a possible future one adopting GNSS technology in a multi sensors environment (full ASTP concept).

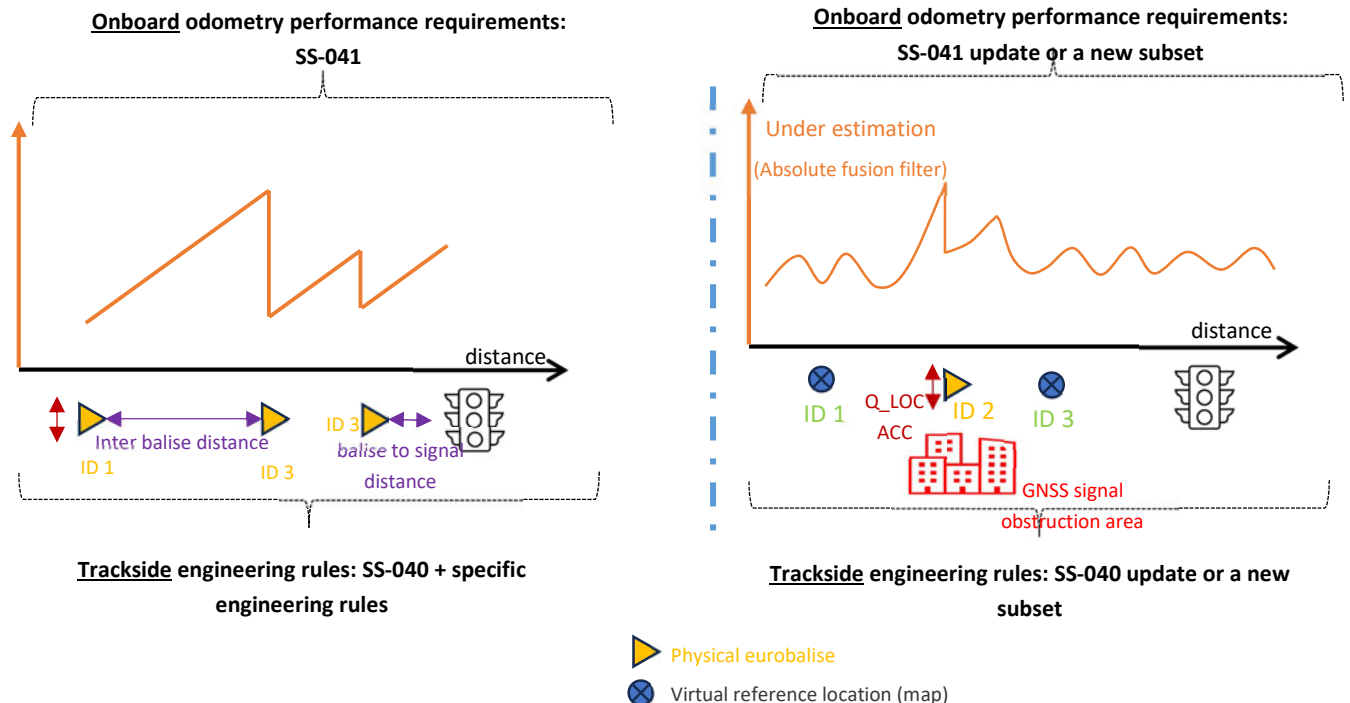


Figure 2 : comparison between models of train position accuracy

4.2 Train speed

4.2.1.1 In this chapter it is reported how train speed accuracy target is defined in the current ETCS specification and in the context of the IP FP2.

4.2.1.2 Measurement of speed only depends on the performance of the on-board odometry (no contribution from trackside is envisaged to achieve the accuracy target).

4.2.2 Current ETCS specifications (B4R1)

4.2.2.1 ETCS on-board speed accuracy target (on-board over/under reading amount) is included into SS-041 (it refers to the on-board performances - §Fel! Hittar inte referensälla.).

4.2.2.2 Subset 41 defines the over/under reading error of on-board to measure the speed as reported hereafter:

5.3.1.2 Accuracy of speed known on-board

Description	accuracy of speed known on-board
Start Event	not applicable
Stop Event	not applicable
Value	± 2 km/h for speed lower than 30 km/h, then increasing linearly up to ± 12 km/h at 500 km/h.
Notes	Only in target speed monitoring when the compensation of the speed measurement inaccuracy is not inhibited: the on-board equipment shall also evaluate a safe confidence interval in case of malfunctioning.

4.2.3 IP FP2 WP21 specifications

4.2.3.1 FP2 WP21 defines the user needs, without allocation of the target between onboard and trackside with a technological agnostic approach with the definition of areas with constraints where the train need to stop accurately. These areas can be stations or area surrounding signals.

To be noticed that speed requirements are expressed independently from the defined area (with or without constraints) since accurate speed is needed in any operational scenario as ceiling speed monitoring or braking curve calculation.

4.2.3.2 The WP21 requirements are reminded thereafter.

[REQ: FP2-ASTP-SRS-040]: *ASTP computed estimated speed accuracy*

[category]: NFR-PERFO.

[Requirement]: For at least 95% of the cases, the absolute error of the estimated train speed provided by ASTP shall not exceed ± 1 km/h for speeds from 0 km/h to 100 km/h and $\pm 1\% \cdot v$ for speeds from 100 km/h to 500 km/h.

[Rationale]: Refer to D21.1 § 7.1.3.

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: ASTP_SF-002 / D21.1 § 6.2.2.

[END REQ]

[REQ: FP2-ASTP-SRS-080]: *ASTP computed confidence interval toward speed performance*

[category]: NFR-PERFO.

[Requirement]: The computed safe $\frac{1}{2}$ confidence interval toward estimated speed shall not exceed 2 km/h (MASO/MASU), for speeds lower than 30 km/h, and increasing linearly up to 12 km/h for speeds between 30 km/h and 500 km/h.

[Rationale]: Refer to D21.1 § 7.1.3.

If speed < 30 km/h, MASO=MASU=2 km/h

If speed ≥ 30 km/h, MASO=MASU= $(2 + (\text{speed}-30) / 47)$ km/h

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: ASTP_SF-002 / D21.1 § 6.2.2.

[END REQ]

The requirement above (FP2-ASTP-SRS-080) is the same as what is defined today in Subset 041 5.1.3.2.

4.2.4 EuroSpec requirements

4.2.4.1 Odometry - Estimated train speed accuracy

- To minimise delays with the ability to drive with real speed close to the permitted speed (esp. important in ceiling speed monitoring and release speed monitoring):

The ETCS OB shall estimate the train speed shown to the driver (V_{est}) with an accuracy of ± 2 km/h for speeds lower or equal to 100 km/h, and 2% of the real speed for speeds higher than 100 km/h for at least 99.7% of estimates (incl. malfunctioning). (In

addition to clause 5.3.1.2 of CCS TSI - SUBSET-041). This results in the following formula:

$0\text{km/h} \leq V_{\text{est}} - V_{\text{real}} \leq 2\text{km/h}$ for real speed lower or equal to 100km/h and 2% of the real speed higher 100km/h for at least 99.7% of the estimates

4.3 Train acceleration

4.3.1.1 In this chapter it is reported how train acceleration accuracy target is defined in the current ETCS specification and in the context of the IP FP2.

4.3.1.2 Measurement of acceleration only depends on the performance of the on-board odometry (no contribution from trackside is envisaged to achieve the accuracy target).

4.3.2 Current ETCS specifications (B4R1)

4.3.2.1 The value of acceleration is used in the ETCS on-board speed and distance monitoring function (SS-026 chapter 3.13) however no accuracy target (on-board over/under reading amount) is defined.

4.3.3 IP FP2 WP21 specifications

4.3.3.1 The WP21 requirements are reminded thereafter.

[REQ: FP2-ASTP-SRS-043]: *ASTP computed estimated acceleration accuracy*

[category]: NFR-PERFO.

[Requirement]: For at least 95% of the cases, the absolute error of the estimated train acceleration provided by ASTP shall not exceed 0.05 m/s^2 .

[Rationale]: To be noticed that these values are subject to evolution especially considering the results of the demonstrations done in the scope of WP22.

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: ASTP_SF-003.

[END REQ]

[REQ: FP2-ASTP-SRS-046]: *ASTP computed estimated 3D acceleration accuracy*

[category]: NFR-PERFO.

[Requirement]: For at least 95% of the cases, the absolute error of the estimated 3D train acceleration shall not exceed 0.05 m/s^2 on each axis of the carriage reference frame.

[Rationale]: Refer to D21.1 §7.1.7.

To be noticed that these values are subject to evolution especially considering the results of the demonstrations done in the scope of WP22.

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: ASTP_SF-006.

[END REQ]

[REQ: FP2-ASTP-SRS-041]: *ASTP computed confidence interval toward acceleration performance*

[category]: NFR-PERFO.

[Requirement]: ASTP shall provide the train estimated acceleration with a computed $\frac{1}{2}$ confidence interval better than 0.2 m/s^2 .

[Rationale]: Refer to D21.1 § 7.1.4 and § 6.2.3. Acceleration performance is required for train protection (computation of the safe braking curve).

[V&V method]: Lab test.

[Safety assumptions]: Not related to safety.

[traceability]: ASTP_SF-003.

[END REQ]

It is important to highlight that the need of a safe confidence interval for acceleration is still debated since braking curves calculation does only use the estimated acceleration.

5 Allocation of accuracy targets to ASTP

- 5.1.1.1 It is also assumed that basic ASTP will be introduced into ETCS specification in a compatible way, meaning its implementation on-board cannot be used (at least from a ETCS SV perspective) as trackside access condition.

5.2 Position and travelled distance

5.3 Basic ASTP

- 5.3.1.1 According to the definition of basic ASTP (STIP_29) and to SP CR_7695 (ASTP performance), it is in the scope of basic ASTP to modify the on-board distance measurement accuracy (see 4.1.2.8 and 4.1.2.10) to align ETCS specification to the status of the best practice of odometry technological solutions in operations.

5.4 Full ASTP

- 5.4.1.1 Full ASTP will be able to provide the train position not always relying on combining balise detection and on-board odometry (allowing to reduce the number of balise groups used as location reference). Full ASTP can generate an absolute position thanks to the availability of a track digital map and to several techniques as:

- GNSS
- IMU map matching
- Perception of the environment (SLAM, fingerprinting)
- Magnetic fingerprinting
- etc.

- 5.4.1.2 Following 5.4.1.1, full ASTP on-board odometry accuracy model may have a different shape from the basic ASTP one (chapter 5.3) with an impact on both on-board and trackside apportionment (exported constraints) of the operational train position accuracy target.

- 5.4.1.3 However, to be noticed that in case the track digital map (or possible other features such as GNSS augmentation) is unavailable, Full ASTP will need to comply to the basic ASTP performances (chapter 5.3) for backward compatibility reasons.

5.4.2 Onboard performance requirements

- 5.4.2.1 The definition of an ASTP onboard performance requirements needs to be agreed by the sector and the feasibility checked through the demonstrations in the scope of R2DATO.
- 5.4.2.2 For example, if the demonstrators can prove that a ½ CI of 10 m is achievable anywhere and anytime, then the onboard requirements can be simple as:
- The ½ CI shall always be lower than 10m.

5.4.3 Trackside exported constraints

5.4.3.1 The identification of ASTP exported constraints to trackside is not yet available. It will mainly be feedback from the demonstrators provided in the scope of R2DATO.

5.4.3.2 For example, if the demonstrators can prove that a ½ CI of 60 m is achievable anywhere and anytime but a ½ CI of 10 m is only achievable in open sky conditions or thanks to a low Q_LOCACC balise, the trackside engineering rules could be :

- Areas with constraints need to be identified as:
 - Operational stopping points.
 - Signals
 - Etc.
- The sky visibility of each area with constraints needs to be verified:
 - If the visibility is sufficient, no action is needed.
 - If the visibility is not sufficient, a balise, with a Q_LOCACC lower than 2m need to be installed 100m before the stopping point or the signal.

5.5 Train speed

5.5.1 Basic ASTP

5.5.1.1 According to the definition of basic ASTP (STIP_29) and to SP CR_7695 (ASTP performance), it is in the scope of basic ASTP to modify the on-board speed measurement accuracy (see 4.2.2.2) to align ETCS specification to the status of the best practice of odometry technological solutions in operations.

5.5.1.2 There is no need to specify a new target in terms of speed CI (requirement 080 in §4.2.3.2 is the same as 5.3.1.2 in subset 041), while the introduction of a new requirement for the estimated speed accuracy should be considered (see 4.2.3.2 requirement 040).

5.5.1.3 No exported constraints or apportionment to trackside is needed to achieve speed accuracy target.

5.5.2 Full ASTP

5.5.2.1 It is not envisaged that the measurement of speed is affected by the introduction of full ASTP features (e.g. digital map and GNSS), therefore, the speed accuracy target as defined for basic ASTP (chapter 5.5.1) will remain valid for full ASTP as well.

5.6 Train acceleration

5.6.1 Basic ASTP

5.6.1.1 According to the definition of basic ASTP (STIP_29) and to SP CR_7695 (ASTP performance), it is not in the scope of basic ASTP to modify the on-board acceleration measurement accuracy.

5.6.1.2 However, the lack of accuracy requirement affecting acceleration can bring the on-board to possible different behaviours when performing the speed and distance monitoring

function. CR 1463 “Jumping V-permitted on DMI” describes how the V-permitted in some cases jumps up and down, causing severe discomfort to the train drivers, making it difficult to approach an EoA efficiently. This phenomenon could be mitigated by improving the acceleration accuracy requirements. Furthermore, this CR has been validated as an enhancement by ERA in the EECT CCM process.

- 5.6.1.3 No exported constraints or apportionment to trackside is needed to achieve acceleration accuracy target.

5.6.2 Full ASTP

- 5.6.2.1 Despite the measurement of the acceleration will be allocated to full ASTP, it is not envisaged that the full ASTP features will contribute to improve the acceleration accuracy. Therefore, the definition of acceleration accuracy requirements in the stage of Basic ASTP, will not need to be further modified for Full ASTP.

6 Impact on ETCS specification

6.1.1.1 In this chapter, the current and possible future impact of train position, speed, acceleration accuracy requirements on ETCS specification are presented.

6.2 Documents tree in ETCS B4 R1

6.2.1.1 Figure 4 represents, in a graphical way, how train position and speed accuracy requirements are allocated into the current ETCS specification (B4 R1) - see also chapter 4.1.2 and 4.2.2. For speed only SS-041 applies.

6.2.1.2 No train position accuracy requirements at level of operational user needs are defined.

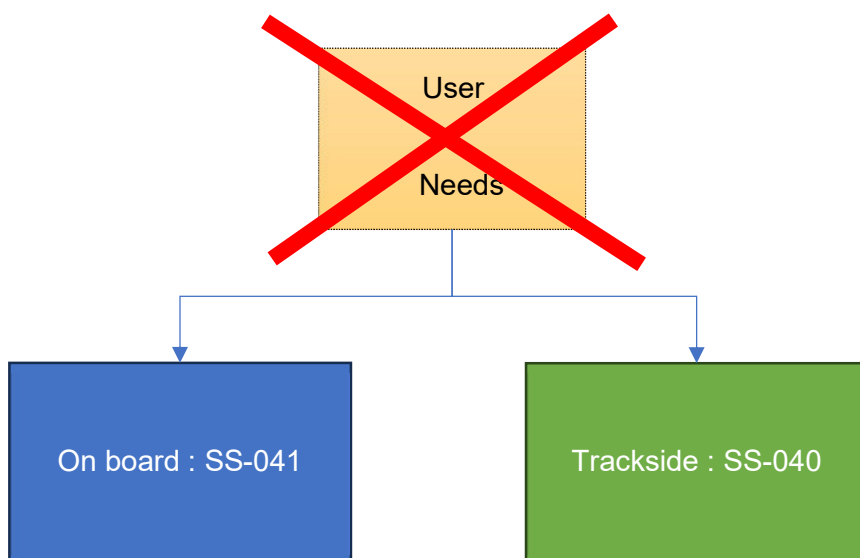


Figure 3 : train position accuracy - documents tree in ETCS B4 R1

6.3 Document tree with basic ASTP

6.3.1.1 Figure 4 represents, in a graphical way, how train accuracy requirements can be allocated into the ETCS specification when basic ASTP requirements (preparation for full ASTP) are fully developed. For speed and acceleration only SS-041 applies.

6.3.1.2 According to the definition of basic ASTP in STIP_29, there is not a clear mandate (neither an impediment) to define train position accuracy requirements at level of operational user needs.

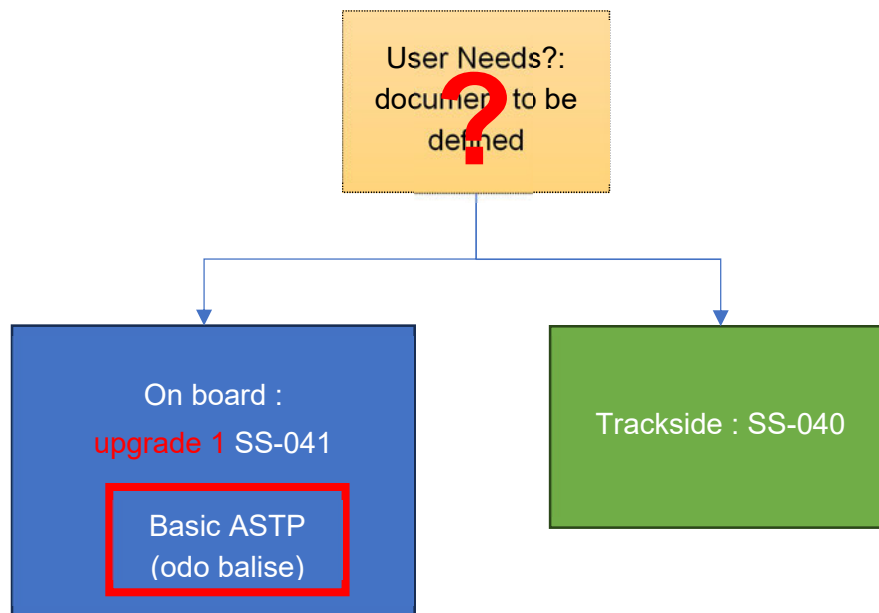


Figure 4 : train position accuracy - documents tree with basic ASTP

6.4 Document tree with full ASTP

- 6.4.1.1 In this chapter, two options are presented as possible ways to introduce accuracy requirements on ETCS specification when full ASTP requirements are fully developed.
- 6.4.1.2 According to the definition of full ASTP in STIP_30, there is not a clear mandate (neither an impediment) to define train position accuracy requirements at level of operational user needs.
- 6.4.1.3 The choice between the two options should be evaluated considering that backward compatibility of full ASTP vs basic ASTP (see 5.4.1.3) shall be ensured.

6.4.2 Option 1

- 6.4.2.1 Figure 5 represents, in a graphical way, a first option on how train position accuracy requirements can be allocated into the ETCS specification together with the introduction of full ASTP. For speed and acceleration only SS-041 applies.
- 6.4.2.2 Within this option, the already existing Subset 41 (already upgraded for basic ASTP) and Subset 40 shall be upgraded including the new full ASTP accuracy requirements for on-board and trackside (engineering rules). Backward compatibility vs basic ASTP shall be ensured (see 5.4.1.3).

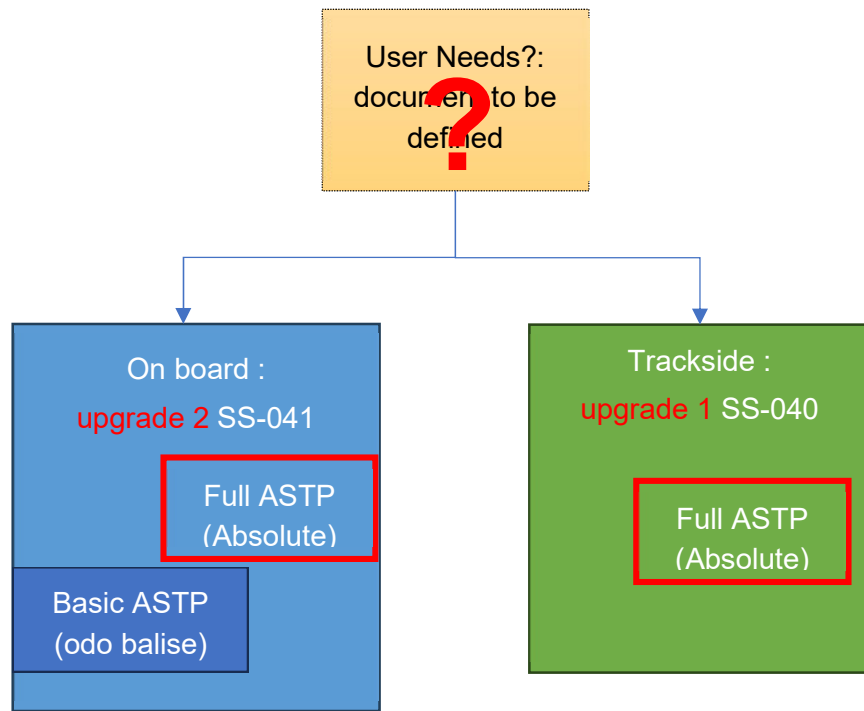


Figure 5 : train position accuracy - documents tree with full ASTP – option 1

6.4.3 Option 2

- 6.4.3.1 Figure 6 represents, in a graphical way, a second option on how train position accuracy requirements can be allocated into the ETCS specification together with the introduction of full ASTP. For speed and acceleration only SS-041 upgraded 1 for basic ASTP applies.
- 6.4.3.2 Within this option, the already existing Subset 41 (already upgraded for basic ASTP) and Subset 40 are not modified. Two new Subsets are defined to include the new full ASTP train position accuracy requirements for on-board and trackside (engineering rules) provided that also backward compatibility vs basic ASTP shall be ensured (see 5.4.1.3).

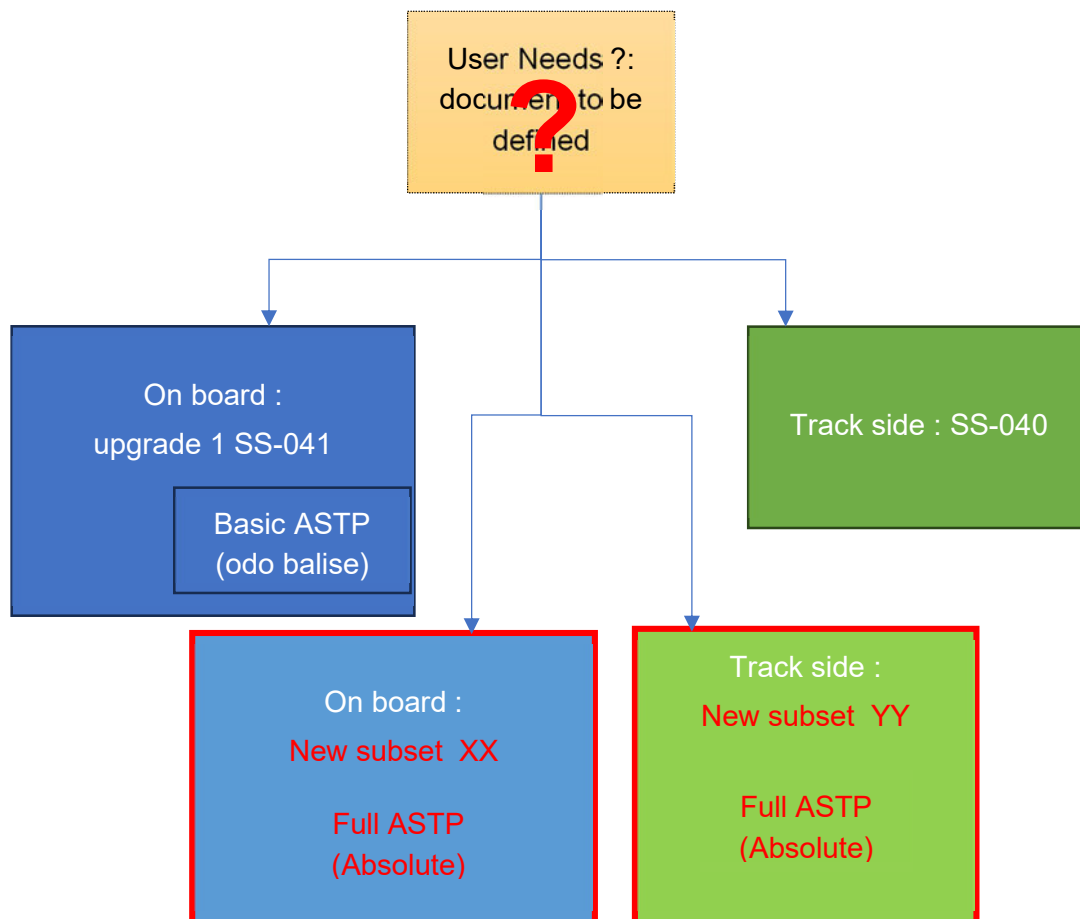


Figure 6 : train position accuracy - documents tree with full ASTP – option 2

7 Conclusions

- 7.1.1.1 Chapter 3 describes the overall user needs which EUG endorses. The preferred approach is top-down (from an operation perspective) and then to allocate on-board target and trackside constraints in terms of engineering rules. Assuming the stepwise way towards full ASTP, at the first stage (basic ASTP) it is also accepted to continue with the bottom-up approach (only focusing on on-board performances) in order to facilitate TSI CCS upgrade. Since EuroSpec requirements are written as bottom-up and do not have impact on existing balise engineering rules, EUG endorses such a kind of requirements for the basic ASTP step. For the Full ASTP step, EUG prefers to follow the top down approach as described in WP21.
- 7.1.1.2 The improvement of the on-board odometry CI requirements (D21.2 req. 036 and 037 which would replace SUBSET-041 §5.3.1.1) for positioning is not needed in the basic ASTP step because this step does not envisage the relax of trackside engineering rules.
- 7.1.1.3 Given that ATO GoA2 already critically relies on the ETCS-estimated train position and estimated speed for its core operational functionalities (e.g. to determine stopping points, optimise braking and acceleration curves), a specification of the estimated position and estimated speed accuracy should be defined already in the scope of basic ASTP.
- 7.1.1.4 The introduction of a new requirement for the estimated speed of the train can already be beneficial in the basic ASTP step (e.g. in CSM when the train is running at maximum speed, the estimated speed is used to calculate the speed shown to the driver and therefore it can have an impact on the mission time), since no requirements for the estimated speed exist in current ETCS specification.
- 7.1.1.5 The introduction of basic ASTP should be the opportunity to separate the terms accuracy - as the error of the estimated values – and the size of the confidence interval. Note that this would also change the meaning of “accuracy” compared to today’s specifications (SUBSET-041. §5.3.1.1).
- 7.1.1.6 The introduction of basic ASTP should be the opportunity to remove the possibility to equalise the over/under reading amount of the measured distance to a maximum fixed value when the calculated ones are lower. This improving efficiency in the computation of the confidence interval.
- 7.1.1.7 Since the estimated acceleration is used to calculate braking curves, the introduction of basic ASTP could be the opportunity to define accuracy requirements for acceleration when proven that acceleration accuracy has a significant impact on-board the speed and distance monitoring function.
- 7.1.1.8 If acceleration accuracy is to be defined, it will not be improved or otherwise affected by GNSS based positioning (full ASTP), therefore, the acceleration accuracy target will be the same for Basic and Full ASTP.
- 7.1.1.9 Introduction of full ASTP should be the opportunity to define the ETCS train position accuracy target referring to the operational user needs (top - down approach) and in a technological agnostic way.

- 7.1.1.10 For interoperability reasons, full ASTP shall define the apportionment of the operational train position accuracy target to on-board, including the way accuracy evolves along the travel and the accuracy to detect the reference position.
- 7.1.1.11 For interoperability reasons, full ASTP shall define the exported constraints of the operational train position accuracy target to trackside engineering rules.
- 7.1.1.12 The speed accuracy is not improved or otherwise affected by GNSS based positioning (full ASTP) (unless in degraded situation such as sensor failures), therefore, the speed accuracy target will be the same for Basic and Full ASTP.