ERJU SYSTEM PILLAR

System Requirements Specification_Train Integrity and Train Length_Part A WP3_1

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Abstract	The purpose of this document is to specify the system and interfaces requirements that must be fulfilled in order to provide an interoperable "Safe Train Length Determination" within the FDFTO Train Functions.
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Table of contents

1 Preamble

1.1 Purpose

SPT4DAC-700 - The purpose of this document is to specify the system and interfaces requirements that must be fulfilled in order to provide an interoperable "Safe Train Length Determination" within the FDFTO Train Functions. **[** Open **]**

SPT4DAC-697 - It defines the following:

a) Use of a two SIL2 channel approach to reach a SIL4 train length information
b) Use of FDFTO train functions (such as Last Consist Detection, Train Composition Detection and Passive Consist Detection) as described in FP5-TRANS4M-R D5.1 "Functional Requirements Specification of Train Functions"
c) The related FDFTO system architecture (including the definition of all interfaces) **[** Open **]**

1.2 Intended audience

SPT4DAC-791 - Intended audience of the document is the whole European Rail freight sector interested in the transition of rail freight operations to Full Digital Freight Train operations enabled by DAC. **[** Open **]**

1.3 Document context

SPT4DAC-695 - The European Railways are currently in the process of implementing ETCS Level 2 Moving Block and Hybrid Train Detection on dedicated lines to increase capacity on existing lines. **[** Open **]**

SPT4DAC-694 - To run trains under such conditions, a "Safe Train Length" is mandatory. **[** Open **]**

SPT4DAC-696 - Using the deployment of DAC as enabler, the Train Functions of FDFTO provide the necessary basis to achieve such a "Safe Train Length Determination" for loco-hauled freight trains. **[** Open **]**

SPT4DAC-699 - The scope of this document is to define the system functional requirements and interfaces with ETCS for an interoperable "Safe Train Length Determination" to be considered by the EU-Rail Flagship Area 5 in the further development of the FDFTO Train Functions. **[** Open **]**

SPT4DAC-698 - This specification is related to ETCS Level 2 Moving Block and Hybrid Train Detection. **[** Open **]**

SPT4DAC-701 - "Safe consist length" to support Supervised Manoeuvre (SM) is currently out of scope of this document. **[** Open **]**

1.4 Glossary

Term	Status	Definition
SPT2TRAIN-4113 - Train Length Merging Function	Open	The Train Length Merging Function (TLMF) receives information from TLM-A and TLM-B. The main task of the TLMF consists of comparing the information received. If the both paths are sending coherent information, then the TLMF shall forward the data to the ETCS-OB.

Term	Status	Definition
		At least following checks are required: • Train length A (TLM-A) is equal to Train length B (TLM-B) • List of vehicle IDs on path A is equal to List of vehicle IDs on path B • (optional) HoT A and EoT A correspond to HoT B and EoT B Once the checks are passed for the first time, during the train inauguration, the TLMF shall send the train length to the ETCS-OB and then starting a continuous monitoring of the information consistency. The TLMF shall inform the ETCS-OB when the train length information is no more available (e.g., the information is not coming from one channel, there is a misalignment between the two channels, etc.) and shall stop the monitoring when a reset takes place (e.g., end of mission). Referenced by: SPT4DAC-717
SPT4DAC-720 - LCDF	Open	LCDF - Last Coupler Detection Function Referenced by: SPT4DAC-718
SPT4DAC-692 - FDFT: Full Digital Freight Train	Open	FDFT: Full Digital Freight Train : designates the rolling stock operated according to FDFTO Referenced by: SPT4DAC-691
SPP-15282 - Hybrid Train Detection	To be approved completely	Hybrid Train Detection is a type of train detection which uses fixed (pre-configured) virtual blocks for the separation of trains which are able to send train integrity confirmation in the position report, while a limited installation of trackside train detection is used for the separation of trains which are not able to send integrity confirmation, as well as for the handling of degraded situations. Referenced by: SPT4DAC-698, SPT4DAC-714
SPLI-1058 - SUPERVISED MANOEUVRE MODE	Done / To be decided	ERTMS/ETCS on-board equipment operating mode which allows a shunting consist to be supervised with a Movement Authority, while the engine and its active cab can be located anywhere in the consist. Referenced by: SPT4DAC-702
SPLI-113 - Full Digital Freight Train Operations	In Progress	Full Digital Freight Train Operations Referenced by: SPT4DAC-691, SPT4DAC-696
SPT2TRAIN-626 - DAC - Digital Automatic Coupling	Open	DAC - Digital Automatic Coupling Referenced by: SPT4DAC-691, SPT4DAC-696
SPLI-951 - MOVING BLOCK	Done / To be decided	A block whose length is defined by the position of the train occupying the section of track ahead. The minimum block length would be from the rear most part of the occupying train to a point on the track where, if the train braked from its current

Term	Status	Definition
		speed, the front of the occupying train would be when the train came to a stand. Referenced by: SPT4DAC-698, SPT4DAC-714

1.4.1 Terms

Full Digital Freight Train Operations

SPT4DAC-691 - FDFTO : Full Digital Freight Train Operation
Concerns Full Digital Rail Freight Operations : Digitalization and automation of operational functions and processes (such as yard/depot/terminal automation and control) which are a prerequisite to meet customer requirements and expectations. Therefore, available assets have to be equipped with automation components and sensor technique.
This will be done based on enabler technologies (Digital Automated Coupler and related automation components), additional sub-systems and components (e. g. systems for the intelligent freight train such as, energy management distributed systems (harvester and storage) as well as freight wagon development and the upgrade of the locomotives for the related DAC-functionalities including the interfaces to ATO technologies. **[** Open **]**

FDFT: Full Digital Freight Train : designates the rolling stock operated according to FDFTO

Black Channel is formally defined into EN 61748-3-3 chapter 3.1.1.2 as "communication channel without available evidence of design or validation according to IEC 61508 series".
More in general, a black channel refers to a communication channel where the characteristics of the communication system are not fully known or trusted, and therefore, safety mechanisms are implemented within the safety-related system itself to ensure reliable and safe data transmission. Essentially, it treats the communication system as a "black box" and relies on safety protocols and error detection/correction mechanisms within the communicating devices to mitigate potential communication failures. Black channel concept application and related safety measures are widely reported into CEI EN 61748-3-3.

The Train Length Merging Function (TLMF) receives information from TLM-A and TLM-B.
The main task of the TLMF consists of comparing the information received. If the both paths are sending coherent information, then the TLMF shall forward the data to the ETCS-OB.
At least following checks are required:

- Train length A (TLM-A) is equal to Train length B (TLM-B)
- List of vehicle IDs on path A is equal to List of vehicle IDs on path B
- (optional) HoT A and EoT A correspond to HoT B and EoT B

Once the checks are passed for the first time, during the train inauguration, the TLMF shall send the train length to the ETCS-OB and then starting a continuous monitoring of the information consistency.
The TLMF shall inform the ETCS-OB when the train length information is no more available (e.g., the information is not coming from one channel, there is a misalignment between the two channels, etc.) and shall stop the monitoring when a reset takes place (e.g., end of mission).

LCDF - Last Coupler Detection Function

1.4.2 Abbreviations

Abbreviation/Acronyms	Description
ASO	Automatic Shunting Operation
ATO	Automatic Train Operation
CEN, CENELEC, CLC	European Committee for Electrotechnical Standardisation
C/U	Coupled/Uncoupled
DAC	Digital Automatic Coupler
EN	European Norm as European Standard
ERA	European Union Agency for Railways
ERTMS	European Rail Traffic Management System
ESO	European Standardisation Organisation, being CEN, CENELEC and ETSI
ETCS	European Train Control System
FDFT	Full Digital Freight Train
FDFTO	Full Digital Freight Train Operation
FP	Flagship Project (within the ERJU Innovation Pillar)
IEC	International Electrotechnical Commission
IP	Innovation Pillar within the ERJU
ISB	International Standardisation Body, being ISO and IEC
ISO	International Organisation for Standardisation
LCDF	Last Coupler Detection Function
OTIF	Intergovernmental Organisation for International Carriage by Rail
RID	Regulation concerning the International Carriage of Dangerous Goods by Rail
SC	Subcommittee (within ESOs and ISBs)
SP	System Pillar within the ERJU
TLFA	Train Length Function of channel A (in consist)
TLFB	Train Length Function of channel B (in consist)
TLMA	Train Length Master of channel A (in leading traction unit)
TLMB	Train Length Master of channel B (in leading traction unit)
TLMF	Train Length Merging Function (in leading locomotive)
TSI	Technical Specification for Interoperability
TSI CCS	TSI Command Control and Signalling
TSI LOC&PAS	TSI Locomotives and Passengers
TSI OPE	TSI Operations & Traffic Management
TSI TAF	TSI Telematics Applications for Freight services
TSI WAG	TSI Freight Wagons
TWG	ERA Topical Working Group
WG	Working Group (within ESOs and ISBs)

2 Assumptions and dependencies

2.1 Supervised Manoeuvre assumption

SPT4DAC-703 - ERA expressed the expectation that it is a requirement to provide the MIN, NOMINAL and MAX value for the length, e.g. all 6 values (in front and rear of traction unit) for Overall Consist Length

Information/Supervised Manoeuvre/Cab Anywhere as defined in CCS TSI V4.0 Subset-034 (chapter 2.6.2). **[** Open **]**

SPT4DAC-702 - The concept described in chapter 3 only shows train length "behind the leading traction unit", but the final implementation shall also apply in the same way to "in front of the leading traction unit". **[** Open **]**

2.2 Safe architecture assumption

SPT4DAC-705 - According to CCS TSI Subset 91 EXT_SR07, the Confirmed Train Length sent in the position report shall be of a quality corresponding to SIL4. For this purpose, a SIL4 train length information (L_TRAIN) and at least SIL2 Train Integrity (Q_INTEGRITY) information are required. Thereby, EXT_SR07 implicitly mandates a SIL4 requirement for the train length information. **[** Open **]**

SPT4DAC-704 - One possible solution is based on having a SIL4 function on every consist belonging to the FDFT, said SIL4 function responsible to transmit the consist ID and length of the said every consist to a SIL4 central unit in the leading locomotive, where the total train length is then calculated and passed to the ETCS.
This solution has been analyzed and considered too complex to be developed and maintained over fleet life, and consequently too expensive for the FDFTO success. **[** Open **]**

An alternative solution has been chosen according to the principle shown in Figure 1 and hereafter described :

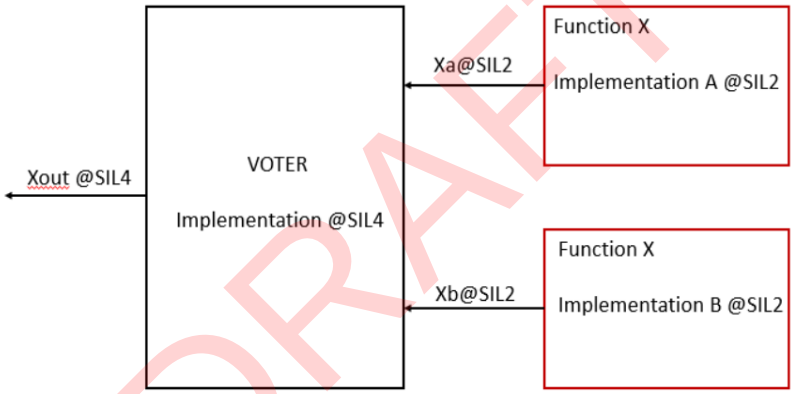


Figure 1

A generic Function X, realised according to two different implementations A and B, produce respectively the information Xa and Xb, with expected Xa=Xb, for a VOTER (DECIDER) that compares Xa and Xb. If Xa=Xb then the VOTER will produce the information Xout=Xa=Xb.

The output information Xout=Xa=Xb can be produced @SIL4 level if:

- the VOTER is implemented @SIL4
- The two Function X implementation A and implementation B are realised @SIL2
- The information Xa and Xb are transported @SIL2
- The Implementation A and Implementation B are INDEPENDENT, that is to say that A and B are designed to be free from resective "dependent failures", proven to be fully independent with common cause failures less than 1%.

SPT4DAC-709 - If the information transport is a communication channel, the architecture in Figure1 can be modified according to Figure2. The safety level of the communication channel can be limited at Basic Integrity pending the EN50159 is respected, providing the proper error detection coding, according to SIL2, to the Xa and Xb information. **[** Open **]**

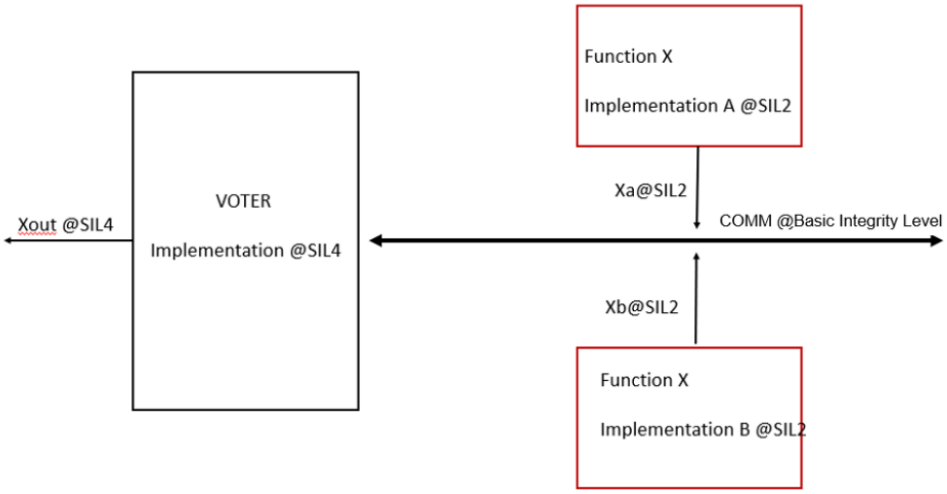


Figure 2

3 System overview

3.1 System context

SPT4DAC-714 - The Train Length Function will be implemented on FDFT to comply with future application of Moving Blocks and Hybrid Train Detection on European railways. **[** Open **]**

SPT4DAC-713 - The onboard ETCS transmits the Train Length L_TRAIN as part of the train data once (start of mission procedure) and afterwards the confirmed train length (L_TRAININT) and train integrity status (Q_INTEGRITY) in each position report to the RBC. (reference to CCS TSI v4.0.0 Subset-026). **[** Open **]**

3.2 System interfaces

3.2.1 Interface to ETCS

SPT4DAC-717 - According to figure 5, the Train Length system, in particular the Train Length Merging Function TLMF will interface with the onboard ETCS following the definition from CCS TSI Subset-119* / Subset-147/V2. **[** Open **]**

3.2.2 Interface between TLMF and FDFT

SPT4DAC-715 - A FFFIS interfaces definition between the Train Length Merging Functions TLMF-A/ TLMF-B and respective Channel-A/Channel-B (rfer to figure 5) is scope of specification of the FP5 TRANS4M-R project. For system coherence (Inteface with ETCS) it is anyway suggested to reflect Subset-147/V2. **[** Open **]**

3.3 System description

Figure 3 extends the concept described in Figure 2 to the real FDFT architecture:

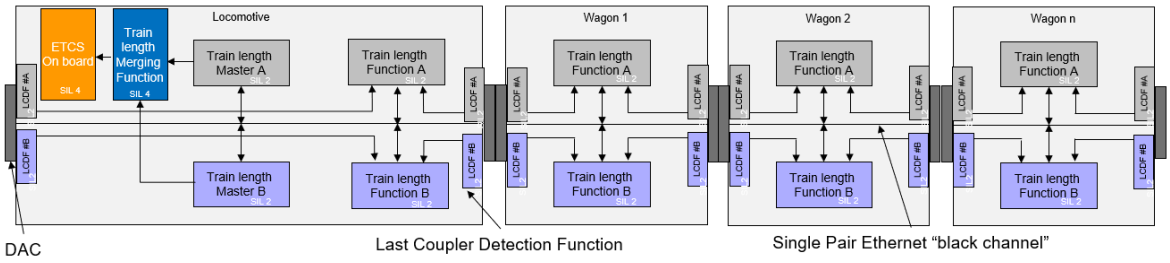


Figure 3

SPT4DAC-719 - Two symmetric functional channels, crossing the whole train, are shown:

- Channel A, consisting of a TLMA Train Length Master A resident on the leading locomotive communicating with a plurality of TLFA Train Length Function A, one per consist (locomotive and wagons) on a communication channel “Data Bus”
- Channel B, consisting of a TLMB Train Length Master B resident on the leading locomotive communicating with a plurality of TLFB Train Length Function B, one per consist (locomotive and wagons) on the same communication channel “Data Bus”

[Open **]**

SPT4DAC-718 - Each FDFT consist (locomotive and wagons) is equipped with two independent LCDF (Last Coupler Detection Function) at each consist extremity, each LCDF consisting of an independent sensing function and respectively connected to TLFA and TLFB. **[** Open **]**

SPT4DAC-724 - Scope of the LCDF is to detect the associated DAC status and to provide it to the connected TLFA/B:

- if the associated DAC is coupled to another DAC, the LCDF reports "COUPLED" Status
- if the associated DAC is not coupled to another DAC, the LCDF reports the "UNCOUPLED" Status

The combination of information provided by the independent LCDFs to the TLFA and TLFB is used to identify the existence and ID of the Last Wagon in the train. (Independent LCDF functions are used to determine sufficiently safe (SIL4) the Last Wagon and the (non-)existence of a passive consist at the train tail) **[** Open **]**

SPT4DAC-723 - TLMA and TLMB are in charge:

- to receive messages from each consist (said messages consisting of the Consist ID, the Consist Length, the both couplers LCDFs status, the message header incl. CRC, message ID, message counter and length) respectively from Channel A and Channel B, and at least one among TLMA and TLMB is in charge to check the Train Integrity.
- to forward the received consists messages, unmodified and unaltered, to the TLMF Train Length Merging Function.
- to detect, with proper means not scope of this document, the presence in the train of "passive consists" (one or more consist present within the train and able to bypass electrical and data lines, but CCU not working or communicating correctly) and provide the information to the TLMF.

[Open **]**

SPT4DAC-726 - The TLMF, corresponding functionally to the Voter in Figure 2, is in charge

- to verify the consistency of each consist data vs the respective attached certification overhead
- to calculate the Train Length A derived from Channel A data and Train Length B derived from Channel B data
- to compare the Train Length A and Train Length B and possibly pairwise comparision of each consist length present in CH A and CH B
- in positive case, and in absence of "passive consists" to report the Train Length, encapsulated into a message with associated SIL4 overhead according to EN 61748-3-3 , to the ETCS.

- to continuously verify the unchanged ID of the Last Consist. This function should be repeated with the periodicity proper of the Train Length refresh timing. According to TSI SS091 EXT_SR08, train integrity information (not scope of this document) shall be provided with at least SIL2 quality, that correspond to a repetition cycle of, at least, one second.

[Open **]**

SPT4DAC-721 - In order to minimize the Hardware costs, it is recommended to use existing on boards devices, satisfying the SIL2 requirement, to implement the TLFA and TLFB functions. Figure 4 shows a possible implementation using on-board existing components: TLFA implemented into the Consist Control Unit and the TLFB implemented into the DCUs (DAC Control Units). More details about this solution can be found in the presentation 2. **[** Open **]**

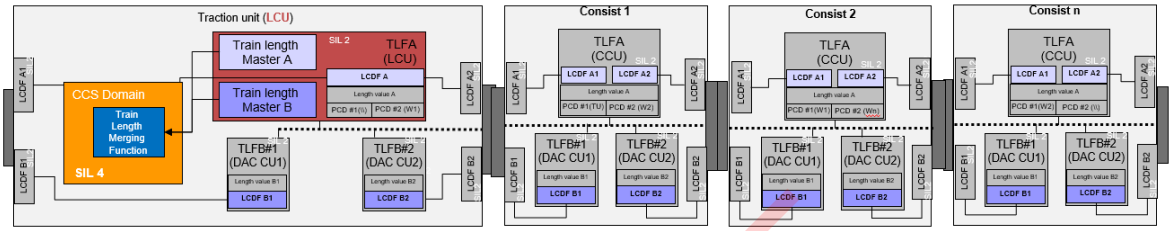


Figure 4

SPT4DAC-749 - Concerning the implementation of the Train Length Merging Fuction, workshops have been taken with System Pillar Task2 and FP2, about the opportunity to integrate the TLMF into the onboard ETCS, due to the same SIL4 technology nature, or to implement TLMF as a separate module. Train Length systems, available for passenger trains have been analyzed with the purpose to possibly re-use, totally or partially, common solutions.
Finally, Pros and cons related to four different possible solutions have been considered and investigated. A detailed anaysis is available and reported into presentation 3. **[** Open **]**

According to decisions commonly taken with SP-T2 and FP2, the final decision is shown hereafter in Figure 5

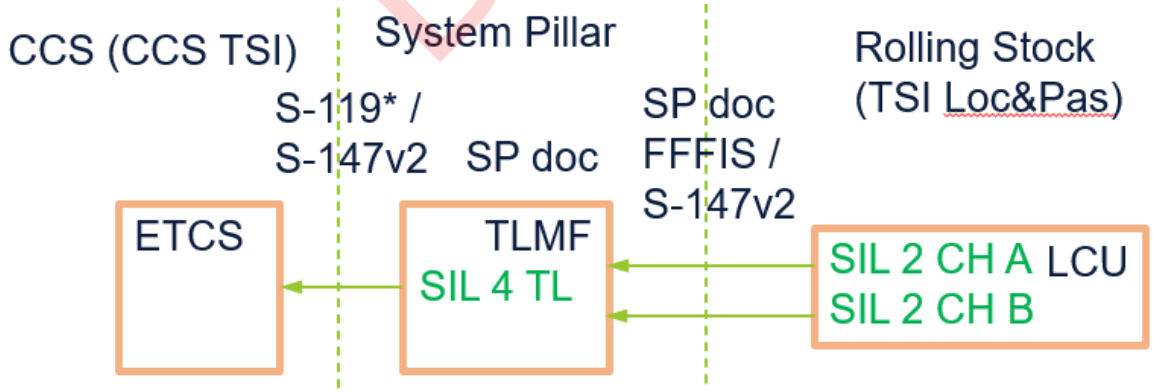


Figure 5

4 System requirements

4.1 Functional requirements

4.1.1 Optional: Functional overview

SPT4DAC-750 - Refer to chapter 3 System Overview **[** Open **]**

4.1.2 FDFT Train Length

Referring to Figure 3, the Train Length Determination system **shall** consist of two independent channels A and B developed according to applicable (at least) SIL2 requirements.

Additionally, the Train Length Determination System **shall** include a Train Length Merging Function TLMF developed according to applicable SIL4 requirements (including all the requiremets/functions attributed to TLMF itself in this chapter).

Channel A and Channel B **shall** consist respectively of one SIL2 TLFA Train Length Function A and TLFB Train Length Function B per each consist in the FDFT, and respectively of one SIL2 TLMA Train Length Master A and one TLMB Train Length Master B on the Leading Traction Unit.

Per each consist, TLFA and TLFB **shall** store static data related to said consist length information and ID information cryptographically secured/hashed with SIL4 CRC

Per each consist in the FDFT, each DAC **shall** be equipped with a SIL2 independent Last Coupler Detection Function A LCDFA and a SIL2 independent Last Coupler Detection Function B LCDFB, connected respectively to the TLFA and TLFB of said each consist, said LCDFA and LCDFB providing antivalent signals.

Each LCDFA and LCDFB **shall** detect and report, to the respective TLFA and TLFB, the COUPLED status when it detects to be coupled with the correspondent DAC of an attached other consist's DAC, and the UNCOUPLED status when it detects not to be coupled with another attached consist's DAC.

Per each consist, the TLFA and TLFB **shall** permanently store the corresponding consist ID and consist length

The process of consist ID and consist length storage for the TLFA and TLFB **shall** be independent according to presentation 1 outcome.

During the FDFT initialization phase each TLFA and TLFB **shall** report to the respective TLMA and TLMB the associated consist ID and consist Length.

During the FDFT initialization phase, and then with a periodicity corresponding to the Train Integrity status refresh, that is at least one second, each TLFA and TLFB **shall** report to the respective TLMA and TLMB the COUPLED/UNCOUPLED status of the associated two LCDFA and two LCDFB.

During the FDFT initialization phase each TLFA and TLFB **shall** report to the respective TLMA and TLMB the detection of passive consists in the FDFT.

Per each consist in the FDFT, each TLFA and TLFB **shall** encapsulate the consist length information, consist ID information, LCDF COUPLED/UNCOUPLED status information, passive consist detection information into messages including SIL2 header (CRC, message ID, message counter and length) according to EN50159, for delivery to the respective TLMA and TLMB.

According to the reception time period, TLMA and TLMB **shall** forward the messages received by the respective TLFAs and TLFBs, including the associated SIL2 header generated by said TLFAs and TLFBs, to the TLMF.

TLMF **shall** verify the consistency of every received message against the associated SIL2 header.

In positive messages consistency verification case, TLMF **shall** verify the presence of "passive consist" in the FDFT.

In presence of "passive consist" in the FDFT, TLMF **shall** report a "not valid train length" message to the ETCS.

In absence of "passive consists" the TLMF shall verify the consistency of the COUPLED/UNCOUPLED status of the LCDFs and the associated identification of the "last consist" in the FDFT.

If consistency of the COUPLED/UNCOUPLED status of the LCDFs is not verified or "last consist" not identified, TLMF **shall** report a "not valid train length" message to the ETCS .

In positive verification cases, TLMF **shall** calculate the total FDFT train lengths TLA and TLB derived from the individual consist lengths provided respectively by TLMA and TLMB and verify the equality between TLA and TLB with the tolerance defined by CCS

If the equality between TLA and TLB, with a given tolerance is verified, TLMF **shall** report the FDFT train length TL to the ETCS according to CCS TSI V4.0 Subset-034 (chapter 2.6.2).

The TLMF **shall** interface with the ETCS onboard following the definition from ETCS Subset S-119* / S-147/V2

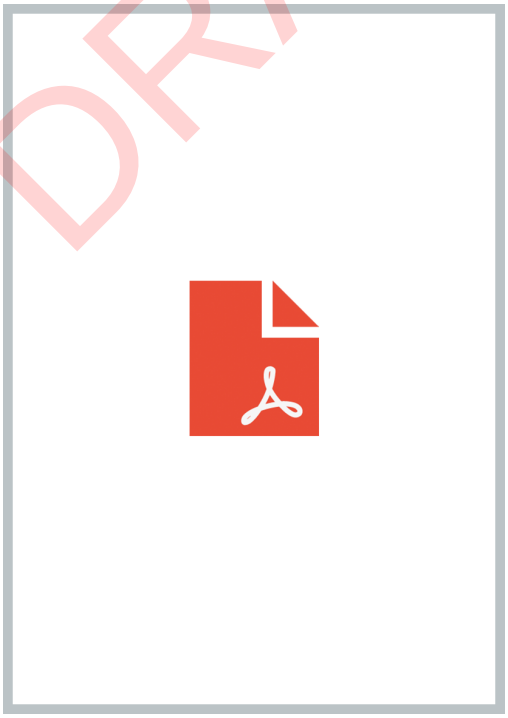
The complete process of Train Lenght determination and release to onboard ETCS **shall** be completed within the FDFT initialization process.

5 Appendix

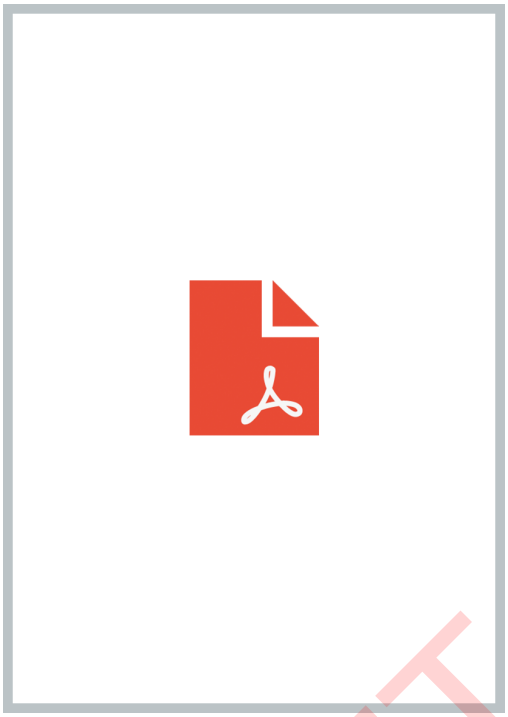
5.1 Input documents

Reference to FP5 delivery document D5.1

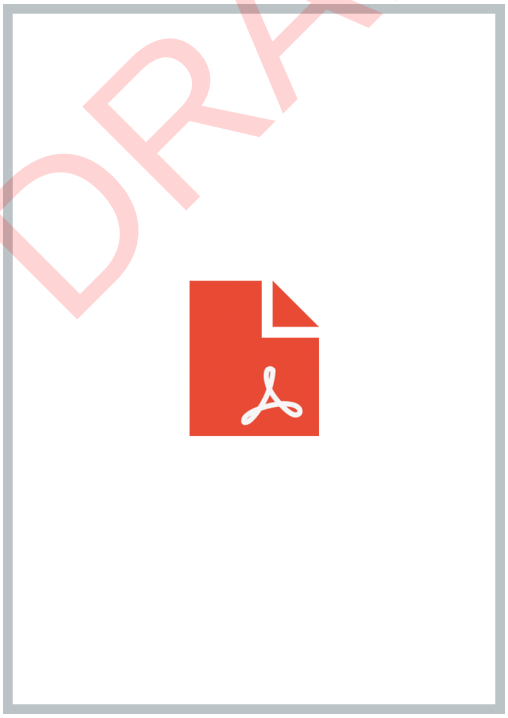
Reference to FP5 delivery document D5.4



Presentation 1 Is merging of 2 SIL2 systems outputs results in a SIL4 system output



Presentation 2 Train length concept working document



Presentation 3 250701 - Localisation and interfaces of TLMF - workshop decision