System Requirements Specification_Train Integrity and Train Length_Part A WP3_1

Abstract	The purpose of this document is to specify on a high-level the system requirements, functional requirements and interfaces that are planned to be fulfilled in order to provide an interoperable "Safe Train Length Determination" and "Train Integrity Status Determination" within the FDFTO Train Functions. This requires a consolidated implementation plan with aspects of - Time, Cost/Financing, Migration and Authorization Planning
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1 Preamble

1.1 Purpose

SPT4DAC-700 - The purpose of this document is to specify on a high level the system requirements, functional requirements and interfaces that must be fulfilled in order to provide an interoperable "Safe Train Length Determination" and "Train Integrity Status Determination" within the FDFTO Train Functions.

SPT4DAC-697 - It defines the following:

- a) Use of a two independent SIL2 channels approach to reach an overall SIL4 train length information)
- b) Train Length Merging Function (TLMF) to determine a SIL4 train length information
- c) Train Integrity Monitoring Function to determine a (at least) SIL2 train integrity status information
- *Note: SIL4 should be achieved, when two independent channels are likewise used to determine the train integrity status or if the train integrity status is determined based on the train length information or last coupler information.*
- d) Use of FDFTO train functions (such as Last Coupler Detection (LCD), Train Composition Detection and Passive Consist Detection (PCD)) as described in FP5-TRANS4M-R D5.1 "Functional Requirements Specification of Train Functions"
- e) The related FDFTO system architecture, including the definition of all relevant interfaces.

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. Further specifications and developments, incl. FRS and SRS for the FDFTO system are in scope of FP5.

SPT4DAC-1060 - Further adaptations, corrections and extensions of the document could be required and necessary after implementation and demonstration of a suitable technical solution in FA5, e.g. in wave 2 and wave 3.

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 to increase capacity on existing lines.

SPT4DAC-694 - To run trains under such conditions, a Train Length and confirmed Train Integrity Status is required to determine the Confirmed Train Length by ETCS on-board.

SPT4DAC-696 - Using the deployment of DAC as enabler, the Train Functions of FDFTO provide the necessary basis to achieve such a Train Length Determination and Train Integrity Status Determination fo r loco-hauled freight trains.

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

SPT4DAC-1061 - The sector strongly recommends to implement "Safe Train Length Determination" and "Train Integrity Status Determination" avoiding the involvement of existing/new wayside system, fully relying only on on-board FDFT systems/subsystems

SPT4DAC-1064 - The sector strongly recommends not to involve the Driver or any other human-being Operator in possible actions applied to implement "Safe Train Length Determination" and "Train Integrity Status Determination" and/or to achieve the requested safety level. Driver or any other human-being Operator intervention could be admitted in specific degraded operational use cases (which definitions are not in the scope of this document) as mitigation option.

SPT4DAC-1026 - The ETCS on-board reactions to the information provided by the TLMF is out of scope of the document.

SPT4DAC-1048 - The potentially required standardization and related CRs to the CCS TSI 2023, resulting from specifications in this document, are out of scope of the document.

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

SPT4DAC-873 - In addition, the determination of the "Overall consist length" to support Supervised Manouevre (SM) is considered.

SPT4DAC-869 - "Train Integrity Monitoring" and determination of the "Train Integrity Status Information" is considered to enable the determination of the "Confirmed Train Length" by the ETCS on-board.

SPT4DAC-875 - In the following described architecture, it is intended that the Train Length Merging Function (TLMF) is used, to determine the "Train Integrity Status" periodically with a sufficient Safety Level.

SPT4DAC-1041 - At system level, SIL4 safety level should be achieved, in relation to hazards associated with undetected changes in the train composition.

SPT4DAC-1042 - Solely for unintended train separation, the CCS TSI 2023 considers that a SIL2 train integrity monitoring function is sufficient if there is a sufficiently low probability of coupling failure, as a hazardous situation occurs only if the monitoring function fails (i.e. erroneously confirms the train integrity) when there has also been a failure of the coupling (see CCS TSI S-091 v4.0.0 and CCS TSI S-120 v4.0.0).

SPT4DAC-1040 - Note: For intentional uncoupling scenarios, failure of the coupling is not a relevant mitigation, and therefore another independent mitigation would be necessary to meet the required SIL4 at system level, if the integrity monitoring function alone fulfils only SIL2. This does not necessarily mean that the train integrity monitoring function alone must fulfil a SIL4 safety level. It is assumed that a "Train Integrity Status" with SIL4 safety level could be achieved by the TLMF when two independent SIL2

channels are used as input.

SPT4DAC-1021 - *Note: SIL4 should be achieved, when two independent channels are likewise used to determine the train integrity status or if the train integrity status is determined based on the train length information.*

SPT4DAC-872 - The scope of the document is limited to ETCS supervised areas, e.g. excluding hump shunting within a shunting yard etc.

1.4 Open Points

SPT4DAC-1047 - The document is requiring an overall consist length information with SIL4. However, this is exceeding the current SIL2 required by the CCS TSI S-091 v4.0.0.

SPT4DAC-1006 - N*ote: CCS TSI S-091 v4.0.0 states, that if SIL2 is not sufficient for the intended operation, project specific higher requirement can be required by RINF*. A SIL2 Overall Consist Length information would restrict the area of use of the train if SIL4 is required by RINF.

SPT4DAC-1049 - All numerical values required for accuracy, latency, tolerances etc. in the document are proposal for the FDFT and should be verified based on implementation of the FDFT in FP5 for the suitability and technical feasibility.

SPT4DAC-1059 - All numerical values required for accuracy, latency, tolerances etc. in the document, which are defined for the interface between TLMF and ETCS on-board should be subject to standardization and subsequent CRs, if necessary.

SPT4DAC-1058 - CRs and adaptation of the TSI CCS 2023 are out of scope of this document.

SPT4DAC-1051 - The sufficient safety of a SIL2 message header (CRC, message ID, message counter and length) for the overall SIL2 of each channel information (e.g. summing up to 100 value per channel from 100 wagons) should be evaluated by a safety analysis.

SPT4DAC-1052 - The measurement accuracy of the min., nom. and max. vehicle length determined for each vehicle has to be derived and defined based on the accuracy of the train length and the accuracy of the Overall Consist Length of the entire train as well as the max. allowable number of vehicles.

SPT4DAC-1053 - The initialization of the FDFT, incl. the TLMF, is out of scope of this document.

SPT4DAC-1054 - It is assumed, that using the larger value of the two max. train length value of either channel TLMA or TLMB is sufficiently safe with regards to the real maximum physical length. It has to be evaluated, if it is required to use the maximum length provided by each vehicle in a pairwise comparison to add up always the larger value.

SPT4DAC-1055 - Is not defined yet, how the proposed periodicity of 200ms and the eventually longer determination duration or age of the train integrity confirmation should be handled. Subject to discussion and standardization in scope of Moving Block operations and CCS on-board and trackside, if intermediate unknown status is reported, if no train integrity confirmed is determined in the meantime or if reporting is only done, once confirmed is determined.

SPT4DAC-1056 - The interface definition between TLMF and ETCS on-board, incl. the definition of the train length value message for validity and the definition of messages for all information exchanged, should be defined in Task 2 Interface Specification and is out of scope of the document.

1.5 Glossary

1.5.1 Terms

FDFTO: Full Digital Freight Train Operations
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.

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

FDFT Train Backbone Communication Network Black Channel
A train wide communication network is implemented in the FDFT, which is considered a black channel. 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".
Note: 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 IEC EN 61748-3-3.

The Train Length Merging Function (TLMF) receives information from TLM-A and TLM-B.

SPT4DAC-951 - The 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 on-board.

SPT4DAC-955 - At least following checks are required:

- The vehicle lengths received from each vehicle on channel TLM-A and TLM-A are equal or within a max. tolerance per vehicle
- Train length A (TLM-A) is equal or within a max. tolerance to Train length B (TLM-B)
- List of vehicle IDs on channel A is equal to List of vehicle IDs on channel B
- No passive consists are present in either channel TLM-A or TLM-B
- The last coupler are identified as uncoupled, and there are no other open coupler detected within

the train

SPT4DAC-954 - Once the checks are passed for the first time, during the train inauguration, the TLMF shall send the train length to the ETCS on-board and then starting a continuous monitoring of the information consistency.

SPT4DAC-948 - The TLMF shall inform the ETCS on-board when the train length information is not known, no more available or invalid (e.g., the information is not coming from one channel, there is a misalignment between the two channels, etc.).

A passive consist is a consist, which is at least mechanically (and may be electrically coupled or not electrically coupled), but is not initialized or not present, or communicating via the train backbone communication network as intended.
The Passive Consist Detection function determines the presence of a passive consist on any neighboring side of both couplers of a wagon or vehicle. The Passive Consist Detection evaluates on each channel independent information to report the presence of any (one or more passive consists) to the TLMF.

LCDF: Last Coupler Detection Function

SPT4DAC-883 - The LCDF determines the (mechanical or electrical) coupling state of both couplers of a wagon or vehicle.

SPT4DAC-958 - The LCDF evaluates on each channel independent information to report the coupler states to the TLMF, e.g. coupled or uncoupled.

Train Integrity Status Information

SPT4DAC-885 - After the initial determination of the train length, and initial confirmation of train composition and train completeness (train integrity confirmed), the TLMF can monitor the integrity of the train (Train Integrity Status Information) periodically

SPT4DAC-904 - Train Integrity status is periodically determined and provided.

SPT4DAC-940 - The train integrity status can be determined as confirmed, unknown or lost.

SPT4DAC-907 - Train Integrity status may be determined based e.g.

SPT4DAC-1023 - a) on unchanged train length

SPT4DAC-1022 - b) unchanged last vehicle ID

SPT4DAC-1024 - c) unchanged last coupler information.

Train Length

SPT4DAC-881 - The train length information can be determined by the TLMF and provided as input for the train length (ERTMS/ETCS SRS [SS026] 7.5.1.56 L_TRAIN) to the ETCS on-board.

SPT4DAC-906 - *Note: A SIL4 train length should be determined using two independent channels.*

SPT4DAC-890 - The TLMF can determine a possible unintended coupling and un-coupling of the train as well as an intended change of the train length due to shunting or coupling manoeuvres based on the FDFT functions.

SPT4DAC-902 - *Note: according to SS-034 2.6.2.4.2: "The vehicle shall provide an updated train length following a change in the train composition". Consequently, after splitting and joining operations, the resulting changed train length information is determined with a sufficient safety level. This implies a reliable and sufficiently safe detection of coupling and uncoupling events (e.g. by technical means in replacement of only operational procedures).*

SPT4DAC-901 - *Note: The safe detection of coupling and uncoupling events may also be realized by a sufficiently safe train integrity monitoring function (SIL4) or last coupler detection function.*

SPT4DAC-903 - *Note: SIL4 should be achieved for the safe detection of coupling and uncoupling events, when two independent channels are likewise used to determine the train integrity status or if the train integrity status is determined based on the train length information.*

1.5.2 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
TLFB	Train Length Function of channel B
TLMA	Train Length Master of channel A (in leading traction unit)
TLMB	Train Length Master of channel B (in leading traction unit)

Abbreviation/Acronyms	Description
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 Train Length assumptions

SPT4DAC-923 - For each vehicle, three values for its vehicle length, the minimal, nominal and maximal length are determined for each channel and are individually, statically and permanently stored on the vehicle on separate devices.

SPT4DAC-1017 - Each vehicle reports its minimal, nominal and maximal vehicle length for each channel to the TLMF using the FDFT train functions.

SPT4DAC-1016 - The Train Length (e.g. L_TRAIN as part of the train data) represents the maximal physical length of the train based on the maximal vehicle length reported by each vehicle.

SPT4DAC-921 - *Note: This means the length of the train at maximum extension, if the train can stretch and contract.*
The maximal vehicle length reported by a vehicle is including the maximum extension of its couplers. For coupled couplers, the distance from coupling plane to coupling plane should be considered. For the train length, the TLMF considers parts of the coupler that extend beyond the coupling plane for the open couplers.

SPT4DAC-927 - The Train Length of the entire train is determined with an accuracy within defined max. limits.

SPT4DAC-925 - *Note: the accuracy of the train length value for the train should be subject to standardization.*

SPT4DAC-917 - Train Length is determined during train inauguration or FDFT initialization for the entire train composition.

SPT4DAC-919 - The Train Length is valid until a change of train length value or train composition (e.g. coupling, uncoupling or train separation).

SPT4DAC-920 - *Note: Train length may be periodically validated or (re-)determined (e.g. if no coupling or uncoupling detection function is implemented or to determine the train integrity status).*

SPT4DAC-918 - Any (intended or unintended) change of train length or train composition is detected.

SPT4DAC-922 - Any change of train length or train composition invalidates the previously known train length and trigger redetermination of the train length.

SPT4DAC-1045 - *Note: In this case, the TLMF provides the train length invalid information and subsequently the updated train length to the ETCS on-board.*

SPT4DAC-928 - A periodical self-test and dedicated test function is required to verify the correct and fault-free system functionalities of the train length determination.

2.2 Train Integrity assumptions

SPT4DAC-936 - Determination of Train Length is required before confirmation of train integrity status.

SPT4DAC-939 - Train Integrity status is determined periodically afterwards.

SPT4DAC-938 - Train Integrity status is determined with regard to a reference time.

SPT4DAC-930 - Train Integrity status confirmed age is depending on communication duration, transmission time, periodicity, and processing or determination time of the train integrity determination function.

SPT4DAC-929 - This overall max. latency is limited to an upper bound.

SPT4DAC-932 - *Note: the latency of the train integrity determination should be subject to standardization.*

SPT4DAC-931 - In case of train length change, coupling or uncoupling manouevre, train integrity status lost is determined.

SPT4DAC-933 - After last confirmation of train integrity, if reporting from TLMF to ETCS on-board is due by cycle time, and if no information is available or is unknown, the train integrity status is determined and reported as unknown.

SPT4DAC-935 - Train Integrity status lost is determined, if a train integrity loss is detected or after change of train length or train composition.

2.3 Overall Consist Length assumptions

SPT4DAC-702 - The overall consist length information consist of 6 values as defined in CCS TSI S-034 v4.0.0.

SPT4DAC-946 - The TLMF determines consist length on both sides of active locomotive/traction unit/cab.

SPT4DAC-945 - *Note: The concept described in this document 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".*

SPT4DAC-943 - The TLMF calculates minimal, nominal and maximal overall consist lengths based on minimal, nominal and maximal vehicle lengths of each vehicle by received by FDFT train functions.

SPT4DAC-942 - An analysis and deterministic evidence should be conducted and the margins should be standardized for max. and min. values defined and guaranteed by suppliers according to mechanical DAC specifications.

SPT4DAC-944 - *Note: according to a first estimation of 100 wagons and draft gear category L for 12.04m wagons (Hbbillns)*

- *the stretch is within the range of +1.3% or max. stretch of 160mm per vehicle*
- *the compression is within the range of -3.0% or max. compression of 356mm per vehicle*
- *a maximum of 100 vehicles is assumed for the train (this would require an intermediate loco after 50 vehicles)*
- *a maximum for 50 vehicles is assumed in front or rear of each single locomotive*

2.4 Safe architecture assumptions

SPT4DAC-705 - According to CCS TSI S-091 v4.0.0 EXT_SR07, the Confirmed Train Length sent in the position report shall be of a quality corresponding to SIL4.

SPT4DAC-947 - For this purpose, a SIL4 train length information (L_TRAIN) and at least SIL2 Train Integrity (Q_INTEGRITY) information are required.

SPT4DAC-949 - Thereby, CCS TSI S-091 v4.0.0 EXT_SR07 implicitly mandates a SIL4 requirement for the train length information.

SPT4DAC-1015 - All information transmitted by the vehicles shall include a SIL2 attached certification overhead (e.g. CRC, message ID, message counter and length etc.).

SPT4DAC-704 - One possible solution is based on having a SIL4 function on every vehicle belonging to the FDFT, said SIL4 function responsible to transmit the vehicle IDs and lengths of the said vehicle with every vehicle lengths to a SIL4 central unit in the leading locomotive, where the total train length is then calculated and passed to the ETCS on-board.

SPT4DAC-950 - 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.

SPT4DAC-953 - An alternative solution has been chosen according to the principle shown in Figure 1

and hereafter described:

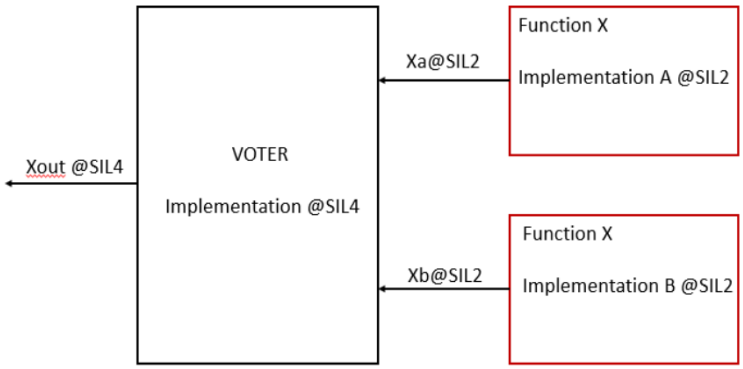


Figure 1

SPT4DAC-707 - 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.

SPT4DAC-706 - 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 respective "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 Figure 1 can be modified according to Figure 2. The safety level of the communication channel can be limited at Basic Integrity pending the EN50159 and EN50176 is respected, providing the proper error detection coding, according to SIL2, to the Xa and Xb information.

SPT4DAC-1044 - *Note: the scope and specifications in this document are assuming the architecture shown in figure 2 with a joint communication channel.*

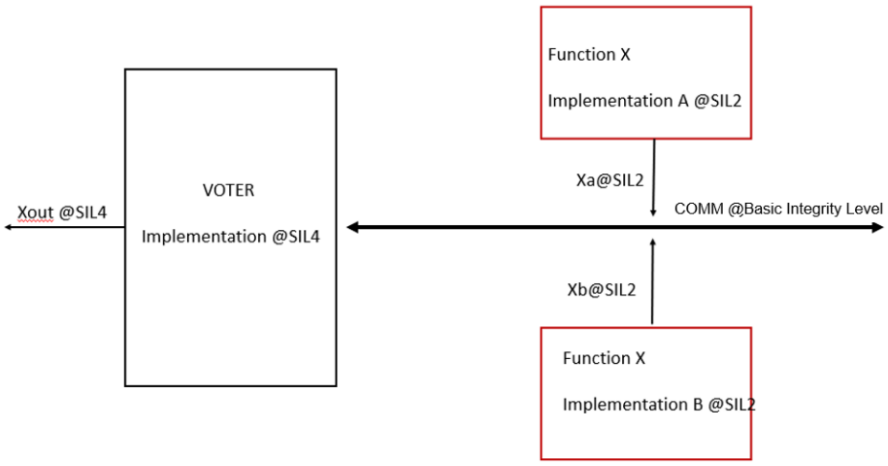


Figure 2

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.

SPT4DAC-871 - The architecture is based on a full “on board train” Train Length determination, avoiding involvement of external-to-train systems (wayside, yard), allowing the FDFT to determine the Train Length in any moment, including uncoupling/coupling outside the shunting yard area.

3.2 System interfaces

3.2.1 Interface to ETCS on-board

SPT4DAC-717 - According to figure 4, the Train Length system, in particular the Train Length Merging Function TLMF will interface with the ETCS on-board following the definition from CCS TSI S-119 v4.0.0* / CCS TSI S-147 v4.0.0*.

SPT4DAC-1014 - *Note: For system coherence regarding the data exchanged with ETCS on-board the interface may be standardized in the new version of Subset-147*.*

SPT4DAC-1013 - *Note*: **the next version of Subset-119/Subset-147 is expected to allow the provision of SIL4 data.*

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 (refer to figure 4) is scope of specification of the FP5 TRANS4M-R project.

3.3 System description

3.3.1 FDFT architecture

SPT4DAC-712 - Figure 3 extends the concept described in Figure 2 to the real FDFT architecture:

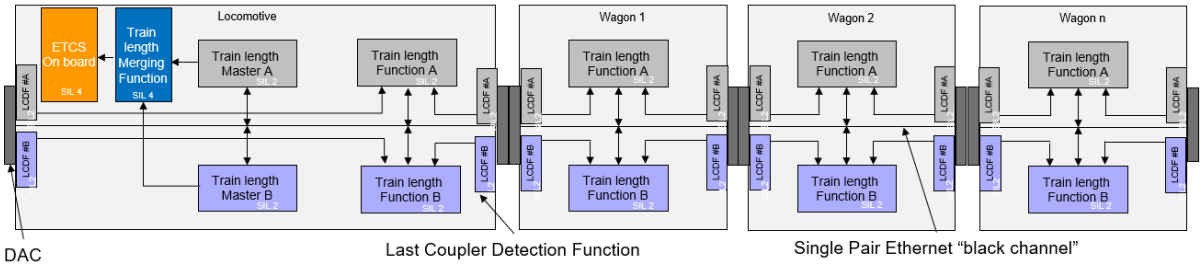


Figure 3

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”
- *Note: The active cab information may be used from ETCS on-board, this is not in scope of the document.*

SPT4DAC-718 - Each FDFT vehicle (vehicles, either locomotive or wagons) is equipped with two independent LCDF (Last Coupler Detection Function) at each vehicle extremity, each LCDF consisting of an independent sensing function and respectively connected to TLFA Train Length Function A and TLFB Train Length Function.

3.3.2 LCDF - TLFA and TLFB

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.

SPT4DAC-957 - The combination of information provided by the independent LCDFs to the TLFA and TLFB is used by the TLMF to identify the existence and ID of the Last Wagon in the train.

SPT4DAC-956 - *Note: Two 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).*

SPT4DAC-963 - The TLMF using the LCDF is able to identify and determine the last vehicle at the very end of a train (Tail). This is based on available input information, e.g. the coupling status (e.g. tail vehicle coupled on one side only and last coupler remaining open).

SPT4DAC-965 - *Note: The presence of the last vehicle and the unchanged open coupler status can be periodically monitored and evaluated to confirm train integrity or determine train integrity as lost.*

3.3.3 Train Length - TLMA and TLMB

SPT4DAC-959 - TLMA and TLMB are in charge:

- to receive messages from each vehicle (said messages consisting of the vehicle ID, the minimal, nominal and maximal length, the both couplers LCDFs status, the message header incl. CRC, message ID, message counter and message length) respectively from Channel A and Channel B.
- to forward the received vehicle messages, unmodified and unaltered, to the TLMF Train Length Merging Function.
- to detect the presence in the train of "passive consists" (one or more vehicles 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.

3.3.4 TLMF

The TLMF, corresponding functionally to the Voter in Figure 2, is in charge:

SPT4DAC-1029 -

- to verify the consistency of each vehicle data vs the respective attached certification overhead (e.g. CRC, message ID, message counter and length etc.)
- 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 pairwise comparison of each vehicle length present in CH A and CH B and are equal or within a tolerance
- *Note: the tolerance of the overall train length and subsequently each vehicle length information should be subject to standardization*
- in positive case, and in absence of "passive consists" to report the Train Length, encapsulated into a message with associated SIL2 overhead according to EN 61748-3-3 , to the ETCS on-board.
- to periodically verify the unchanged ID of the last vehicle or the last coupler. This function should be repeated with the periodicity according to the Train Length or Train Integrity cycle time.
- determine the train integrity status, e.g. using unchanged train length information, or unchanged ID of the last vehicle or unchanged information of FDFTO last coupler detection function

SPT4DAC-1028 - According to CCS TSI S-091 v4.0.0 EXT_SR08, train integrity information shall be provided with at least SIL2 quality.

SPT4DAC-1031 - *Note: SIL4 should be achieved, when two independent channels are likewise used to determine the train integrity status or if the train integrity status is determined based on the train length information.*

SPT4DAC-1030 - The maximum duration of each cycle of the train integrity status determination should be 200ms according to CCS TSI S-119 v4.0.0.

SPT4DAC-1027 - The maximum age of the time (t), when the train integrity was last determined, e.g. incl. the cycle time, number of confirmations, the latency for determining and transmitting the information by the FDFT functions, the processing time of the TLMF, the latency of transmitting the train integrity status (Q_INTEGRITY) by the TLMF to the ETCS on-board etc., should be limited to one second or less.
Note: This age (t) of the train integrity status should be subject to standardization.

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.

SPT4DAC-966 - *Note: Presentation 2 SPT4DAC-722 - Presentation # Train length concept working document 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).*

SPT4DAC-749 - *Note: Concerning the implementation of the Train Length Merging Function, workshops have been taken with System Pillar Task2 and FP2, about the opportunity to integrate the TLMF into the ETCS on-board, 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 analysis is available and reported into presentation 3 SPT4DAC-727 - Presentation # 250701 - Localisation and interfaces of TLMF - workshop decision .

SPT4DAC-716 - According to decisions commonly taken with SP-T2 and FP2, the final decision is shown

hereafter in Figure 4.

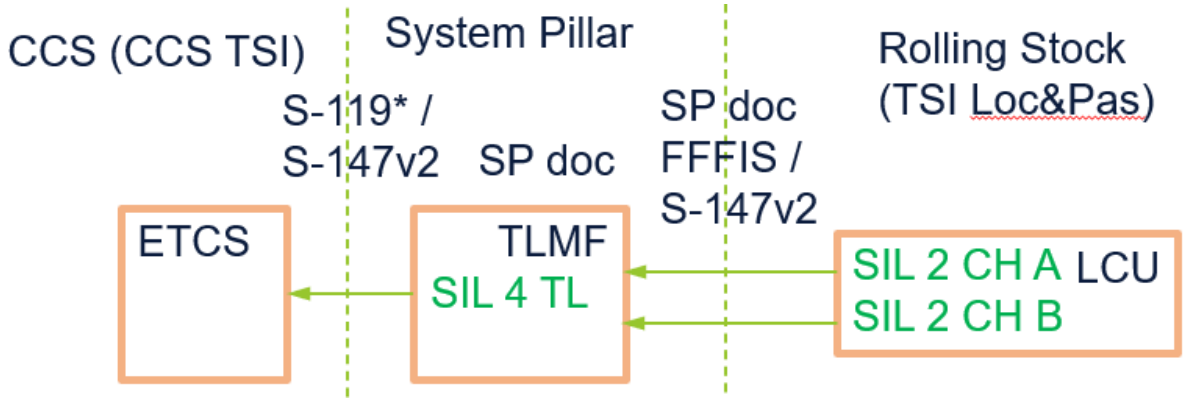


Figure 4

3.3.5 Overall consist length

SPT4DAC-970 - The Overall Consist Length is consisting of the following six lengths, three (minimal, nominal and maximal) of the consist in front and three (minimal, nominal and maximal) of the consist in rear of the engine, excluding the engine length.

SPT4DAC-969 - *Note: The maximum, and minimum overall consist lengths are determined by the TLMF for the entire train, while each minimal, nominal and maximal vehicle length are three static values reported from each vehicle by FDFT functions:*

- *the maximum vehicle length is when the springs of the couplers on both sides are extended to their maximum length.*
- *the nominal vehicle length is when the wagon is standing free without any constraints.*
- *the minimum vehicle length is when the springs of the couplers on both sides are compressed to their minimum length.*

SPT4DAC-972 - The TLMF determines these six values of the overall consist length information using the minimal, nominal and maximal vehicle length received from the FDFT.

SPT4DAC-973 - *Note: SIL4 should be achieved for the Overall Consist Length, when two independent channels are likewise used to determine the train length information and a TLMF SIL4 function is used to determine the six values based on the SIL4 train length.*

3.3.6 Train Integrity

SPT4DAC-975 - The TLMF is periodically determining the integrity status of the entire train.

SPT4DAC-1043 - Note: The TLMF is determining the integrity using the inputs from FDFT functions, if it consists of several (two or more) vehicles. If the train is running as single loco, TLMF confirms that no vehicles are attached to confirms its own integrity to the ETCS on-board.

SPT4DAC-976 - If the integrity of the train cannot be confirmed (e.g. the information about the integrity of the train is not available or the train integrity is lost), corresponding information is generated and provided in time.

SPT4DAC-977 - The TLMF is providing an output with the information that:
a) the integrity of the train is confirmed or
b) the integrity of the train has been lost if an intentional or unintentional train separation occurs, or
c) the integrity of the train is unknown if the integrity of the train cannot be confirmed and no train separation has been detected.

SPT4DAC-978 - The train integrity status can only be confirmed if the train length has been safely determined previously.

4 System requirements

4.1 Functional requirements

4.1.1 Optional: Functional overview

SPT4DAC-750 - Refer to chapter 3 System Overview.

4.1.2 Train Length requirements

Referring to **SPT4DAC-1061**, "Safe Train Length Determination" implementation **shall** avoid the involvement of existing/new wayside systems, fully relying only on on-board FDFT systems/subsystems.

Referring to **SPT4DAC-1064**, the Driver or any other human-being Operator **shall not** be involved in possible actions applied to implement "Safe Train Length Determination" and/or to achieve the requested safety level.

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 requirements and 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 SIL2 TLMB Train Length Master B on the Leading Traction Unit.

Per each vehicle, TLFA and TLFB **shall** store static data related to said vehicle length information, incl. the minimal, nominal and maximal vehicle lengths, and ID information cryptographically secured and hashed with SIL4 CRC.

Per each vehicle 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 vehicle in the FDFT **shall** be equipped with a SIL2 independent Passive Consist Detection Function A PCDFA and SIL2 independent Passive Consist Detection Function B PCDFB, connected respectively to the TLFA and TLFB of said each vehicle, said PCDFA and PCDFB in charge to detect a possible connected consist unable to communicate.

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 vehicles DAC, and the UNCOUPLED status when it detects not to be coupled with another attached vehicles DAC.

Per each vehicle, the TLFA and TLFB **shall** permanently store the corresponding vehicle ID and vehicle lengths.

The process of vehicle ID and vehicle length storage for the TLFA and TLFB **shall** be independent according to presentation 1 SPT4DAC-710 - Presentation # Is merging of 2 SIL2 systems outputs results in a SIL4 system out... outcome.

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

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 vehicle in the FDFT, each TLFA and TLFB **shall** encapsulate the vehicle lengths information, vehicle 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 on-board.

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 vehicle" or "Last coupler" in the FDFT.

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

In positive verification cases, TLMF **shall** calculate the total FDFT train lengths TLA and TLB derived from the individual vehicle lengths provided respectively by TLMA and TLMB

The TLMF shall verify if the equality of the train length between TLA and TLB is within the tolerance.

> **SPT4DAC-1039 -** *Note: the acceptable tolerance of the train length value between TLA and TLB should be subject to standardization* .

In case of a tolerable difference of the train length determined between TLA and TLB within the acceptable tolerance, the larger value **shall** be considered as train length TL.

In case of a difference of the train length determined between TLA and TLB exceeding the acceptable tolerance, TLMF **shall** report a "not valid train length" message to the ETCS on-board.

TLMF **shall** report a "not valid train length" message to the ETCS on-board.

If the equality between TLA and TLB, with a given tolerance is verified, TLMF **shall** report the FDFT train length TL to the ETCS on-board according to CCS TSI S-034 v4.0.0 chapter 2.6.2.

> **SPT4DAC-1018 -** *Note: The reported Train Length TL represents the maximal physical length of the train based on the maximal vehicle length reported by each vehicle.*

The TLMF **shall** interface with the ETCS on-board following the definition from CCS TSI S-119 v4.0.0* / C CS TSI S-147 v4.0.0/V2.

The complete process of Train Length determination and release to ETCS on-board **shall** be completed within the FDFT initialization process.

The individual vehicle lengths, related to the Channel A and Channel B, **shall** be derived from different independent sources.

The TLMF **shall** have a dedicated test function, which enables to verify the correct and fault-free system functionalities of the train length determination.

The TLMF **shall** determine a change of train composition (e.g. last coupler or last vehicle) or a change of train length with SIL4.

If there is an intended change in the train configuration (coupling or uncoupling), the TLMF **shall** determin e the resulting changed train length.

The train length **shall** be determined by the TLMF with an error of less than. *-0 m to max. +1 m* between the determined overall train vs. the physical maximum real length of the train.

The train length **shall** be rounded up to the nearest integer value.

SPT4DAC-979 - *Note: the accuracy of the train length value should be subject to standardization*.

4.1.3 Train Integrity requirements

Referring to **SPT4DAC-1061**, "Train Integrity Status Determination" implementation **shall** avod the involvment of existing/new wayside systems, fully relying only on on-board FDFT systems/subsystems.

Referring to **SPT4DAC-1064**, the Driver or any other human-being Operator **shall not** be involved in possible actions applied to implement "Train Integrity Status Determination" and/or to achieve the requested safety level.

The TLMF **shall** determine the integrity status of the entire train.

The TLMF **shall** determine the train integrity at Start of Mission and periodically afterwards during train operation.

The TLMF **shall** provide an output with the train integrity information (confirmed, unknown or lost) to the E TCS on-board.

The TLMF **shall** determine the Train Integrity status based on information provided by the FDFT functions.

Train Integrity **shall** be determined periodically, after initial determination of train composition and completeness.

A Train Integrity status **shall** consider time and latency, transmitted to ETCS on-board of the time when the train integrity was reported.

If Train Integrity can not be confirmed, or the train integrity status is not available or known, it **shall** be reported as unknown.

The Train integrity **shall** be reported as lost, if this information is determined by the TLMF using the FDFT functions.

If there is an intended change in the train configuration (coupling or uncoupling), the TLMF **shall** determin e the train integrity status lost.

SPT4DAC-992 - *Note: The probability of occurrence of an unintended loss of train integrity (e.g. train separation due to movement) is assumed with a THR of <= 2.61*10-6/h for passenger trains and with a THR of <= 6.98*10-5/h for freight trains [ERTMS/ETCS SRS [SS091] 10.3.2.10 Max. unexpected loss of train integrity].*

SPT4DAC-999 - *Note: For the FDFT mechanical part of the DAC, at least the equivalent rate is assumed and shall be demonstrated.*

The maximum duration of each reporting cycle of each train integrity status shall be 200ms or less according to CCS TSI S-119 v4.0.0.

The maximum age of the time when the train integrity was last determined, e.g. incl. the cycle time, number of confirmations, the latency for determining and transmitting the information by the FDFT functions, the processing time of the TLMF, the latency of transmitting the train integrity status (Q_INTEGRITY) by the TLMF to the ETCS on-board etc., **shall** not exceed *one* second.

SPT4DAC-1002 - *Note: This maximum age of the train integrity status should be subject to*

standardization.

The TLMF **shall** have a dedicated test function, which enables to verify the correct and fault-free system functionalities of the train integrity determination.

The overall train integrity monitoring function **shall** achieve at least SIL2.

SPT4DAC-988 - *Note: SIL4 should be achieved, when two independent channels are likewise used to determine the train integrity status or if the train integrity status is determined based on the train length information.*

4.1.4 Overall consist length requirements

The estimated max. expected stretch and compression of standardised DAC coupler **shall** be determined and to be considered to determine the minimal and maximal length for each vehicle based on its nominal length.

SPT4DAC-1005 - *Note: These values should be subject to standardization* within TSI Loc&Pas or wagons or similar standards (e.g. prEN 18171 (Railway applications — Railway rolling stock — Digital Freight Automatic Coupler).

For each vehicle, three values for its vehicle length, the minimal, nominal and maximal length **shall** be determined during installation and are statically and permanently stored on the vehicle.

On each channels TL CH A and TL CH B, each vehicle **shall** provide its minimal, nominal and maximal length to the TLM A and TLM B.

The TLMF **shall** determine the resulting minimal, nominal and maximal consist length in front and rear of the engine.

The TLMF **shall** provide the Overall Consist Length Information to the ETCS on-board, consisting of the lengths of the consists in front and in rear of the engine (including the engine length).

Overall consist length information **shall** achieve at least SIL4.

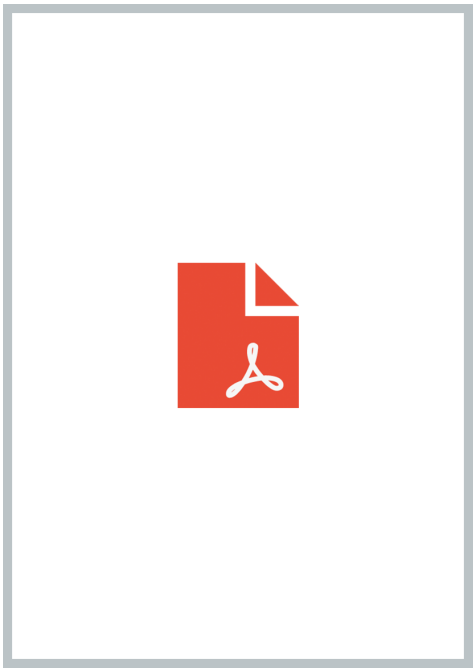
SPT4DAC-1008 - *Note: SIL4 should be achieved for the Overall Consist Length, when two independent channels are likewise used to determine the overall consist length information.*

5 Appendix

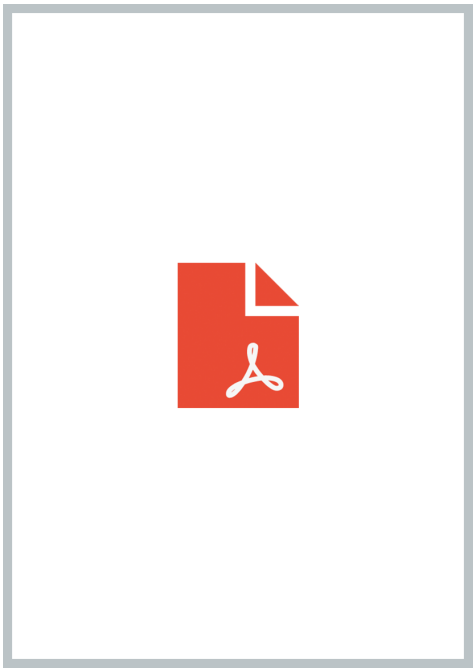
5.1 Input documents

Reference to FP5 delivery document D5.1

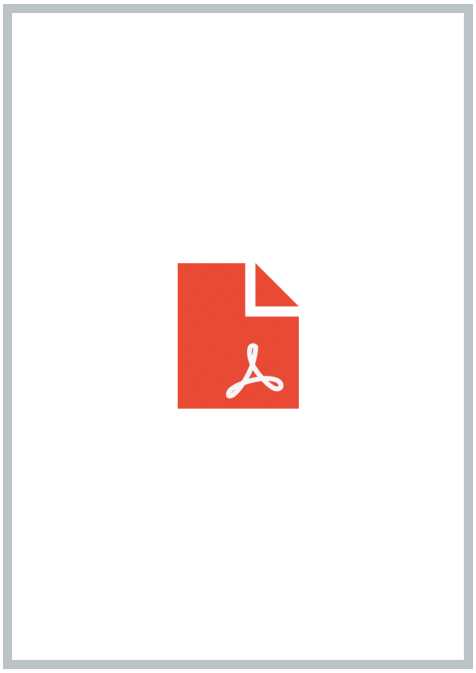
Reference to FP5 delivery document D5.4



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