

ERTMS/ETCS

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		analysis of serial transmission faults re-worked according to comment of Siemens; EBF analyses reworked, see RAMS WG comment	
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0.2.8	all	§3.3.1 and §5.1.4.4.1.1 changed according to comments of RAMS WG	FB, JM
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0.2.10	3.4.7, 4.4.7, 5.1.5.6, 6.1	Update according to changes in Subset-119 ed.	FB

	and sections on STM orders	0.1.13, i.e. TCO, solution 1 deleted and added analysis for STM orders	
0.2.11	all	Changes according to RAMS WG internal comments and SG comments	FB, JM



TABLE OF CONTENTS

1. INTRODUCTION	9
1.1 Purpose.....	9
1.2 References.....	9
1.3 Abbreviations and Glossary.....	10
1.4 Requirements Designation	11
1.5 Methodology.....	11
2. SYSTEM UNDER INSPECTION.....	13
2.1 Context.....	13
3. SINGLE FAULTS DESCRIPTION	15
3.1 General	15
3.1.2 Consideration of redundant and antivalent signals	15
3.1.3 Consideration of serial transmission faults	15
3.2 Description of the Hazardous Events of Mode Control	16
3.2.1 Sleeping	16
3.2.2 Passive Shunting.....	18
3.2.3 Non Leading	18
3.2.4 Isolation.....	19
3.3 Description of the Hazardous Events of Control of Brakes	19
3.3.1 Service Brake Command.....	19
3.3.2 Brake pressure	19
3.3.3 Emergency Brake Command	19
3.3.4 Special Brake Inhibit – Trackside Orders	20
3.3.5 Special Brake Inhibit – STM Orders	20
3.3.6 Special Brake Status	20
3.3.7 Additional Brake Status	20
3.4 Description of the Hazardous Events of Control of Train Functions.....	20
3.4.1 Change of traction system.....	20
3.4.2 Pantograph (Trackside orders / STM orders)	21
3.4.3 Air tightness (Trackside orders / STM orders)	21
3.4.4 Passenger door	21
3.4.5 Main Power Switch – Trackside orders.....	21
3.4.6 Main Power Switch – STM orders.....	21
3.4.7 Traction Cut-off	21



3.4.8	Change of allowed current consumption (ACC).....	22
3.5	Description of the Hazardous Events of Train Status Information.....	22
3.5.1	Cab status	22
3.5.2	Direction controller status	22
3.5.3	Train integrity	23
3.5.4	Traction Status	23
3.6	Description of the Hazardous Events of Train Data	23
3.6.1	Type of train data entry	23
3.6.2	Train data information	23
3.7	Description of the Hazardous Events of National System Isolation.....	23
3.7.1	National System Isolation	23
3.8	Hazardous Events Schedule ETCS on-board.....	24
3.9	Hazardous Events Schedule vehicle part	24
4.	MULTIPLE FAULTS EFFECTS DESCRIPTION	26
4.1	General	26
4.2	Description of the Fault Effects of Mode Control	26
4.2.1	Sleeping	26
4.2.2	Passive Shunting.....	29
4.2.3	Non Leading	30
4.2.4	Isolation.....	31
4.3	Description of the Fault Effects of Control of Brakes	31
4.3.1	Service Brake Command.....	31
4.3.2	Brake Pressure	31
4.3.3	Emergency Brake Command	31
4.3.4	Special Brake Inhibit – Trackside Orders	32
4.3.5	Special Brake Inhibit – STM Orders	32
4.3.6	Special Brake Status	33
4.3.7	Additional Brake Status	33
4.4	Description of the Fault Effects of Control of Train Functions	33
4.4.1	Change of traction system.....	33
4.4.2	Pantograph (Trackside orders / STM orders)	33
4.4.3	Air tightness (Trackside orders / STM orders)	33
4.4.4	Passenger door	33
4.4.5	Main Power Switch – Trackside orders.....	33
4.4.6	Main Power Switch – STM orders.....	33
4.4.7	Traction Cut-Off.....	34



4.4.8	Change of allowed current consumption.....	34
4.5	Description of the Fault Effects of Train Status Information.....	34
4.5.1	Cab status	34
4.5.2	Direction Controller status	35
4.5.3	Train integrity	35
4.5.4	Traction Status	36
4.6	Description of the Hazardous Events of Train Data	36
4.6.1	Type of train data entry	36
4.6.2	Train data information	36
4.7	Description of the Fault Effects of National System Isolation.....	36
4.7.1	National System Isolation	36
5.	CONCLUSIONS: REQUIREMENTS FOR TI.....	37
5.1	Interface Requirements	37
5.1.1	General Considerations.....	37
5.1.2	Periodic Self Tests	37
5.1.3	Signals for Mode Control	37
5.1.4	Signals for the Control of Brakes.....	39
5.1.5	Signals for the Control of Train Functions	42
5.1.6	Signals for Train status Information.....	44
5.1.7	Train Data	45
5.1.8	National System Isolation	45
5.2	Serial transmission	45
5.2.1	Example for serial input with two inputs.....	45
5.2.2	Architecture a).....	46
5.2.3	Architecture b).....	46
6.	ANNEX A – SAFETY ANALYSIS.....	48
6.1	FMEA	48
6.1.1	Objective	48
6.1.2	Assumptions.....	48
6.2	Fault Trees	91



1. INTRODUCTION

1.1 Purpose

- 1.1.1.1 This document defines the generic safety requirements for Train interface information relating ETCS operating in either Level 1 or Level 2. The figures given are the minimum that must be achieved in order to ensure that ERTMS/ETCS on-board equipment may be safely integrated in any interoperable vehicles.
- 1.1.1.2 The architectures, signals and implementation functions described in Subset-119 were the subject of the safety analysis.
- 1.1.1.3 Alternatively to the analysis described in this document, further safety analyses with other safety measures can be provided which may result in product specific safety requirements.
- 1.1.1.4 If the technical solutions of Subset-119 are applied for a specific product then the results of this Subset can be used in the product specific safety analysis without further examinations. If another solution is selected than specified in Subset-119 then a solution specific safety analysis shall be provided.

1.2 References

- 1.2.1.1 The following documents, part of TSI CCS Annex A, were consulted in the development in this document:
 - Railway applications – The specification and demonstration of reliability, availability, maintainability and safety (RAMS) EN 50126
 - Railway applications – Communication, signalling and processing systems – Safety related electronic systems for signalling EN 50129
 - Railway applications – Communication, signalling and processing systems EN 50159
 - System Requirements Specification Subset-026
 - FIS for the Train Interface Subset-034
 - Safety Requirements Subset-091
 - FFFIS for the Train Interface Subset-119
- 1.2.1.2 The following documents, not part of TSI CCS Annex A, were consulted in the development in this document:



		<u>Version</u>
• Causal analysis process	Subset-077	2.3.2
• TIU FMEA	Subset-080	3.0.12
• Functional Safety of Electrical/ Electronic/Programmable Electronic Safety- related Systems	IEC 61508	2010-04
• Industrial communication networks	IEC 61784-3	2010-06

1.3 Abbreviations and Glossary

1.3.1.1 In addition to the general UNISIG glossary, there are terms which are used in the following parts that benefit from defining as follows.

Information	Information is a datum which will be transmitted between a source and a receiver. This is independent from an implementation.
Parallel Interface	An interface where each signal is transmitted by a separate pair of wires.
Project	Integration project of an ERTMS/ETCS on-board equipment on a vehicle.
Serial Interface	An interface where multiple signals are transmitted via a bus/network or a point-to-point connection.
Signal	Signal is a part of information in case of a multiple-channel implementation (e.g. redundancy or anticoincidence). A signal is equivalent to information in case of a single-channel implementation.
Traction Cut-Off	Inhibit positive traction effort (i.e. driving effort).

Table 1: Terms

ACC	Allowed Current Consumption
BW	Backward
CCS	Control-Command and Signalling
EB	Emergency Brake
ECS	Eddy current brake for service brake
ECE	Eddy current brake for emergency brake
FDT	Fault Detection Time

FR	Failure rate
FW	Forward
HR	Hazard Rate
MG	Magnetic shoe brake
MVB	Multifunction Vehicle Bus
OBU	On-board Unit
RB	Regenerative Brake
RST	Rolling Stock
TCMS	Train Control and Monitoring System
TFR	Tolerable Failure Rate
THR	Tolerable Hazard Rate
TR	Train
TSI	Technical Specification for Interoperability

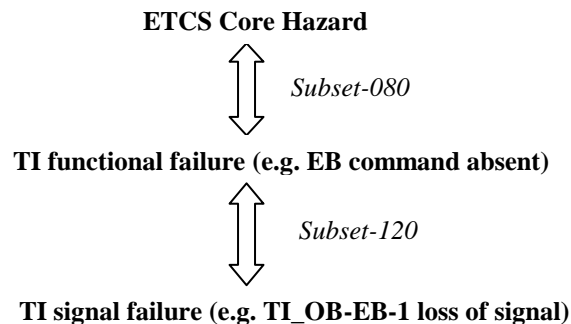
Table 2: Abbreviations

1.4 Requirements Designation

- 1.4.1.1 A designation system for the quantified requirements has been introduced; TI_OB-xxx refers to a requirement on the ETCS on-board equipment and similarly TI_VE-xxx refers to a requirement on the vehicle equipment.

1.5 Methodology

- 1.5.1.1 Chapter 2 describes the system under consideration (Train Interface) for the safety analysis of this document.
- 1.5.1.2 The FMEA described in Annex A, chapter 6.1 is based on the description of chapter 2, the architectures and signals described in Subset-119 and the functional FMEA of Subset-080.
- 1.5.1.3 The purpose of the FMEA described in Annex A, chapter 6.1 is to analyse which single faults lead to which effects and in the end to which hazard.
- 1.5.1.4 The FMEA analyses the relationship between the TI signals and the TI functional failures already identified in Subset-080. Subset-080 and Subset-120 correspond in the TI functional failure. The Subset-080 considers the relation between TI functional failures and the ETCS Core Hazard. The Subset-120 considers the relation between TI signal failures and the TI functional failures, compare the following illustration:



- 1.5.1.5 Subset-120 provides an analysis for all failures which are considered as catastrophic or critical in Subset-080 or for which there is an additional architectural aspect to be considered. In these cases it is referenced to Subset-080 for the corresponding failure modes in Subset-120.
- 1.5.1.6 The failure modes are identified by using the failure mode guide-words listed in chapter 6.1.2 for the architectures described in Subset-119 for all TI functions.
- 1.5.1.7 Serial architecture has been analysed exemplarily for Sleeping.
- 1.5.1.8 Chapter 3 describes all events related to the functions for which a safety-relevant effect (severity catastrophic or critical) has been described in the FMEA. In general these single faults are used as basic events in the fault trees in annex A, chapter 6.2.
- 1.5.1.9 The safety targets used in the FTA are determined by TSI Loc&Pas (EB safety requirements) and UNISIG Subset-080 and Subset-091 (Hazardous TI events related to ETCS Core Hazard).
- 1.5.1.10 Chapter 3.8 lists all TI related events on ETCS on-board side which are hazardous according to FMEA and FTA.
- 1.5.1.11 Chapter 3.9 lists all TI related events on ETCS vehicle side which are hazardous according to FMEA and FTA.
- 1.5.1.12 Chapter 4 explains most of the gates (multiple fault effects), all barriers and all conditions used in the fault trees in annex A, chapter 6.2.
- 1.5.1.13 From FTA TFR values are derived for the basis events.
- 1.5.1.14 Chapter 5 summarizes all the results obtained (requirements for TI) including the exported constraints and the TFR and FDT values resulting from the FTA. Related assumptions are listed. This chapter is the input to Subset-119 and it is included in that document classified as safety requirements.

2. SYSTEM UNDER INSPECTION

2.1 Context

2.1.1.1 For different vehicle systems, different TI configurations might be necessary. The following figure outlines the TI configurations and their interaction with external entities (driver and trackside) in order to show how a safe implementation of TI configurations ensures the overall safety at TSI CCS/Loc&Pas system level. The black arrows show interactions in the system and the blue arrows show information flows which could lead to a hazard. Configurations define different interface types from where a wrong-side failure could be propagated up to the TSI CCS/Loc&Pas system level and thus failing to prevent the occurrence of hazardous situations (Top Hazard, e.g. a wrong-side failure at emergency brake interface could lead the vehicle braking system to not apply effectively the vehicle emergency brake).

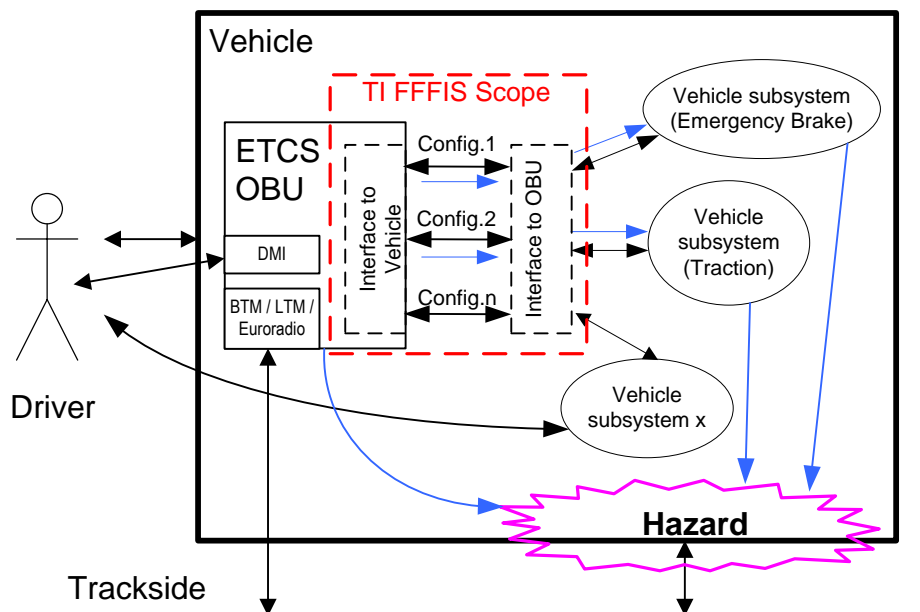


Figure 1: Safety Boundaries

2.1.1.2 From the figure above the following entities and their contribution to system definition are identified:

- Vehicle subsystems like Emergency Brake, Traction, Pantograph... as a Black Box – described in the TSI Loc&Pas.
- ETCS OBU (Black Box) – a subsystem inside the vehicle. This is part of the TSI CCS signalling subsystem providing the ETCS on-board functionality.
- Trackside – outside the scope of this document.



- 2.1.1.3 Note that from a safety point of view two relevant interfaces can be identified but none of them dealing with TI functionality. The first one is the ETCS data transmission interface for OBU transmission units interacting for data transmission between track and vehicle. The second interface is between the rail and vehicle wheels and provides the adhesion capability of vehicle to rails in order to ensure braking effect. Failures from these interfaces will be considered out of the scope of TI safety.
- 2.1.1.4 Driver – Outside the boundaries of TI safety. Driver interacts with ETCS OBU and vehicle systems. Failures from this interface (driver actions) will be considered out of the scope of TI safety.
- 2.1.1.5 Maintenance and Commissioning Staff are outside the boundaries of TI safety. They interact with ETCS OBU and vehicle systems at maintenance and/or commissioning work. Failures from this source will be considered out of the scope of TI safety.
- 2.1.1.6 Physically, the TI consists only of transmission components (cables and connectors). It is just an interface, which connects the ETCS OBU and the vehicle systems. The vehicle integrator (contract specific) is responsible for the engineering of the train interface including cable connections.
- 2.1.1.7 Note: The ETCS Core Hazard is related exclusively to the ETCS on-board unit as defined in Subset-091. It ends at the Train Interface.

3. SINGLE FAULTS DESCRIPTION

3.1 General

3.1.1.1 The intention of this chapter is to explain the hazardous events of the several functions used in the fault trees in annex A, 6.2.

3.1.1.2 The FR and FDT values used in this chapter are only examples to reach the safety target. Other values could be used if they reach the targets (e.g. higher FR value with shorter FDT).

3.1.2 Consideration of redundant and antivalent signals

3.1.2.1 Redundant signals are used in Subset-119 when it is necessary according to the analysis of multiple failures in Subset-120, chapter 4.

3.1.2.2 Antivalence is used as a measure against common mode failures and for fault detections .

3.1.2.3 If there are redundant or antivalent signals given by Subset-119 then this is considered in the single faults analysis (FMEA) already. As a consequence redundancy and antivalence are not used as barriers in the FMEA but are already considered in the failure effects (which failure effects are credible). In this way a too large FMEA table is avoided.

3.1.3 Consideration of serial transmission faults

3.1.3.1 Serial architecture a) (see Subset-119, chapter 4.2.2)

3.1.3.1.1 Analysis of serial architecture a) is performed using Sleeping signals, which can be used as an example for other safety-relevant TI inputs.

3.1.3.1.2 In architecture a) causes for transmission failures can be failures of a simple I/O device, failures of the bus interface card or undetected failures due to the performance of the transmission code (compare explanations and reasoning in the sections 3.2.1.1 and 4.2.1.4.4).

3.1.3.1.3 The failure rate R_a for serial transmission is determined by undetected failures due to the performance of the transmission code (R_{uf}) and hardware failures at transmission (R_{HW}).

Bus information are evaluated by OBUs, only if these are constant over at least 2 Bus cycles. For a CRC-16 a failure rate of $R_{uf} = 1E-5$ /h can be assumed conservatively.



Most failures due to the transmission hardware are detected due to the check of the antivalency of the signals on application level in ERTMS/ETCS on-board equipment. But there are residual failures which have to be considered with the failure rate of the bus interface card. It is assumed that a typical failure rate of a bus interface card is $R_{HW} = 1E-5$ /h.

$$R_a = R_{uf} + R_{HW} = 2E-5 \text{ /h}$$

It is assumed that there is a transmission failure detection so that $FDT < 1$ min. But a failure in a bus interface card can be detected always when a telegram is received. In a conservative assumption it is supposed that every 24 h a telegram is received so that the bus interface card has a $FDT=24$ h.

3.1.3.1.4 Note: For examples for calculation of a hazardous failure rate of the complete transmission system see IEC 61784-3.

3.1.3.2 Serial architecture b) (see Subset-119, chapter 4.2.3)

3.1.3.2.1 Architecture b) has to be implemented strictly according to EN 50159. The hazardous failure rate of the transmission system is lower than the typical signal failure rate $1E-5$ /h (compare the following sections). That means the influence on the hazards can be neglected. Therefore no specific analysis is necessary in addition to the analysis of the parallel interface.

3.1.3.2.2 The communication partners in architecture b) need at least the safety level of the information which is transmitted. The HR of the TCMS depends on the information which is transmitted.

3.1.3.2.3 Note: For examples for calculation of a hazardous failure rate of the complete transmission system see IEC 61784-3.

3.2 Description of the Hazardous Events of Mode Control

3.2.1 Sleeping

3.2.1.1 Event description (serial and parallel connection)

Event	Explanation
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Event	Explanation
TI_OB-SL-1.1, TI_OB-SL-1.2, TI_VE-SL-1.1 and TI_VE-SL-1.2	<p>It is assumed that a failure rate for the sleeping signals is $FR = 1E-5$ /h as typically for input signals from vehicle.</p> <p>As typical FDT for TI inputs 48 h are assumed for the vehicle side. For the ETCS on-board equipment side an FDT of 1 minute is assumed due to the fault detection based on antivalency.</p> <p>The antivalent sleeping signals T_SL_E1_N and T_SL_E2_I shall have two sources. Nevertheless common cause failures have to be taken into account. This is considered with a β-factor of 10% according to IEC 61508-6 on vehicle side. For OBU side the independence according to EN50129 has to be shown.</p>
TI_OB-SL-1 and TI_VE-SL-1	<p>It is assumed that a failure rate for the sleeping signal T_SL_E is $FR = 1E-5$ /h as typically for input signals from vehicle.</p> <p>As typical FDT for TI inputs 48 h are assumed for the vehicle and ETCS on-board equipment side.</p>
TI_VE-BUS-1.0	<p>It is assumed that a typical failure rate of a simple I/O device is $FR = 5E-6$ /h.</p> <p>A failure in a simple I/O device can be detected e.g. by the driver. In a conservative assumption it is supposed that FDT=24 h.</p>
TI_VE-BUS-2.0	<p>According to section 3.1.3.1.3 a failure rate for undetected failures due to the performance of the transmission code and hardware failures at transmission is assumed of $FR = 2E-5$ /h for architecture a). In case of architecture b) the transmission channel can be neglected in the fault trees.</p> <p>It is assumed that there is a transmission failure detection so that FDT = 1 min.</p>

3.2.1.2 Event description for general analysis for serial communication with two inputs by means of sleeping.

Event	Explanation
TI_VE-SL-1.1 and TI_VE-SL-1.2	<p>It is assumed that a failure rate for the sleeping signals is $FR = 1E-5$ /h as typically for input signals from vehicle.</p> <p>As typical FDT for TI inputs 48 h are assumed for the vehicle side. For the ETCS on-board equipment side an FDT of 1 minute is assumed due to the fault detection based on antivalency.</p> <p>The antivalent sleeping signals T_SL_E1_N and T_SL_E2_I shall have two sources. Nevertheless common cause failures have to be taken into account. This is considered with a β-factor of 10% according to IEC 61508-6 on vehicle side. For OBU side the independence according to EN50129 has to be shown.</p>

Event	Explanation
TI_VE-BUS-1.1 and TI_VE-BUS-1.2	It is assumed that a typical failure rate of a simple I/O device is $FR = 5E-6$ /h. Because there is only one bus connected to both simple I/O devices, common cause failures are possible. This is considered with a β -factor of 10% according to IEC 61508-6. It is the same common cause as for TI_OB-BUS1.1, TI_OB-BUS1.2, TI_VE-BUS-2.1, and TI_VE-BUS-2.2.
TI_VE-BUS-2.1 and TI_VE-BUS-2.2	According to section 3.1.3.1.3 a failure rate for undetected failures due to the performance of the transmission code and hardware failures at transmission is assumed of $FR = 2E-5$ /h for architecture a). In case of architecture b) the transmission channel can be neglected in the fault trees. It is assumed that there is a transmission failure detection so that $FDT = 1$ min. Most common cause failures are detected due to the check of the antivalency of the signals on application level in ERTMS/ETCS on-board equipment. Residual common cause failures due to only one bus connected to both simple I/O devices and due to only one bus interface card are considered with a β -factor of 10% according to IEC 61508-6. It is the same common cause as for TI_OB-BUS1.1, TI_OB-BUS1.2, TI_VE-BUS-1.1, and TI_VE-BUS-1.2.

3.2.2 Passive Shunting

3.2.2.1 Event description

Event	Explanation
TI_OB-PS and TI_VE-PS	It is assumed that a failure rate for the Passive Shunting signal is $FR = 1E-5$ /h as typically for input signals from vehicle. As FDT for TI inputs 48 h are assumed (under condition that it is checked in the scope of the start-up tests or regular functional test).

3.2.3 Non Leading

3.2.3.1 Event description

Event	Explanation
TI_OB-NL and TI_VE-NL	It is assumed that a failure rate for the Non Leading signal is $FR = 1E-5$ /h as typically for input signals from vehicle. As typical FDT for TI inputs 48 h are assumed (under condition that it is checked in the scope of the start-up tests or regular functional test).

3.2.4 Isolation

- 3.2.4.1 Under the assumptions described in chapter 5.1.3.4.2 single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1.

3.3 Description of the Hazardous Events of Control of Brakes

3.3.1 Service Brake Command

- 3.3.1.1 Safety does not rely on the service brake.
- 3.3.1.2 Assumption: No impact on emergency brake model.
- 3.3.1.3 A project specific safety analysis is needed in order to show that, in case of use of service brake, a failure of service brake is recognized and the emergency brake is applied as safeguarding.
- 3.3.1.4 Single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1.

3.3.2 Brake pressure

- 3.3.2.1 Single failures have no safety-relevant effect in the system. According to Subset-026-3, clause A.3.10.1 only the SBI is effected by the signal.

3.3.3 Emergency Brake Command

- 3.3.3.1 Event description (solution 1 and 2)

Event	Explanation
TI_OB-EB-1, TI_OB-EB-2, TI_VE-EB-1 and TI_VE-EB-2	<p>It is assumed that a failure rate for the emergency brake output signal on parallel interface is $FR = 1E-7$ /h on vehicle side and $3E-6$ /h on ETCS/ERTMS on-board equipment side, compare note in section 4.3.3.1.1.</p> <p>The two EB signals O_EB1_C and O_EB2_C shall be output physically independent according to EN 50129 by the ERTMS/ETCS on-board equipment. On vehicle side common cause failures are taken into account. This is considered with a β-factor of 1% according to IEC 61508-6.</p> <p>As typical FDT 48 h are assumed (under condition that it is checked in the scope of the start-up tests or regular functional test).</p>

3.3.3.2 Event description (solution 3)

Event	Explanation
TI_OB-EB-3, TI_OB-EB-4, TI_VE-EB-3 and TI_VE-EB-4	<p>The two EB signals O_EB1_C and OBU_TR_EB3_C shall be output physically independent according to EN 50129 by the ERTMS/ETCS on-board equipment.</p> <p>The two EB signals O_EB1_C and OBU_TR_EB3_C are output diverse due to O_EB1_C is output on parallel and OBU_TR_EB3_C is output on serial interface. Due to the diversity no common cause failures have to be taken into account.</p> <p>It is assumed that a failure rate for the emergency brake output signal O_EB1_C on parallel interface is $FR = 3E-6$ /h on vehicle side and on ETCS/ERTMS on-board equipment side.</p> <p>For serial communication the FR value shall be $1E-7$ /h for OBU_TR_EB3_C on vehicle and on ERTMS/ETCS on-board equipment side.</p> <p>As typical FDT 48 h are assumed (under condition that it is checked in the scope of the start-up tests or regular functional test).</p>

3.3.4 Special Brake Inhibit – Trackside Orders

3.3.4.1 To be harmonized.

3.3.5 Special Brake Inhibit – STM Orders

3.3.5.1 Analysis is national system specific..

3.3.6 Special Brake Status

3.3.6.1 If vehicle is equipped with special brakes the special brake status is relevant to calculate the brake model, see clause 5.1.4.6.2.

3.3.6.2 If vehicle is not equipped with special brakes, no failure may arise.

3.3.7 Additional Brake Status

3.3.7.1 Currently, no additional brakes in addition to the special brakes are known. Hence, no failure may arise.

3.4 Description of the Hazardous Events of Control of Train Functions

3.4.1 Change of traction system

3.4.1.1 To be harmonized.

3.4.2 Pantograph (Trackside orders / STM orders)

3.4.2.1 For trackside orders: To be harmonized.

3.4.2.2 For STM orders: Single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1.

3.4.3 Air tightness (Trackside orders / STM orders)

3.4.3.1 For trackside orders: To be harmonized.

3.4.3.2 For STM orders: Single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1.

3.4.4 Passenger door

3.4.4.1 To be harmonized.

3.4.5 Main Power Switch – Trackside orders

3.4.5.1 To be harmonized.

3.4.6 Main Power Switch – STM orders

3.4.6.1 Single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1.

3.4.7 Traction Cut-off

3.4.7.1 TCO with serial output O_TC2_C and parallel output O_TC1_C allowing a safe TCO affecting the braking curves.

3.4.7.1.1 Event description

Event	Explanation
TI_OB-TCO-1, TI_OB-TCO-2, TI_VE-TCO-1, TI_VE-TCO-2	<p>It is assumed that a failure rate for the TCO output signal on parallel interface (O_TC1_C parallel) is $FR = 1E-5$ /h on vehicle side and on ETCS/ERTMS on-board equipment side.</p> <p>The second output is on serial interface (O_TC2_C serial) the SIL for serial communication must be SIL 2 according to the required FR value.</p> <p>The two outputs have to be output physically independent. Due to the diversity of the output paths no common cause factors have to be considered in the fault tree.</p> <p>As typical FDT 48 h are assumed for parallel interface (under condition that EB is checked in the scope of the start-up tests or regular functional test). For serial interface conservatively a FDT of 1 h is assumed.</p>

3.4.8 Change of allowed current consumption (ACC)

3.4.8.1 To be harmonized.

3.5 Description of the Hazardous Events of Train Status Information

3.5.1 Cab status

3.5.1.1 Single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1.

3.5.1.2 Due to multiple failure analysis the following events are described.

3.5.1.3 Event description

Event	Explanation
TI_OB-CS-1, TI_OB-CS-2, TI_VE-CS-1 and TI_VE-CS-2	<p>These events are used as cab status failures.</p> <p>The two Cab status signals TI_OB-CS-1 and TI_OB-CS-2 shall be physically independent according to EN 50129 by the ERTMS/ETCS on-board equipment.</p> <p>Due to Subset 034 2.5.1.3 each cab will be connected to its individual input on vehicle side. Nevertheless common cause failures have to be taken into account. This is considered with a β-factor of 10% according to IEC 61508-6 on vehicle side. For OBU side the independence according to EN50129 has to be shown.</p> <p>It is assumed that a failure rate for the cab status signal is $FR = 1E-5$ /h as typically for input signals from vehicle.</p> <p>As typical FDT for TI inputs 48 h are assumed.</p>

3.5.2 Direction controller status

3.5.2.1 Event description

Event	Explanation
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Event	Explanation
TI_OB-DC-1, TI_OB-DC-2, TI_VE-DC-1 and TI_VE-DC-2	<p>These events are used as direction signal failure. T_FW_S failure (TI_OB-DC-1 and TI_VE-DC-1) is relevant for a downhill slope. T_BW_S (TI_OB-DC-2 and TI_VE-DC-2) failure would be relevant for an uphill slope.</p> <p>It is assumed that a failure rate for the direction signal is $FR = 1E-5$ /h as typically for input signals from vehicle.</p> <p>As typical FDT for TI inputs 48 h are assumed.</p>

3.5.3 Train integrity

3.5.3.1 To be harmonized.

3.5.4 Traction Status

3.5.4.1 The traction status is forwarded to the STM. The information related to STMs is seen as out of scope of this safety analysis focusing on level 1 and level 2 aspects.”

3.6 Description of the Hazardous Events of Train Data

3.6.1 Type of train data entry

3.6.1.1 Single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1.

3.6.2 Train data information

3.6.2.1 To be harmonized.

3.7 Description of the Hazardous Events of National System Isolation

3.7.1 National System Isolation

3.7.1.1 This is level NTC only which is seen as out of scope of this safety analysis focusing on level 1 and level 2 aspects.

3.8 Hazardous Events Schedule ETCS on-board

Event Id.	Hazardous Event Description	Corresponding to FIS event	Reference to FTA
TI_OB-SL-1.1	Inappropriate reception of faulty Sleeping signal T_SL_E1_N	TI-3	4.2.1.4.1_SL_PAR
TI_OB-SL-1.2	Inappropriate reception of faulty Sleeping signal T_SL_E2_I	TI-3	4.2.1.4.1_SL_PAR
TI_OB-SL-1	Inappropriate reception of faulty Sleeping signal T_SL_E	TI-3	4.2.1.4.2_SL_PAR_ALT
TI_VE-BUS-2.0, TI_VE-BUS-2.1, TI_VE-BUS-2.2	Bus falsifies first telegram (serial transmission architecture a) - contribution on ERTMS/ETCS on-board equipment side: Bus interface card failure	It is related to the TI-x of the corresponding TI function for which the serial transmission is used (e.g.: TI-3)	e. g. 4.2.1.4.4_SL_BUS and 4.2.1.4.3_SL_BUS_ALT
TI_OB-PS,	Inappropriate reception of faulty Passive Shunting signal T_PS_E	TI-7	4.2.2.1_PS_PAR
TI_OB-NL	Inappropriate reception of Non Leading signal T_NL_E	TI-8	4.2.3.1_NL_PAR
TI_OB-EB-1	Loss of Emergency Brake signal O_EB1_C	TI-1	4.3.3.1-0_EB_Solution1-2, 4.3.3.2_EB_Solution3
TI_OB-EB-2	Loss of Emergency Brake signal O_EB2_C (solution 1-2) or OBU_TR_EB3_Cmd (solution 3)	TI-1	4.3.3.1-0_EB_Solution1-2, 4.3.3.2_EB_Solution3
TI_OB-CS	Wrong Cabin considered as Active due to falsification of both cab status signals T_CS_A = 1 and T_CS B are falsified at the same time.	TI-6b, KERNEL-15	4.5.1.1_CS_PAR
TI_OB-DC-1	Loss of Direction Controller status signal T_FW_S	TI-5	4.5.2.1_DCP_PAR
TI_OB-DC-2	Loss of Direction Controller status signal T_BW_S	TI-5	No fault tree but equivalent to 4.5.2.1_DCP_PAR
TI_OB-TCO-1	Loss of TCO signal O_TC1_C on parallel output	TI-11	4.4.7.2-0_TCO_PAR_SER
TI_OB-TCO-2	Loss of TCO signal O_TC2_C on serial bus	TI-11	4.4.7.2-0_TCO_PAR_SER

3.9 Hazardous Events Schedule vehicle part

Event Id.	Hazardous Event Description	Reference to FTA
TI_VE-SL-1.1	Inappropriate output of faulty Sleeping signal T_SL_E1_N	4.2.1.4.1_SL_PAR
TI_VE-SL-1.2	Inappropriate output of faulty Sleeping signal T_SL_E2_I	4.2.1.4.1_SL_PAR
TI_VE-SL-1	Inappropriate output of faulty Sleeping signal T_SL_E	4.2.1.4.1_SL_PAR and 4.2.1.4.3_SL_BUS_ALT
TI_VE-BUS-1.0	Simple I/O device failure (serial transmission architecture a)	e.g. 4.2.1.4.3_SL_BUS_ALT
TI_VE-BUS-1.1	Simple I/O device 1 failure (serial transmission architecture a)	e.g. 4.2.1.4.4_SL_BUS

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Event Id.	Hazardous Event Description	Reference to FTA
TI_VE-BUS-1.2	Simple I/O device 2 failure (serial transmission architecture a)	e.g. 4.2.1.4.4_SL_BUS
TI_VE-BUS-2.0	Bus falsifies first telegram (serial transmission architecture a)	e. g. 4.2.1.4.3_SL_BUS_ALT
TI_VE-BUS-2.1	Bus falsifies first telegram (serial transmission architecture a)	e. g. 4.2.1.4.4_SL_BUS
TI_VE-BUS-2.2	Bus falsifies second telegram (serial transmission architecture a)	e. g. 4.2.1.4.4_SL_BUS
TI_VE-BUS	Bus falsifies telegram undetected (serial transmission architecture b)	PD_BUS
TI_VE-PS	Inappropriate output of faulty Passive Shunting signal T_PS_E	4.2.2.1_PS_PAR
TI_VE-NL	Inappropriate output of Non Leading signal T_NL_E	4.2.3.1_NL_PAR
TI_VE-EB-1	Loss of emergency brake signal O_EB1_C (no brake command received when required)	4.3.3.1-0_EB_Solution1-2, 4.3.3.2_EB_Solution3
TI_VE-EB-2	Loss of emergency brake signal O_EB2_C (solution 1-2) or OBU_TR_EB3_Cmd (solution 3) (brake release command received when not required)	4.3.3.1-0_EB_Solution1-2, 4.3.3.2_EB_Solution3
TI_OB-CS	Wrong Cabin considered as Active due to falsification of both cab status signals T_CS_A = 1 and T_CS B are falsified at the same time.	4.5.1.1_CS_PAR
TI_VE-DC-1	Loss of direction controller status signal T_FW_S	4.5.2.1_DCP_PAR
TI_VE-DC-2	Loss of direction controller status signal T_BW_S	No fault tree but equivalent to 4.5.2.1_DCP_PAR
TI_VE-TCO-1	Loss of TCO signal O_TC1_C on parallel output	4.4.7.2-0_TCO_PAR_SER
TI_VE-TCO-2	Loss of TCO signal O_TC2_C on serial bus	4.4.7.2-0_TCO_PAR_SER

4. MULTIPLE FAULTS EFFECTS DESCRIPTION

4.1 General

4.1.1.1 The intention of this chapter is to explain the TIU-related hazards, barriers and conditions of the fault trees included in annex A, 6.2.

4.1.1.2 In all cases when a driver action is considered as barrier in a fault tree the driver error is modelled as a probability.

4.2 Description of the Fault Effects of Mode Control

4.2.1 Sleeping

4.2.1.1 Each single failure will be detected but safe reaction will be triggered not before standstill.

4.2.1.2 Assumptions of the cases considered in the fault trees:

- All cabs are closed (e.g. because the driver wanted to enter to mode SB from any mode or the driver wants to change the cab).
- ETCS mode is Stand-By.
- Vehicle is standing still.
- Vehicle is on a slope or there is heavy wind.

4.2.1.3 Barriers

Event	Explanation
E-ext-SPV	<p>The vehicle is in charge to ensure the standstill. Before closing all the cabs, the vehicle has been obviously braked. To roll away the brakes have to be released which is assumed with a frequency of 1E-5 /h.</p> <p>Standstill information from ETCS odometer is only a mitigation for vehicle running but not for the described case of standstill.</p>
E-ext-SPD	<p>The driver or the vehicle is in charge to ensure the standstill (e.g. brakes applied). Before closing the cabs, the vehicle has been obviously braked. To roll away the brake would have been released already which is assumed with an unavailability of 1E-3.</p> <p>Standstill information from ETCS odometer is only a mitigation for vehicle running but not for the described case of standstill.</p>

4.2.1.4 TIU-related hazards

4.2.1.4.1 Fault tree for the case of parallel interface with two sleeping signals (4.2.1.4.1_SL_PAR)

Gate	Explanation
G-SL-2	<p>A failure leads to inappropriate transition to mode SL, only if there are two failures (T_SL_E1_N and T_SL_E2_I) at the same time.</p> <p>The antivalent sleeping signals T_SL_E1_N and T_SL_E2_I must be input from two sources in the vehicle. If this is not provided 4.2.1.4.2_SL_PAR_ALT is an alternative solution with only one sleeping signal and a standstill protection on vehicle side (E-ext-SPV), i.e. an ERTMS/ETCS on-board equipment independent system is in charge to ensure the standstill.</p> <p>Preconditions: Vehicle is at standstill AND all desks connected to the ERTMS/ETCS on-board equipment are closed (Subset-026, 4.6.3, [14]).</p>

4.2.1.4.2 Fault tree for the case of parallel interface with one sleeping signal (4.2.1.4.2_SL_PAR_ALT)

Gate	Explanation
G-SL-7	<p>A failure leads to inappropriate transition to mode SL, if there is a failure of T_SL_E.</p> <p>Preconditions: Vehicle is at standstill AND all desks connected to the ERTMS/ETCS on-board equipment are closed (Subset-026, 4.6.3, [14]).</p>

4.2.1.4.3 Fault tree for the case of serial interface with one sleeping signal (4.2.1.4.3_SL_BUS_ALT)

Gate	Explanation
G-SL-9	<p>A failure leads to inappropriate transition to mode SL, if there is a failure in the source of the sleeping signal TI_VE-SL-1, if there is a failure in the simple I/O device (TI_VE-BUS-1.0), if there is an undetected failure due to the performance of the transmission code (TI_VE-BUS-2.0):</p> <p>Preconditions: Vehicle is at standstill AND all desks connected to the ERTMS/ETCS on-board equipment are closed (Subset-026, 4.6.3, [14]).</p> <p>It can be neglected that other bus partners send wrong information. E.g. for MVB a reasoning could be that due to the functionality of MVB the following conditions would have to be fulfilled:</p> <ul style="list-style-type: none"> An unknown bus partner has to generate a complete and valid Slave Frame

Gate	Explanation
	<p>(including checksum).</p> <ul style="list-style-type: none"> This slave frame has to be sent directly after the master frame was sent but before the slave frame of the answering simple I/O device. The slave frame has to contain the identification of the addressed clip station. These failure combinations must succeed over two successive cycles. During this time failures must not have the effect that the bus communication is stopped (e.g. as in case of permanent wrong sending). <p>Those failures cannot be excluded, in general. But they can be neglected in comparison to the other considered failures.</p>

4.2.1.4.4 Fault tree for the case of serial interface with two sleeping signals (4.2.1.4.4_SL_BUS)

Gate	Explanation
G-SL-4.1	<p>A failure leads to inappropriate transition to mode SL, only if there are two other failures at the same time: The first failure is depicted with G-SL-1.0 and the second one with G-SL-2.0.</p> <p>Preconditions: Vehicle is at standstill AND all desks connected to the ERTMS/ETCS on-board equipment are closed (Subset-026, 4.6.3, [14]).</p> <p>It can be neglected that other bus partners send wrong information. E.g. for MVB a reasoning could be that due to the functionality of MVB the following conditions would have to be fulfilled:</p> <ul style="list-style-type: none"> An unknown bus partner has to generate a complete and valid Slave Frame (including checksum). This slave frame has to be sent directly after the master frame was sent but before the slave frame of the answering simple I/O device. The slave frame has to contain the identification of the addressed clip station. These failure combinations must succeed over two successive cycles. During this time failures must not have the effect that the bus communication is stopped (e.g. as in case of permanent wrong sending). <p>Those failures cannot be excluded, in general. But they can be neglected in comparison to the other considered failures.</p> <p>The simple I/O devices are separate physical components. The common influence by power supply and environmental conditions do not have to be considered because a similar falsification of telegrams does not have to be assumed due to these influences. Simple I/O devices are physically connected. Therefore possible common cause failures are considered with the β-factor according to IEC 61508-6.</p>

4.2.1.4.5 Fault tree for parallel and serial interface (4.2.1.4.1_SL_PAR, 4.2.1.4.2_SL_PAR_ALT and 4.2.1.4.3_SL_BUS_ALT)

Gate	Explanation
G-SL-1 / G-SL-6 / G-SL-8	<p>If the responsibility is on ETCS only, then two sleeping signals would be needed due to no single fault must lead to a hazard.</p> <p>With the additional technical barrier E-ext-SPV it is also fulfilled with one sleeping signal T_SL_E that no single fault leads to a hazard.</p>
4.2.1.4.3_SL_BUS_ALT / 4.2.1.4.1_SL_PAR / 4.2.1.4.2_SL_PAR_ALT / 4.2.1.4.4_SL_BUS	<p>Loss of standstill without driver on-board is a hazard which is not inherent to ETCS and was addressed previously with specific means which are still applicable. ETCS OBU is not able to improve the safety level of the “sleeping status” provided by the vehicle. Indeed the hazard rates of the TOP events 4.2.1.4.1_SL_PAR, 4.2.1.4.3_SL_BUS_ALT and 4.2.1.4.2_SL_PAR_ALT are directly resulting from the “sleeping status” provided by the vehicle.</p> <p>Therefore the THR of the ETCS Core Hazard does not have to be reached and it is sufficient that the initial end effect “exceedance of the safe speed because of failure in SL” is in the range of SIL4.</p>

4.2.2 Passive Shunting

4.2.2.1 Fault tree for the parallel interface (4.2.2.1_PS_PAR)

4.2.2.1.1 Safe reaction will be triggered immediately in case of single failure detection at passive shunting input signal. Other safety-related faults will be stored on-board until the vehicle leaves the PS mode (compare Subset-026, 4.4.20.1.6 and 4.4.20.1.10).

4.2.2.1.2 Preconditions of the considered case in the fault tree:

- Vehicle is standing still.
- Vehicle is on a slope.
- ETCS mode is Shunting.
- Cabs are closed after all the conditions are fulfilled (Subset-026, 4.6.3, [26]).

4.2.2.1.3 Barriers

Event	Explanation
E-ext-SPD	If no Cab is occupied the driver or the vehicle is in charge to ensure the standstill (e.g. brakes applied). Before closing the cabs, the vehicle has been obviously braked. To

Event	Explanation
	roll away the brake would have been released already which is assumed with an unavailability of 1E-3. Standstill information from ETCS odometer is only a mitigation for vehicle running but not for the described case of standstill.
MMI-1a	False acknowledgement of mode change to less restrictive mode (compare Subset-091). As a second failure there can be a driver request PS mode mistimed or a DMI failure. It is assumed that a conservatively failure rate of DMI is $FR = 1E-5 /h$ with $FDT=48 h$. Fault of the driver input to DMI is neglected in the fault tree.
E-ext-DPS	Driver erroneously commands the transition to mode PS. Driver interaction failure with a frequency of 1E-3 is assumed as worst case.

4.2.2.1.4 TIU-related hazards

Gate	Explanation
G-PS-2	A failure leads to inappropriate transition to mode PS, only if there are three failures at the same time: <ul style="list-style-type: none"> - Passive Shunting signal T_PS_E failure. - Loss of external standstill protection (driver or vehicle does not ensure the standstill before leaving the cab). - DMI failure. Information from the DMI is necessary to change to Mode PS. Therefore DMI failure leads unwanted to change to Mode PS so that there is no more movement protection.

4.2.3 Non Leading

4.2.3.1 Fault tree for the parallel interface (4.2.3.1_NL_PAR)

4.2.3.1.1 Assumptions of the cases considered in the fault trees:

- Vehicle is standing still.
- Vehicle is on a slope.
- ETCS mode is SB, SH, FS, LS, SR or OS

4.2.3.1.2 Barriers

Event	Explanation
E-ext-MDD	Driver does not realise the new mode displayed on DMI. Driver interaction failure with a unavailability of 1E-3 is assumed as worst case.

Event	Explanation
MMI-1b	False command to enter Non Leading mode (compare Subset-091). As a second failure there can be a driver request NL mode mistimed or a DMI failure. It is assumed that a conservatively failure rate of DMI is $FR = 1E-5$ /h with FDT=48 h. Fault of the driver input to DMI is neglected in the fault tree.
E-ext-DNL	Driver erroneously commands to enter NL mode. Driver interaction failure with a frequency of $1E-3$ is assumed as worst case.

4.2.3.1.3 TIU-related hazards

Gate	Explanation
G-NL-2	A failure leads to inappropriate transition to mode NL, only if there are three failures at the same time so that there is no more movement protection: <ul style="list-style-type: none"> - Non Leading signal T_NL_E failure. - Driver does not realise of the new mode displayed on the DMI. - DMI failure leads to unwanted change to NL mode.

4.2.4 Isolation

- 4.2.4.1 Multiple failures have no effect in the system because another train protection system supervises the vehicle movement.
- 4.2.4.2 The driver knows when the OBU is isolated and it can be ensured that the driver will be informed of the isolation mode.

4.3 Description of the Fault Effects of Control of Brakes

4.3.1 Service Brake Command

- 4.3.1.1 Under the assumption described in clause 5.1.4.1.1 multiple failures have no effect in the system.

4.3.2 Brake Pressure

- 4.3.2.1 Multiple failures have no effect in the system.

4.3.3 Emergency Brake Command

- 4.3.3.1 Fault tree for the case of parallel interface (4.3.3.1-0_EB_Solution1-2)

4.3.3.1.1 TIU-related hazards

Gate	Explanation
G-EB-1	<p>A failure leads to EB command failure, only if there are two failures for loss of emergency brake signal (O_EB1_C and O_EB2_C) at the same time.</p> <p>The signals O_EB1_C and O_EB2_C must be output physically independent. The independence has to be shown in the project safety cases according to the valid standards. If necessary a beta factor has to be used in calculation or/and better TFRs have to be used for TI_OB-EB-1 and TI_OB-EB-2.</p> <p>The signals O_EB1_C and O_EB2_C must be processed in the vehicle with independence as required by TSI Loc&Pas, section 4.2.4.4.1.</p>

4.3.3.1.2 Note: According to TSI Loc&Pas, safety target for EB on the vehicle side shall reach the tolerable hazard rate of 1E-09 per hour, which is lower than ETCS Core Hazard related to the ETCS on-board unit. According to the FTAs 4.3.3.1.2_OBU-EB and 4.3.3.1.2_VEHICLE-EB both values are reached.

4.3.3.2 Fault tree for the case of solution 3 (combined parallel and serial interface – 4.3.3.2_EB_Solution3)

4.3.3.2.1 There shall be only a serial EB output as a redundant output in combination with a parallel EB output.

4.3.3.2.2 TIU-related hazards

Gate	Explanation
G-EB3-1	<p>A failure leads to EB command failure, only if there are two failures for loss of emergency brake signal (O_EB1_C and OBU_TR_EB3_C) at the same time.</p> <p>The signals O_EB1_C and OBU_TR_EB3_C are output physically independent on parallel and on serial interface (diverse output).</p> <p>The signals O_EB1_C and OBU_TR_EB3_C must be processed in the vehicle with independence as required by TSI Loc&Pas section 4.2.4.4.1.</p>

4.3.4 Special Brake Inhibit – Trackside Orders

4.3.4.1 To be harmonized.

4.3.5 Special Brake Inhibit – STM Orders

4.3.5.1 Analysis is national system specific.



4.3.6 Special Brake Status

- 4.3.6.1 If vehicle is equipped with special brakes the special brake status can be relevant to calculate the brake model, see 5.1.4.6.
- 4.3.6.2 If vehicle is not equipped with special brakes, no failure may arise.

4.3.7 Additional Brake Status

- 4.3.7.1 See 5.1.4.7.1.

4.4 Description of the Fault Effects of Control of Train Functions

4.4.1 Change of traction system

- 4.4.1.1 To be harmonized.

4.4.2 Pantograph (Trackside orders / STM orders)

- 4.4.2.1 Trackside orders: To be harmonized.
- 4.4.2.2 STM orders: Multiple failures have no effect in the system.

4.4.3 Air tightness (Trackside orders / STM orders)

- 4.4.3.1 Trackside orders: To be harmonized.
- 4.4.3.2 STM orders: Multiple failures have no effect in the system.

4.4.4 Passenger door

- 4.4.4.1 To be harmonized.

4.4.5 Main Power Switch – Trackside orders

- 4.4.5.1 To be harmonized.

4.4.6 Main Power Switch – STM orders

- 4.4.6.1 Multiple failures have no effect in the system.

4.4.7 Traction Cut-Off

4.4.7.1 TCO with parallel output O_TC1_C and serial output O_TC2_C allowing a safe TCO affecting the braking curves (failure to cut the traction when EBI is exceeded). Fault tree for this case (4.4.7.2-0_TCO_PAR_SER):

4.4.7.1.1 TIU-related hazards

Gate	Explanation
G-TCO-2.1, G-TCO-2.2	<p>A failure leads to TCO command failure only if there are two failures for loss of TCO signal (O_TC1_C parallel and O_TC2_C serial) at the same time.</p> <p>The failure rate of the on-board part must be a part of the ETCS Core Hazard (6,7 E-10 /h) which is fulfilled according to the FTA 4.4.7.2.1_OBU-TCO.</p> <p>The signals O_TC1_C parallel and O_TC2_C serial must be output physically independent which is fulfilled due to the diversity of the output paths.</p>

4.4.8 Change of allowed current consumption

4.4.8.1 To be harmonized.

4.5 Description of the Fault Effects of Train Status Information

4.5.1 Cab status

4.5.1.1 Fault tree for the parallel interface (4.5.1.1_CS_PAR)

4.5.1.2 Single failures have no safety-relevant effect in the system; compare FMEA in Annex A, 6.1. Therefore it can be assumed that the first single failure of one of the two individual inputs is detected by ETCS and reaction is applied since cab A active /cab B active is a not admitted condition. But in addition to this consideration there is the following multiple failure analysis.

4.5.1.2.1 Assumption of the cases considered in the fault tree:

4.5.1.2.1.1 Mitigation condition according to analysis of KERNEL15 in Subset-088: MA points in the allowed direction.

4.5.1.2.1.2 Modes: All expect NP, SF and IS, see analysis of KERNEL15 in Subset-088.

4.5.1.2.2 Barriers

Event	Explanation
E-ext-IL	According to Subset-088 an exported condition against incorrect cab status is that the interlocking must protect against track occupancy and there must be appropriate

Event	Explanation
	operational rules. The interlocking system is designed as a safe system with an appropriate failure rate.

4.5.1.2.3 TIU-related hazards

Gate	Explanation
G-CS-1	The wrong desk reported open resulting in incorrect train position is reported to Trackside due to a multiple fault of T_CS_A = 1 and T_CS B = 0 fails to T_CS_A = 0 and T_CS B = 1, or vice versa.

4.5.2 Direction Controller status

4.5.2.1 Fault tree for the parallel interface (4.5.2.1_DCP_PAR)

4.5.2.1.1 Assumption of the cases considered in the fault tree:

Vehicle is on a downhill slope (T_FW_S failure is relevant for downhill slope and T_BW_S is not considered due to relevant for uphill only).

4.5.2.1.2 Barriers

Event	Explanation
E-ext-RP	The vehicle is in charge to ensure the roll away protection (e.g. brakes applied safely). Driver interaction failure with a frequency of 1E-3 is assumed as worst case. Standstill information from ETCS odometer is only a mitigation for vehicle running but not for the described case of standstill.
E-ext-DS	Driver's activity control function is supported by Fail-safe Dead-Man Supervision (TSI Loc Pas, chapter 4.2.9.3.1).

4.5.2.1.3 TIU-related hazards

Gate	Explanation
G-DCP-1	A single failure of the Direction Controller signals could lead to the direction controller information "no direction (neutral)" (coding T_FW_S = 0 and T_BW_S = 0) and consequently to loss of vehicle roll away protection.

4.5.3 Train integrity

4.5.3.1 To be harmonized.



4.5.4 Traction Status

- 4.5.4.1 The traction status is forwarded to the STM. The information related to STMs is seen as out of scope of this safety analysis focusing on level 1 and level 2 aspects.”

4.6 Description of the Hazardous Events of Train Data

4.6.1 Type of train data entry

- 4.6.1.1 Multiple failures have no effect in the system.

4.6.2 Train data information

- 4.6.2.1 To be harmonized.

4.7 Description of the Fault Effects of National System Isolation

4.7.1 National System Isolation

- 4.7.1.1 This is level NTC only which is seen as out of scope of this safety analysis focusing on level 1 and level 2 aspects.

5. CONCLUSIONS: REQUIREMENTS FOR TI

5.1 Interface Requirements

5.1.1 General Considerations

- 5.1.1.1 In this chapter TFR values are required depending on certain FDT values and in some cases on certain common cause factors. Also other values can be used in project specific safety cases as long as the quantitative analysis (with the Fault Trees given in this Subset) demonstrates that the THR of the ETCS Core Hazard and the quantitative requirements of TSI Loc&Pas are reached.

5.1.2 Periodic Self Tests

- 5.1.2.1 If an FDT is required in section 5.1 it has to be shown project specific that an adequate measure is implemented for fault detection on the respective interface side (ERTMS/ETCS on-board equipment or vehicle).
- 5.1.2.2 Exported constraints to the ERTMS/ETCS on-board equipment: The ERTMS/ETCS on-board equipment has to ensure periodical self-tests according to the FDT specified for the different functions. If the ERTMS/ETCS on-board equipment cannot perform the technical solution there has to be an exported constraint to the vehicle.
- 5.1.2.3 Exported constraints to the vehicle: The vehicle has to ensure periodical self-tests according to the FDT specified for the different functions. If the vehicle cannot perform the technical solution there has to be an exported constraint to the operation.

5.1.3 Signals for Mode Control

5.1.3.1 Sleeping

5.1.3.1.1 Requirements for ERTMS/ETCS on-board equipment:

- 5.1.3.1.1.1 In case of a failure (inappropriate reception of faulty antivalent Sleeping signal / loss of Sleeping signal) ERTMS/ETCS on-board equipment shall memorize the fault.
- 5.1.3.1.1.2 ERTMS/ETCS on-board shall not be able to switch to SL mode as long as a failure (inappropriate reception of faulty antivalent Sleeping signal / loss of Sleeping signal) is memorized.
- 5.1.3.1.1.3 The alternative reaction is the transition to SF mode in case of the failure.
- 5.1.3.1.1.4 TFR of T_SL_E1_N erroneously takes the value 'Sleeping requested': 1E-05 /h
- 5.1.3.1.1.5 TFR of T_SL_E2_I erroneously takes the value 'Sleeping requested': 1E-05 /h



5.1.3.1.1.6 FDT = 1 min

5.1.3.1.2 Requirements for vehicle:

5.1.3.1.2.1 TFR of T_SL_E1_N erroneously takes the value 'Sleeping requested': 1E-05 /h

5.1.3.1.2.2 TFR of T_SL_E2_I erroneously takes the value 'Sleeping requested': 1E-05 /h

5.1.3.1.2.3 FDT = 48 h

5.1.3.1.3 Exported constraints to the ERTMS/ETCS on-board equipment: The antivalent sleeping signals T_SL_E1_N and T_SL_E2_I shall be read independently according to EN50129.

5.1.3.1.4 Exported constraint to the vehicle: The antivalent sleeping signals T_SL_E1_N and T_SL_E2_I shall have two sources (common cause failures considered with 10%).

5.1.3.1.5 Exported constraint to the vehicle or operation: In the case of vehicle is at standstill and all desks connected to the ERTMS/ETCS on-board equipment are closed, an ERTMS/ETCS on-board equipment independent system is in charge to ensure the standstill (e.g. the driver applied brakes) or a desk connected to another ERTMS/ETCS on-board equipment is open.

5.1.3.2 Passive shunting

5.1.3.2.1 Requirements for ERTMS/ETCS on-board equipment:

5.1.3.2.1.1 TFR of T_PS_E erroneously takes the value 'Passive Shunting permitted': 1E-05 /h

5.1.3.2.1.2 FDT = 48 h

5.1.3.2.2 Requirements for vehicle:

5.1.3.2.2.1 TFR of T_PS_E erroneously takes the value 'Passive Shunting permitted': 1E-05 /h

5.1.3.2.2.2 FDT = 48 h

5.1.3.2.3 Exported constraint to the vehicle or operation: In the case of vehicle is at standstill and all desks connected to the ERTMS/ETCS on-board equipment are closed, an ERTMS/ETCS on-board equipment independent system is in charge to ensure the standstill (e.g. the driver or the vehicle applied brakes).

5.1.3.3 Non Leading

5.1.3.3.1 Requirements for ERTMS/ETCS on-board equipment:

5.1.3.3.1.1 TFR of T_NL_E erroneously takes the value 'Non-Leading permitted': 1E-05 /h

5.1.3.3.1.2 FDT = 48 h

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5.1.3.3.2 Requirements for vehicle:

5.1.3.3.2.1 TFR of T_NL_E erroneously takes the value 'Non-Leading permitted': 1E-05 /h

5.1.3.3.2.2 FDT = 48 h

5.1.3.4 Isolation

5.1.3.4.1 O_IS_S is not safety-related.

5.1.3.4.2 Assumption: This signal is not used for safety purposes e.g. it is not used to isolate the ERTMS/ETCS on-board from brakes.

5.1.4 Signals for the Control of Brakes

5.1.4.1 Service Brake Command

5.1.4.1.1 O_SB_C is not safety-related if the ETCS On-board is not implemented to use Service Brake to protect the train against undesirable movements. If it is, a project specific safety analysis is needed in order to show that a failure of this signal is recognized and the EB is applied as safeguarding.

5.1.4.2 Brake pressure

5.1.4.2.1 T_BP_S is not safety-related.

5.1.4.2.2 If the ETCS On-board is implemented using Service Brake to protect the train against undesirable movements and the Brake Pressure signal is used as Service Brake feedback, then a project specific safety analysis is needed.

5.1.4.3 Emergency Brake Command

5.1.4.3.1 Solution 1:

5.1.4.3.1.1 Requirements for ERTMS/ETCS on-board equipment:

5.1.4.3.1.1.1 TFR of O_EB1_C_1 and O_EB1_C_2 erroneously take the value 'EB not commanded: 3E-06 /h (compare note in section 4.3.3.1.1.)

5.1.4.3.1.1.2 TFR of O_EB2_C_1 and O_EB2_C_2 erroneously take the value 'EB not commanded': 3E-06 /h (compare note in section 4.3.3.1.1.)



5.1.4.3.1.1.3 The two EB signals O_EB1_C_1 and O_EB1_C_2 on the one hand must be output physically independent according to EN 50129 from O_EB2_C_1 and O_EB2_C_2 on the other hand.

5.1.4.3.1.1.4 FDT = 48 h

5.1.4.3.1.2 Requirements for vehicle:

5.1.4.3.1.2.1 TFR of O_EB1_C_1 and O_EB1_C_2 erroneously take the value 'EB not commanded': 1E-07 /h

5.1.4.3.1.2.2 TFR of O_EB2_C_1 and O_EB2_C_2 erroneously take the value 'EB not commanded': 1E-07 /h

5.1.4.3.1.2.3 FDT = 48 h

5.1.4.3.1.3 Exported constraint to the operator: FDT = 48 h.

5.1.4.3.1.4 Exported constraint to the vehicle: The emergency brake signals O_EB1_C_1 and O_EB1_C_2 on the one hand must be independent from O_EB2_C_1 and O_EB2_C_2 on the other hand (common cause failures considered with 1%).

5.1.4.3.2 Solution 2:

5.1.4.3.2.1 Requirements for ERTMS/ETCS on-board equipment:

5.1.4.3.2.1.1 TFR of O_EB1_C erroneously takes the value 'EB not commanded': 3E-06 /h (compare note in section 4.3.3.1.1.)

5.1.4.3.2.1.2 TFR of O_EB2_C erroneously takes the value 'EB not commanded': 3E-06 /h (compare note in section 4.3.3.1.1.)

5.1.4.3.2.1.3 The two EB signals O_EB1_C and O_EB2_C must be output physically independently according to EN 50129.

5.1.4.3.2.1.4 FDT = 48 h

5.1.4.3.2.2 Requirements for vehicle:

5.1.4.3.2.2.1 TFR of O_EB1_C erroneously takes the value 'EB not commanded': 1E-07 /h

5.1.4.3.2.2.2 TFR of O_EB2_C erroneously takes the value 'EB not commanded': 1E-07 /h

5.1.4.3.2.2.3 FDT = 48 h



- 5.1.4.3.2.3 Exported constraint to the operator: FDT = 48 h.
- 5.1.4.3.2.4 Exported constraint to the vehicle: The emergency brake signals O_EB1_C and O_EB2_C must be independent (common cause failures considered with 1%).
- 5.1.4.3.3 Solution 3:
 - 5.1.4.3.3.1 Requirements for ERTMS/ETCS on-board equipment:
 - 5.1.4.3.3.1.1 TFR of O_EB1_C erroneously takes the value 'EB not commanded': 3E-06 /h
 - 5.1.4.3.3.1.2 TFR of OBU_TR_EB3_C erroneously takes the value 'EB not commanded': 1E-7 /h, serial communication of OBU_TR_EB3_C has to be SIL2, i.e. $1E-07 /h \leq THR < 1E-06 /h$
 - 5.1.4.3.3.1.3 FDT = 48 h
 - 5.1.4.3.3.2 Requirements for vehicle:
 - 5.1.4.3.3.2.1 TFR of O_EB1_C erroneously takes the value 'EB not commanded': 3E-06 /h
 - 5.1.4.3.3.2.2 TFR of OBU_TR_EB3_C erroneously takes the value 'EB not commanded': 1E-07 /h, serial communication of OBU_TR_EB3_C has to be SIL2, i.e. $1E-07 /h \leq THR < 1E-06 /h$
 - 5.1.4.3.3.2.3 FDT = 48 h
 - 5.1.4.3.3.2.4 SIL for TCMS (incl. brake control or other electronic devices): SIL 2, i.e. $1E-07 /h \leq THR < 1E-06 /h$
 - 5.1.4.3.3.3 Exported constraint to the operator: FDT = 48 h.
 - 5.1.4.3.3.4 Exported constraint to the vehicle: The emergency brake signals O_EB1_C and OBU_TR_EB3_C must be processed in the vehicle with independence as required by TSI Loc&Pas, section 4.2.4.4.1..
- 5.1.4.4 Special Brake Inhibit – Trackside Orders
 - 5.1.4.4.1 To be harmonized.
- 5.1.4.5 Special Brake Inhibit – STM Orders
 - 5.1.4.5.1 Analysis is national system specific.



5.1.4.6 Special Brake Status

- 5.1.4.6.1 If the vehicle is equipped with special brakes the special brake status can be relevant to calculate the brake model.
- 5.1.4.6.2 It is assumed that EB curve is calculated in such a way that EB distance is not extended by a faulty special brake status signal. This can be achieved if the degree of reliability of O_ECE_I, O_MG_I, O_RB_I, T_MG_S, T_EC_S, T_RB_S, and T_BM_S is considered adequately in the Kdry_rst (V, EBCL, set) values.
- 5.1.4.6.3 Application Constraint (see Subset-080): If using Special Brake as available and affecting the Emergency Brake curve, the failure of the input 'Special Brake status' could have catastrophic safety severity. A project specific safety analysis is required.

5.1.4.7 Additional Brake Status

- 5.1.4.7.1 Currently no Additional Brakes, in addition to the special brakes, are known. Additional brakes should be handled identically as the special brakes are.

5.1.5 Signals for the Control of Train Functions

5.1.5.1 Change of traction system

- 5.1.5.1.1 To be harmonized.

5.1.5.2 Pantograph (trackside orders / STM orders)

- 5.1.5.2.1 Trackside orders: To be harmonized.
- 5.1.5.2.2 STM orders: Pantograph information is not safety-related.

5.1.5.3 Air tightness (trackside orders / STM orders)

- 5.1.5.3.1 Trackside orders: To be harmonized.
- 5.1.5.3.2 STM orders: Air tightness is insignificant for safety.

5.1.5.4 Passenger door

- 5.1.5.4.1 To be harmonized.

5.1.5.5 Main Power Switch – Trackside orders / – STM orders



5.1.5.5.1 Trackside orders: To be harmonized.

5.1.5.5.2 STM orders: Main Power Switch information is not safety-related.

5.1.5.6 Traction Cut-Off

5.1.5.6.1 TCO with parallel output O_TC1_C and serial output O_TC2_C allowing a safe TCO affecting the braking curves:

5.1.5.6.1.1 Requirements for ERTMS/ETCS on-board equipment:

5.1.5.6.1.1.1 TFR of O_TC1_C parallel erroneously takes the value 'Do not cut off traction': $1E-5$ /h

5.1.5.6.1.1.2 FDT of O_TC1_C parallel = 48 h

5.1.5.6.1.1.3 TFR of O_TC2_C serial erroneously takes the value 'Do not cut off traction' $< 1E-06$ /h, serial communication of O_TC2_C serial has to be SIL2, i.e. $1E-07$ /h \leq THR $< 1E-06$ /h

5.1.5.6.1.1.4 FDT of O_TC2_C serial = 1 h

5.1.5.6.1.2 Requirements for vehicle:

5.1.5.6.1.2.1 TFR of O_TC1_C parallel erroneously takes the value 'Do not cut off traction': $1E-05$ /h

5.1.5.6.1.2.2 FDT of O_TC1_C parallel = 48 h

5.1.5.6.1.2.3 TFR of O_TC2_C serial erroneously takes the value 'Do not cut off traction' $< 1E-06$ /h, serial communication of O_TC2_C serial has to be SIL2, i.e. $1E-07$ /h \leq THR $< 1E-06$ /h

5.1.5.6.1.2.4 FDT of O_TC2_C serial = 1 h

5.1.5.6.1.2.5 SIL for TCMS (incl. brake control or other electronic devices): SIL 2, i.e. $1E-07$ /h \leq THR $< 1E-06$ /h.

5.1.5.7 Change of allowed current consumption (ACC)

5.1.5.7.1 To be harmonized.

5.1.6 Signals for Train status Information

5.1.6.1 Cab Status

5.1.6.1.1 Requirements for ERTMS/ETCS on-board equipment:

5.1.6.1.1.1 TFR of T_CS_A erroneously takes the value of the opposite boolean value: 1E-05 /h

5.1.6.1.1.2 TFR of T_CS_B erroneously takes the value of the opposite boolean value: 1E-05 /h

5.1.6.1.1.3 FDT = 48 h.

5.1.6.1.2 Requirements for vehicle:

5.1.6.1.2.1 TFR of T_CS_A erroneously takes the value of the opposite boolean value: 1E-05 /h

5.1.6.1.2.2 TFR of T_CS_B erroneously takes the value of the opposite boolean value: 1E-05 /h

5.1.6.1.2.3 FDT = 48 h.

5.1.6.1.3 Exported constraints to the ERTMS/ETCS on-board equipment: The cab status signals T_CS_A and T_CS_B shall be read independently according to EN50129.

5.1.6.1.4 Exported constraint to the vehicle: The cab status signals T_CS_A and T_CS_B shall have two sources (common cause failures considered with 10%).

5.1.6.2 Direction Controller

5.1.6.2.1 Requirements for ERTMS/ETCS on-board equipment:

5.1.6.2.1.1 TFR of T_FW_S erroneously takes the value 'Forward': 1E-05 /h

5.1.6.2.1.2 TFR of T_BW_S erroneously takes the value 'Backward': 1E-05 /h

5.1.6.2.1.3 FDT = 48 h.

5.1.6.2.2 Requirements for vehicle:

5.1.6.2.2.1 TFR of T_FW_S erroneously takes the value 'Forward': 1E-05 /h

5.1.6.2.2.2 TFR of T_BW_S erroneously takes the value 'Backward': 1E-05 /h

5.1.6.2.2.3 FDT = 48 h.

5.1.6.2.3 Exported constraint to the vehicle or operation: In case of vehicle is at standstill an ERTMS/ETCS on-board equipment independent system is in charge to ensure the roll away protection.



5.1.6.3 Train integrity

5.1.6.3.1 To be harmonized.

5.1.6.4 Traction status

5.1.6.4.1 The traction status is forwarded to the STM. The information related to STMs is seen as out of scope of this safety analysis focusing on level 1 and level 2 aspects.”

5.1.7 Train Data

5.1.7.1 Type of train data entry

5.1.7.1.1 Type of train data entry is not safety-related.

5.1.7.1.2 Exported constraint to the operation (see Subset-080): Driver shall be informed on the type of train when Train Data entry is selected.

5.1.7.2 Train data information

5.1.7.2.1 To be harmonized.

5.1.8 National System Isolation

5.1.8.1.1 This is level NTC only which is seen as out of scope of this safety analysis focusing on level 1 and level 2 aspects.

5.2 Serial transmission

5.2.1 Example for serial input with two inputs

5.2.1.1 In the following a safe serial input on two channels input signal is described by means of sleeping with the two channels antivalent sleeping signal (T_SL_E1_N and T_SL_E2_I), see section 5.1.3.1.

5.2.1.1.1 Requirements for ERTMS/ETCS on-board equipment:

5.2.1.1.1.1 TFR of T_SL_E1_N erroneously takes the value '1': 1E-05 /h

5.2.1.1.1.2 TFR of T_SL_E2_I erroneously takes the value '0': 1E-05 /h

5.2.1.1.1.3 FDT = 1 min



5.2.1.1.2 Requirements for vehicle:

5.2.1.1.2.1 TFR of T_SL_E1_N erroneously takes the value '1': 1E-05 /h

5.2.1.1.2.2 TFR of T_SL_E2_I erroneously takes the value '0': 1E-05 /h

5.2.1.1.2.3 FDT = 48 h

5.2.1.1.3 Exported constraints to the ERTMS/ETCS on-board equipment: The antivalent sleeping signals T_SL_E1_N and T_SL_E2_I shall be read independently (common cause failures considered with 10%).

5.2.1.1.4 Exported constraint to the vehicle: The antivalent sleeping signals T_SL_E1_N and T_SL_E2_I shall have two sources (common cause failures considered with 10%).

5.2.1.1.5 Exported constraint to the vehicle or operation: In the case of vehicle is at standstill and all desks connected to the ERTMS/ETCS on-board equipment are closed an ERTMS/ETCS on-board equipment independent system is in charge to ensure the standstill (e.g. the driver applied brakes).

5.2.2 Architecture a)

5.2.2.1 Requirement for ERTMS/ETCS on-board equipment and vehicle:

5.2.2.1.1 With assumptions made in 3.1.3.1.3 the following example is valid. On basis of subset-120 a safety case has to be created on ERTMS/ETCS on-board equipment side in which these assumptions have to be confirmed or the calculation has to be adopted accordingly.

5.2.2.1.2 Example:

5.2.2.1.2.1 TFR and FDT of signals as for parallel interface.

5.2.2.1.2.2 Two simple I/O devices with respectively TFR = 5E-6 /h and a FDT = 24 h.

5.2.2.1.2.3 TFR = 1,65E-5 /h for bus transmission failures with CRC-16 as transmission code and a bus cycle of 128 ms, and a bus interface card (OBU side) with TFR = 1E-5 /h and a FDT = 24 h.

5.2.3 Architecture b)

5.2.3.1 Requirement for ERTMS/ETCS on-board equipment and vehicle:

5.2.3.1.1 Architecture b) has to be implemented strictly according to EN 50159.

5.2.3.1.2 The communication partners need at least the safety level of the information which is transmitted. The ERTMS/ETCS on-board equipment fulfils this in all cases with a HR



of $6,7E-10$ /h. The THR of the TCMS depends on the information which is transmitted.

- 5.2.3.1.3 All signals requiring a higher SIL than provided by the TCMS shall be transmitted using the Parallel Interface, so that signals are transmitted directly from the source to the ERTMS/ETCS on-board equipment without using TCMS in any part of the transmission.
- 5.2.3.1.4 With assumptions made in 3.1.3.2.3 the following example is valid. On basis of subset-120 a safety case has to be created on ERTMS/ETCS on-board equipment side in which these assumptions have to be confirmed or the calculation has to be adopted accordingly.
- 5.2.3.1.5 Example:
 - 5.2.3.1.5.1 Assumptions: Hardware failure rate of the non-trusted transmission system $R_{HW} = 2E-5$ /h, CRC-8 as transmission code, CRC-32 as safety code, a bus cycle of 128ms and a time of 1 sec as time span T. If more than a defined number of corrupted messages were received within this time T, the safe fall back state will be entered.
 - 5.2.3.1.5.2 Hazardous failure rate of hardware faults (with consideration of the safety code) without transmission code checker $R_{H1} = 4,6 E-14$ / h.
 - 5.2.3.1.5.3 Hazardous failure rate of EMI $R_{H2} = 2,6E-8$ /h
 - 5.2.3.1.5.4 Hazardous failure rate of transmission code checker $R_{H3} = 8,2E-11$ /h
 - 5.2.3.1.5.5 FDT = 1 min.



6. ANNEX A – SAFETY ANALYSIS

6.1 FMEA

6.1.1 Objective

6.1.1.1 The purpose of this FMEA is to analyse, based on architectures described in Subset-119, which single failures lead to which effects and in the end to which hazard.

6.1.2 Assumptions

Column “Ref ID”:

Reference to Subset-119.

Column “Macro function: Data item”:

Macro functions have been numerated taking into account Subset-026, 4.5.2 Active Function Table.

Column “Failure Mode”:

Corruption, deletion, insertion, repetition, re-sequence, delay will be considered, the Failure Mode Guide-words for Data Transmission recommended in Subset-077. Every type of failure can be classified in one or more of these categories.

Column “Failure Cause”:

Possible failure causes are identified in order to estimate its probability of occurrence and to devise corrective action.

Column “Operational mode”:

NP, TR, SF and IS are modes without speed or distance supervision so that they do not have to be mentioned in this column.

Column “Failure Effects”:

Local effect refers to the related interface function.

Intermediate effect refers to the related ETCS supervision function.

Initial End Effect gives a description of the result of this failure. This could be a hazardous situation on system level.

Column “External Protection / Mitigation / Barriers”:

It defines the constraints to be considered for each interface implementation.



Column “Severity”:

A severity level will be assigned to each Initial End Effect, repeated for every failure mode associated with it. The categorisation system to be used will be as the example in EN 50126 for a passenger, part of which is repeated here for convenience, and also complemented with events without safety effect. Classification is according to Subset-077:

Severity Level	Consequence
Catastrophic	Single fatality and/or multiple injuries
Critical	Single severe injury
Marginal	Minor injury
Insignificant	Possible minor injury
RAM issue	Service impact not safety-related
No effect	None

Column “Event-ID”:

Event-ID replaces the former one named as “Failure Rate” (originally in FMEA template). This column will be used to provide the link of all failure effects to TI_OB-xxx and TI_VE-xxx hazardous events in chapter 3.8 (see chapter 1.4).

Column “Internal Barriers”:

References to Subset-026 or other Subsets are contained in brackets.



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
1.	5.1.1.2	Mode Control – Sleeping request information (with two sleeping signals)	Corruption / Deletion / Insertion: Inappropriate reception of faulty antivalent Sleeping signal (T_SL_E1_N or T_SL_E2_I)	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components	SH, FS, LS, SR, OS, NL, UN, PT, SN, RV	ERTMS/ET CS on-board does not change the current mode.			-	RAM issue		



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
2.			Corruption / Deletion / Insertion: Inappropriate reception of faulty antivalent Sleeping signal (T_SL_E1_N or T_SL_E2_I)	Any single failure of the ERTMS/ETCS on-board system or/and of the vehicle components	SB	ERTMS/ETCS on-board does not change the current mode.			-	RAM issue		E.g. ERTMS/ETCS on-board equipment shall memorize the fault. ERTMS/ETCS on-board shall not be able to switch to SL mode as long as the failure is memorized. Alternative reaction e.g.: Transition to SF mode.



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
3.			Corruption / Deletion / Insertion: Inappropriate reception of faulty antivalent Sleeping signal (T_SL_E1_N or T_SL_E2_I)	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components	SL	ERTMS/ET CS on-board equipment shall memorize the fault and shall also try to send an error information to the RBC (Subset-026, 4.4.6.1.6).	Transition to SB mode if the vehicle is at standstill (Subset-026, 4.4.6.1.8).	In case of leaving a tunnel (leading engine in mode RV) then reverse movement will not be possible if the slave engine is in mode SB. TI-3	-	Marginal	SL-1.1 TL_OB-SL-1.2 TL_VE-SL-1.2 TL_OB-SL-1.1 TL_VE-	The engine is remote controlled by the leading engine (Subset-026, 4.4.6.1.3). In addition e. g. ERTMS/ETCS on-board shall not be able to switch to SL mode as long as the failure is memorized.



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
4.			Corruption / Deletion / Insertion: Inappropriate reception of faulty antivalent Sleeping signal (T_SL_E1_N or T_SL_E2_I)	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components	PS	ERTMS/ET CS on-board equipment shall try to memorize the fault and shall also try to send an error information to the RBC (Subset-026, 4.4.20.1.10)..			-	RAM issue		



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
5.	5.1.1	Mode Control – Sleeping request information (with single sleeping signal)	Insertion: Inappropriate reception of Sleeping signal (T_SL_E)	Any single failure of the ERTMS/ETCS on-board system or/and of the vehicle components	SB	“Sleeping requested” state unduly selected during normal operation	Loss of Standstill protection	TI-3	In the case of vehicle is at standstill and all desks connected to the ERTMS/ETCS on-board equipment are closed an ERTMS/ETCS on-board equipment independent system is in charge to ensure the standstill	Catastrophic	TI_OB-SL-1, TI_VE-SL-1	



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
6.			Insertion: Inappropriate reception of faulty Sleeping signal (T_SL_E) Already analysed in Subset-080	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components	SL, PS							
7.	5.1.1.2	Mode Control – Sleeping request information (solution 1 – serial transmission with architecture a) on two channels input, no safety layer is used)	Insertion / Corruption/ Re-sequence: Inappropriate reception of faulty antivalent Sleeping signal (T_SL_E1_N or T_SL_E2_I)	Simple I/O-device failure (vehicle part) or bus falsifies telegram	SH, FS, LS, SR, OS, NL, UN, PT, SN, RV	ERTMS/ET CS on-board does not change the current mode.			-	RAM issue		

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Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
8.		Mode Control – Sleeping request information (solution 1 – serial transmission with architecture a) on two channels input, no safety layer is used)	Insertion / Corruption/ Re-sequence: Inappropriate reception of faulty antivalent Sleeping signal (T_SL_E1_N or T_SL_E2_I)	Simple I/O-device failure (vehicle part) or bus falsifies telegram or Bus interface card failure (OBU part)	SB	ERTMS/ETCS on-board does not change the current mode.			-	RAM issue		E.g. ERTMS/ETCS on-board equipment shall memorize the fault. ERTMS/ETCS on-board shall not be able to switch to mode SL as long as the failure is memorized. Alternative reaction e.g.: Transition to SF mode.



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
9.			Insertion / Corruption/ Re-sequence: Inappropriate reception of faulty antivalent Sleeping signal (T_SL_E1_N or T_SL_E2_I)	Simple I/O-device failure (vehicle part) or bus falsifies telegram	PS	ERTMS/ETCS on-board equipment shall try to memorize the fault and shall also try to send an error information to the RBC (Subset-026, 4.4.20.1.10).			-	RAM issue		ERTMS/ETCS on-board shall not be able to switch to SL mode as long as the failure is memorized



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
10.			Insertion / Corruption / Re-sequence: Inappropriate reception of faulty antivalent Sleeping signal on two channels input (T_SL_1C-N and T_SL_2C-I)	Bus interface card failure (OBU part)	SH, FS, LS, SR, OS, NL, UN, PT, SN, RV	Transition to SL mode not possible; current mode is not changed.				No effect		



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
11.			Insertion / Corruption // Re-sequence: Inappropriate reception of faulty antivalent Sleeping signal on two channels input (T_SL_E1_N or T_SL_E2_I)	Simple I/O-device failure (vehicle part) orbus falsifies telegram or bus interface failure (OBU part)	SL	ERTMS/ETCS on-board equipment shall memorize the fault and shall also try to send an error information to the RBC (Subset-026, 4.4.6.1.6).	Transition to SB mode if the vehicle is at standstill (Subset-026, 4.4.6.1.8).	In case of leaving a tunnel (leading engine in mode RV) then reverse movement will not be possible if the slave engine is in mode SB. TI-3	-	Marginal	TI_OB-SL-1.2TI_VE-SL-1.1 TI_VE-SL-1.1	The engine is remote controlled by the leading engine (Subset-026, 4.4.6.1.3). In addition e. g. ERTMS/ETCS on-board shall not be able to switch to SL mode as long as the failure is memorized



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
12.	5.1.2.2	Mode Control – Passive Shunting information	Corruption / Insertion: Inappropriate reception of faulty Passive Shunting signal (T_PS_E)	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components	SH	Transition to PS mode during normal operation.	No more movement protection, unable to apply brakes.	TI-7	Driver has to ensure the standstill (e.g. by applying the parking brake before leaving the cab).	Catastrophic	TI_OB-PS, TI_VE-PS	Second information from the DMI is necessary to change to PS mode.
13.			Corruption / Deletion: Loss of Passive Shunting signal (T_PS_E) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
14.	5.1.3.2	Mode Control – Non Leading information	Corruption / Insertion: Inappropriate reception of Non Leading signal (T_NL_E)	Any single failure of the ERTMS/ETCS on-board system or/and of the vehicle components	SB, SH, FS, LS, SR, OS	Transition to Non Leading mode if vehicle is at standstill and driver selects Non Leading in the DMI.	No more movement protection, unable to apply brakes.	TI-8	New mode is displayed on the DMI. Driver is not going to leave the cab.	Catastrophic	TI_VE-NL, TI_OB-NL	Vehicle at standstill and second information from the DMI are necessary to change to NL mode (Subset-026, 4.6.3, [46]).
15.			Corruption / Deletion: Loss of Non Leading signal (T_NL_E) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
16.	5.1.4.2	Mode Control – Isolation	Deletion / Delay: Loss of Isolation signal (O_IS_S) (O_IS_S = 0 instead of 1) Already analysed in Subset-080									
17.			Corruption / Insertion: Inappropriate output of isolation signal (O_IS_S = 1 instead of 0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
18.	5.2.1.2	Signals for the Control of Brakes – Service Brake command	Deletion/Delay: Loss of SB command signal (O_SB_C = 0 instead of 1) Already analysed in Subset-080									
19.			Corruption/Insertion: Inappropriate output of SB command signal (O_SB_C is = 1 instead of 0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
20.	5.2.2.2	Signals for the Control of Brakes – Brake pressure	Corruption/ Insertion: Inappropriate reception of Brake pressure signal (T_BP_S) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
21.	5.2.3.2.10	Signals for the Control of Brakes – Emergency Brake command (solution 1 - 3)	Deletion/Delay: Loss of Emergency Brake command signal (Failure to Command Emergency Brake Application when required) (solution 1/2: O_EB1_C, O_EB2_C; solution 3: O_EB1_C, OBU_TR_EB3_Cmd)	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components.	SB, SH, FS, LS, SR, OS, UN, PT, SN, RV	EB application command not transmitted to the vehicle	EB Not activated when required	TI-1	Two independent EB lines (e.g. brake valves) are necessary	Catastrophic	TI_OB-EB-1, TI_VE-EB-1, TI_OB-EB-2, TI_VE-EB-2	



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
22.			Corruption/ Insertion: Inappropriate output of Emergency Brake command signal (commanded when not required) (solution 1/2: O_EB1_C, O_EB2_C; solution 3: O_EB1_C, OBU_TR_EB3_Cmd) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
23.	5.2.4	Signals for the Control of Brakes – Special Brake inhibit – Trackside Orders										To be harmonized
24.	5.2.5	Signals for the Control of Brakes – Special Brake inhibit – STM Orders	Deletion/Delay: Loss of any Inhibition of Special Brakes signal (O_RB_I, O_MG_I, O_ECS_I or O_ECE_I = 0 instead of 1) Already analysed in Subset-080	Analysis is national system specific.								



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
25.			Corruption/ Insertion: Inappropriate output of any Inhibition of Special Brakes signal (O_RB_I, O_MG_I, O_ECS_I or O_ECE_I = 1 instead of 0)	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components	SN	Analysis is national system specific.						
26.	5.2.6.3	Signals for the Control of Brakes – Special Brake Status	Deletion/ Delay: Loss of active state information (special brake enabled) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
27.			Insertion / Incorrect: Inappropriate output of active state information (special brake enabled)	Any single failure of the ERTMS/ETCS on-board system or/and of the vehicle components	All modes except SL, NL, PS, SH, SB, RV	Special Brake is erroneously not used for EB.	OBU assumes too optimistic braking curves.	TI-1		Insignificant		EB model (Kdry_rst) is calculated in such a way that EB distance is exceeded only according to the actual EBCL.
28.	5.3.2	Signals for the Control of Train Functions – Change of traction system (CTS)										To be harmonized.



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
29.	5.3.3	Signals for the Control of Train Functions – Pantograph – Trackside orders										To be harmonized.
30.	5.3.4	Signals for the Control of Train Functions – Pantograph – STM orders	Corruption: Inappropriate output of Pantograph information Already analysed in Subset-080									
31.	5.3.5	Signals for the Control of Train Functions – Air tightness – Trackside orders										To be harmonized.

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Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
32.	5.3.6	Signals for the Control of Train Functions – Air tightness – STM orders	Corruption: Inappropriate output of Air tightness information Already analysed in Subset-080									
33.	5.3.7	Signals for the Control of Train Functions - Passenger door										To be harmonized.



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
34.	5.3.8	Signals for the Control of Train Functions – Main Circuit Breaker – Trackside orders										To be harmonized.
35.	5.3.9	Signals for the Control of Train Functions – Main Circuit Breaker – STM orders	Corruption: Inappropriate output of Main Circuit Breaker information Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
36.	5.3.11	Signals for the Control of Train Functions – Traction Cut-Off	Corruption / Insertion: Inappropriate output of Traction Cut-Off (request when not required) for Already analysed in Subset-080									
37.			Corruption / Deletion: Loss of TCO Signal (O_TC1_C parallel or O_TC2_C serial)	Any single failure of the ERTMS/ETCS on-board system or/and of the vehicle components	All modes except SL, NL, PS, SH, SN, RV	TCO application command (CUT OFF TRACTION state) transmitted to the vehicle via second path.	Traction is cut off at warning limit		Two diverse TCO paths	Catastrophic	TL_OB-TCO-1, TL_OB-TCO-2, TL_VE-TCO-1, TL_VE-TCO-2	



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
38.	5.3.10	Signals for the Control of Train Functions – Change of allowed current consumption (ACC)										To be harmonized.
39.	5.4.1.2	Signals for Train Status Information – Cab Status	Deletion/Delay: Loss of Cab Status signal (T_CS_A or T_CS_B) (cases 1/0 or 0/1 fails to 0/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
40.			Corruption/ Insertion: Inappropriate reception of Cab Status signal (T_CS_A or T_CS_B) (cases 1/0 or 0/1 fails to 1/1) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
41.			Corruption/ Insertion: Inappropriate reception of Cab Status signal (T_CS_A or T_CS_B) (cases 0/0 fails to 0/1 or 1/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
42.			Corruption/ Insertion: Inappropriate reception of Cab Status signal (T_CS_A or T_CS_B) (cases 0/0 fails to 0/1 or 1/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
43.			Corruption/ Insertion: Inappropriate reception of Cab Status signal (T_CS_A or T_CS_B) (cases 0/0 fails to 0/1 or 1/0) Case: driver changes the Cab Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
44.			Corruption/ Insertion: Inappropriate reception of Cab Status signal (T_CS_A or T_CS_B) (cases 0/0 fails to 0/1 or 1/0) Case: Slave engine Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
45.			Corruption/ Insertion: Inappropriate reception of Cab Status signal (T_CS_A or T_CS_B) (cases 0/0 fails to 0/1 or 1/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
46.			Deletion/Delay: Loss of Cab Status signal (T_CS_A or T_CS_B) (cases 1/0 or 0/1 fails to 0/0) Already analysed in Subset-080									
47.			Deletion/Delay: Loss of Cab Status signal (T_CS_A or T_CS_B) (cases 1/0 or 0/1 fails to 0/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
48.			Deletion/Delay: Loss of Cab Status signal (T_CS_A or T_CS_B) (cases 1/0 or 0/1 fails to 0/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
49.	5.4.2.2	Signals for Train Status Information – Direction Controller status	Deletion/Delay: Loss of Direction Controller status signal (T_FW_S or T_BW_S) (cases 1/0 or 0/1 fails to 0/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
50.			Corruption/ Insertion: Loss of Direction Controller status signal (T_FW_S or T_BW_S) (cases 1/0 or 0/1 fails to 1/1)	Any single failure of the ERTMS/ET CS on-board system or/and of the vehicle components	SH, SR, OS, NL, UN, PT, RV, FS, LS, SR	Incorrect Direction Controller status (fault condition).	Transition to SF mode and EB applied.	Vehicle will be at standstill.		RAM issue	-	



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
51.			Corruption/ Insertion: Inappropriate reception of Direction Controller status signal (T_FW_S or T_BW_S) (cases 0/0 to 0/1 or 1/0) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
52.			Corruption/ Insertion: Inappropriate reception of Direction Controller status signal (T_FW_S or T_BW_S) (cases 0/0 to 0/1 or 1/0)		SH, SR, OS, UN, PT, RV, FS, LS	Incorrect Direction Controller status.	Roll away protection is deactivated	No more protection of the vehicle by ETCS. TI-5	1.) Driver (knows the direction controller position) 2.) Safety-related function: Roll away protection and driver's activity control function is supported by Fail-safe Dead-Man Supervision (TSI Loc Pas, chapter 4.2.9.3.1) or additionally other vehicle side roll away protection systems 3.) The driver has to ensure the standstill before leaving the cab.	Catastrophic	TI_OB-DC-1, TI_OB-DC-2, TI_VE-DC-1, TI_VE-DC-2	Reverse movement protection.
SUBSET 0.2.11	120				FFFI	TI – Safety Analysis		Page 86/91				

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Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
53.			Corruption/ Insertion: Inappropriate reception of Direction Controller status signal (T_FW_S or T_BW_S) (cases 0/0 to 0/1 or 1/0) Already analysed in Subset-080		NL, SB							
54.	5.4.3	Signals for Train Status Information – Train integrity	To be harmonized									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
55.	5.4.4.2	Signals for Train Status Information – Traction Status	Not harmonized, since the signal is only related to STMs									
56.	5.5.1.3	Train data – Type of train data entry	Deletion / Delay: Loss of Type of train data entry signal (T_TT_S1 / T_TT_S2 unwantedly equal to Flexible) Already analysed in Subset-080									



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
57.			Corruption / Insertion: Inappropriate reception of Type of train data entry signal (T_TT_S1 / T_TT_S2 unwantedly equal to Fixed) Already analysed in Subset-080									
58.	5.5.2.2.2	Train data – Train data information										To be harmonized



Line No.	Ref ID	Macro Function: Data Item	Failure Mode	Failure Cause	Operational Mode	Failure Effects			External Protection / Mitigation / Barriers	Severity	Event-ID	Internal Barriers
						Local	Intermediate	Initial End Effect				
59.	5.6.1.2	National System Isolation	Level NTC only, see Subset-080.									

6.2 Fault Trees



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