UNISIG

ERTMS/ETCS

ETCS Application Level 2 - Safety Analysis

Part 2 - Functional Analysis

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ALSTOM		
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THALES		

1. MODIFICATION HISTORY

Issue Number Date	Section Number	Modification / Description	Author
0.0.1. 14-05-01	All	Document Creation	WLH
0.0.2 25-05-01	4	Key to the fault tree symbols added	WLH
0.1.0 14-06-01	3.1.1.2 & 5.2.1.2	Inclusion of Ansaldo comments. Release for general Unisig review	WLH
0.1.1. 25-06-01	Section 8 Appendix B	Initial comments added Fault tree raised to issue 005.	WLH
0.1.2. 06-08-01	All	Document restructured into 4 parts. This part becoming part 3	WLH
0.1.2. Draft 06-08-01	All	Draft Issue	GM
0.1.3. 22-08-01	All	Updated following review in Stuttgart.	GM
0.1.4 24-08-01	Part Number	Part Number changed from Part 3 to Part 2	GM
0.1.5. 03-09-01	All	Updated following UNISIG RAMS group review.	GM
0.1.6. 18-09-01	All	Minor modification following UNISIG RAMS review meeting	GM
0.1.7. 31-09-01	All	Minor modification following UNISIG Supergroup / RAMS Group meeting	GM
0.2.0. 01-10-01	Sections 3 & 4	Minor modifications and raised in issue for release to Esrog	WLH
0.2.1. 01-11-16	All	Modifications suggested by Bombardier	DARI

0.2.2 01-11-21	5.1.1.5	Comments on Emergency Message	RAMS meeting 2001-11-21
0.2.3 01-11-28	All	Comments by BTS	DARI
0.2.4 01-11-30	All	consistency check with Part 1	Ado
0.2.5 01-12-13	All	Updates after RAMS-meeting 2001-12-06	DARI
0.3.0 02-01-15	All	Minor updates after comments from ANS, CSEE, SIE and comments at RAMS-meeting 02-01-10	DARI
2.0.0. 26-02-02	Minor changes to 3.1.1.1 & 3.1.1.2.	Raised in issue for release to the EEIG	WLH
2.0.1 26-10-02	Document title 4.1.1.2. Added as new paragraph. Analysis work sheets MMI-2, TI-6 and TRACK	Report Number deleted Notes re MMI-2 and TI-6 breakout added to the analysis sheets. Note regarding analysis of TRACK events clarified. Sections 7 & 8 moved to Part 3 of Subset 088	WLH
2.0.2. 10-12-02	4.1.1.2 rewritten Minor modifications to section 6	Address review comments from Ans and Sie. Improve links to the Fault tree and clarification of events	WLH
2.0.3 15-01-03	4.1.1.2 ODO 4 amended Some event descriptions improved. TRANS events rationalised	Comments raised at the review meeting of 14-01-03	WLH
2.0.4 27-01-03	Diagram added		WLH
2.1.0. 31-01-03		Raised in issue for release to the Users Group	WLH

2.2.2 21-03-03		Final release after amendment to reflect the comments in the final report from the ISA's version 1.1 dated 07-03-03 as proposed via the Unisig consolidated review comments on the ISA report v 0.0.2 March 03.	WLH
2.2.3 25-05-04	All	Updated with new events added to Fault Tree: Kernel-33 Kernel-34	IS
2.2.4 19-10-04	Section 6	Section 6.- Mode Column reviewed and updated with applicable modes Section 6.- Changed affected functions of events Kernel-23, 33 & 34	IS
2.2.10 08-07-05		Raised in issue for release to the Users Group. Version number to be consistent with SUBSET-091.	DARI
2.2.11 20-09-07		Formal changes, corrections of grammar and spelling	KN
2.3.0 02-04-08		Administrative updates for baseline 2.3.0	DARI
2.3.1 15-03-11	Section 6	Include new mode Limited Supervision Insert new column "mitigation conditions" in FMEA and update according to methodology concluded in RAMS group	KN
		"MMI" changed to "DMI" except for "MMI-x" events	
		Change "location" to "position" where applicable according to CR808	

		Adaptation to Subset.026, 3.2.0 Update with new/changed MMI-x events according to final version of Subset-079 (updated to 2.3.0)	
2.3.2	Section 6	Update according to Subset-079: MMI-4 removed	KN
2.3.3		Update according to Subset-079: MMI-2j and MMI-4 added, MMI-2i removed	KN
3.0.0		Update according to Subset-079: MMI- 2j, MMI-2k and MMI-5 added, MMI-2a split into MMI-2a.1 and MMI-2a.2	KN
3.0.1	Section 6	Update according to Subset-079: Event description changed, MMI-1g added, modes added	KN
3.0.2		Update after internal RAMS WP review	KN
3.0.3		Minor updates during RAMS-meeting	DR
3.1.0		CR1106 considered. Administrative changes for release to ERA.	DR
3.2.0		• Use ETCS Core Hazard. As standardized term • Override EoA is renamed to Override • MMI-6 added • MMI-2d: LS mode removed • MMI-2a.2: First Line of Intervention added	KN

3.3.0		Update after internal RAMS WP review	KN
3.4.0		Minor updates during RAMS-meeting	DR
3.5.0		Baseline 3 release version	DR
3.5.1 2013-01-31		Updated relevant modes for TI-1	KN
3.5.2		Update for B3 MR1 based on changes in Subset-079 (event description changed) and in Subset-080 (new events added)	KN
3.5.3		Updated during RAMS-meeting	DARI
3.5.4	Section 6	Renaming of MMI-2F	KN
3.5.5	TI-10	Update according to SUBSET-080	KN
3.5.6	Section 6	TI-6a deleted according to SUBSET-080 Formal Updates	KN
3.5.7	Section 6	TI-4 updated according to SUBSET-080	KN
3.6.0 2016-06-20	No change	Baseline 3 2nd release version	RAMS WP
3.7.0	No change	Release version	RAMS WP
3.7.1	Section 6	ODO-4: description was changed to clarify that this base event also covers relocation function. This issue is related to CR1370 ODO-5: this new base event is introduced in connection with analysis of CR1345 for cold movement functionality	KN
3.7.2	Section 6	Formal correction	KN
		New template	KN

3.7.3	Section 6	New events EXT-4, EXT-5, DRV-6	TH
3.7.4	Section 6 Section 5.1.1.5	Level 2 exchanged with Level R TI-12, TI-13 added Confirmed train length added	KN
3.7.5	5.1.1.5 Section 6 Section 6.1	Use of channel clarified ENG-4, EXT-4, DRV-3 (length) updated Change due to CR1354 MMI-1i and MMI-2l added VBC Analysis added	KN
3.7.6	Section 6 5.1.1.5.3	SIL2 requirement added to EXT-4 and EXT 5 ODO-5: clarification added TI-13: mode SM removed Note to High Priority Channel deleted (CR1423)	KN
3.7.7	No change	Internal RAMS Baseline	RAMS WP
3.7.8	Section 6	Changes in alignment with Subset-120	KN
3.7.9	Section 6 5.1.1.5	Changes in alignment with Subset-120 EECT Meeting 2023/02/14, MMI-1j and MMI-2m added Changes based on CR940	KN
3.7.10	Whole document Kernel-35, -36 added ODO-4	Level R exchanges with Level 2 New events for relocation Delete reference to relocation	KN

3.7.11		Editorial changes: Official release to SG Note: A previous edition was used to update and finalise SUBSET-091 (ed. 4.0.0). In the meantime, this document was also completed and the updated edition of this document does not affect the content of SUBSET-091	RAMS WP
3.8.0 07-05-24	Cover page, footer, 4.1.1, 6.1.3	Application of quality checks proposed by SG Baseline 4 release version	KN

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3. INTRODUCTION

3.1.1.1 This document is Part 2 of the ETCS analysis. It contains the Application Level 2 analysis and provides the functional analysis of a Level 2 system in order to identify issues that are key to achieving technical interoperability.

3.1.1.2 The first objective of this analysis is to analyse the effect of potentially catastrophic failures at the mandatory boundaries to the ERTMS/ETCS UNISIG reference architecture (as captured in the FMEA's listed in Part 0) and also within ETCS. The second objective is to determine all claims that could be made to prevent or reduce the probability of the ETCS Core Hazard defined in Part 1 occurring as a result of these failures.

3.1.1.3 The analysis includes consideration of each of the main operational modes of the system applicable to level 2in a manner whereby all assumptions are clearly visible.

4. DESCRIPTION

4.1.1.1 This functional analysis considers each fault tree base event from the functional fault tree in turn. The fault tree base events represent the low-level functions and data items of ETCS.

4.1.1.2 The fault tree in Part 1 of SUBSET-088 is oriented to system functionality. For the quantitative apportionment of the ETCS THR to constituents be undertaken in Part 3 of SUBSET-088, some events indicated in the fault tree have been decomposed to a lower level in order to clearly align as on-board, air gap or trackside. This has been undertaken in accordance with the allocation defined in the ERTMS/ETCS UNISIG reference architecture. More precisely:

The TRANS-ENTITY-X events in the following table refer only to errors occurring in the communication channel including the non-trusted parts of transmitting and receiving entities. As a consequence, events corresponding to errors in the on-board and trackside kernel functionality that were not explicitly identified in the fault tree have been added. This has required the changing of some names from the fault tree.

Note: the entities considered for Level 2 are Balise and Radio (on-board or trackside) where X is allocated as,

1 for Corruption

2 for Deletion

3 for insertion

These being the hazardous events identified in the transmission FMEAs.

TRACK-X events identified in the fault tree included errors in the engineering process in order to identify data errors that could affect functionality, both in the ETCS equipment and in the communication channel. They therefore represent a combination of events already identified. Thus, the TRACK-X events are listed in the following table but are not used in the apportionment process undertaken in Part 3 of SUBSET-088.

4.1.1.3 For each base event, the fault tree gates or hierarchical functions that the base event can affect are identified. This identifies the core functionality of ETCS that could fail as a result of the base event failure. This is used to trace the failure progression of each base event through the fault tree.

4.1.1.4 For each base event a brief explanation is provided to explain the context and content of the base event in relation to the ETCS Core Hazard. This describes the effects of the base event failure on the function of ETCS and how this relates to the ETCS Core Hazard. Base events that cannot be classed as initiating events, for example failures of inherent protective functions (see further 4.1.1.6) of ETCS, are identified as such in the Explanation column.

4.1.1.5 If the relationship of the base event to the ETCS Core Hazard is dependent on the ETCS mode of operation then this is identified within the analysis and the relevant modes

assessed. If the base event is applicable through all modes of operation then this is identified as such.

4.1.1.6 The role of ETCS is to display to the driver and to enforce the respect of a safe speed and distance. This mitigates against a large number of technical and operational hazards that can occur in the railway environment. ETCS achieves this role by reading information form external entities, estimating the position of trains, elaborating and sending information between on-board and trackside, displaying information and supervising train braking. These are considered the core functions of ETCS.

Moreover, in order to mitigate the possible failures in the core functions, ETCS also implements a set of protective functions, such as supervision of balise group linking, safety coding of messages, etc.

4.1.1.7 Finally, a criticality is assigned to each base event, without taking into consideration any mitigating conditions, based upon whether the event can be classed as Safety Critical, Safety Related or Not Safety Related. These classifications - set by expert judgement - have been used as a guideline for the analysis performed in Part 3 in order to establish the safety requirements for interoperability. The Part 2 classifications are not themselves the requirements.

The following table presents the base event criticality categorisation together with a brief definition of each category as used within the analysis.

4.1.1.8

Assigned Criticality of Base Event	***Interpretation of the Assignment***
Safety Critical Function/Data	A function or data item of ETCS which, if it failed would lead directly to the ETCS Core Hazard.
Safety Related Function/Data	A function or data item of ETCS which if failed in addition with other independent functions or conditions could result in the ETCS Core Hazard.
Not Safety Related	A function or data item of ETCS which if failed in addition with other independent safety related functions or conditions would not result in the ETCS Core Hazard.

4.1.1.9 In assessing mitigating conditions, all possible sources are considered.

5. INTEROPERABILITY CONSIDERATIONS FOR ETCS

5.1.1.1 The following ETCS interoperability considerations have been identified from the analysis in section 6 where dependencies and mitigating conditions that ensure the safe functionality of ETCS are defined. These dependencies are both internal and external relative to the ERTMS/ETCS UNISIG reference architecture.

5.1.1.2 The following ETCS interoperability considerations are grouped into four distinct categories that reflect the core functions of ETCS.

5.1.1.3 Speed and Position Determination:

To ensure that the ETCS on-board system is able to determine its speed and position, reliance is placed upon;

- Eurobalise integrity (reliability and deployment)
- Eurobalise separation (maximum distance between Eurobalise)
- The use of linking information
- Odometry integrity (both reliability and accuracy)

5.1.1.4 Train Speed;

To ensure that the ETCS on-board system is able to respect the maximum permitted train speed and the true speed profile of the track, reliance is placed upon;

- Speed and position determination (as above)
- Driver (respect of indicated information and driver operating procedures)
- Train data (the data entry process, handling of train speed related data and the integrity of this data)
- DMI (integrity of displayed information)
- Receipt of correct information from Trackside (MA Data)

5.1.1.5 Movement Authority Data;

To ensure that the ETCS on-board system is able to respect train separation and dynamic coupling, location of obstructions/restrictions, speed profile and topography, reliance is placed upon;

- Receipt of a correct Movement Authority from the RBC, including optionally Mode Profile and respecting confirmed train length from train ahead for train separation function.
- Generation of a correct location report by the on-board system, (speed and location determination, as above)
- Integrity of displayed information and acknowledgement of these information by driver (e.g. mode profiles or track conditions)

- Calculation of confirmed train length based on overall consist length or train length from train data and train integrity status information

5.1.1.5.1 Note: The Emergency Message is a service that is provided by ETCS to reduce the risk due to hazards coming from outside such as avalanches, road vehicles on track etc.

5.1.1.5.2 Note: The integrity of the Emergency Message is dependent upon the quality and availability of the radio network, which is outside the scope of ETCS. The operator must take into account the probability of delay, deletion or corruption of Emergency messages when estimating the performances that can be achieved by ETCS emergency messages. If very stringent performances are required, it is possible that an additional independent emergency management is needed.

5.1.1.6 Brake Command;

To ensure that the ETCS on-board system is able to enforce respect of all speed and distance limits, reliance is placed upon;

- Correct and timely braking application and execution
- The train braking system
- Train data (the data entry process, handling of train brake assurance and performance related data and the integrity of this data)
- Track data (topography and track conditions)
- The driver (driver vigilance and operating procedures)

5.1.1.7 The safety requirements associated with these ETCS interoperability considerations are developed in Part 3 of this document.

6. FUNCTIONAL ANALYSIS

While executing the FMEA below mitigation conditions are taken into account before assigning the criticality.

A mitigation condition is a barrier or circumstance (either internal or external to ETCS) which help **decreasing the probability** of the Base Event reaching the ETCS Core Hazard. The condition can either be specified in the TSI Annex A or be a commonly accepted property of a railway system (e.g. train acceleration rate).

In the last column of the FMEA conditions can be exported to application or external entity, whereas

- a barrier which has not been judged possible to use as a Mitigation Condition on generic specification level, but that should be further studied in the safety analysis of an application is exported to **application** and
- a derived safety requirement for an external entity (interfacing system or process) is exported to the **external entity**.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
ENG-1a	Incorrect data to trackside constituents from engineering process	Balise Data. System Data, MA Data, Linking data	Balises are positioned incorrectly in relation to its content/embedded information, the on-board confidence interval and / or co-ordinate data.	All		Safety Critical	Engineering data processing and installation procedures need to be of a SIL4 quality
ENG-1b	Incorrect data to trackside constituents from engineering process	Radio Data. MA Data, System Data, Linking data from trackside	Incorrect data preparation for a specific scheme	All		Safety Critical	Engineering data processing need to be of a SIL4 quality

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
ENG-2	Incorrect data to on-board from engineering process for a mission	Train Data	Incorrect data preparation for a specific scheme	All		Safety Critical	Engineering data processing need to be of a SIL4 quality
ENG-3	Incorrect train data from engineering process for permanent storage	Fixed Train Data, ETCS ID	Provision of incorrect train data to the data entry process	All		Safety Critical	Scheme Specific Process External to ETCS Engineering data processing need to be of a SIL4 quality
ENG-4	Incorrect data preparation for overall consist length	Safe Consist Length, Confirmed Train Length, Position Report	Incorrect value of train length configured on-board	All		Safety Critical	Engineering data processing need to be of a SIL4 quality.
EXT-1	Wrong route or aspect transmitted by interlocking function	Route information linked to MA Data, System Data, Linking data	Error in the interlocking function resulting in incorrect information to ETCS	All		Safety Critical	Interlocking required to provide proper routes
EXT-2	Incorrect train data given to engineering process	Train Data, as for ENG-3	Incorrect data preparation for a specific scheme	All		Safety Critical	Engineering data processing need to be of a SIL4 quality

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
EXT-3	Failure to command Emergency Message (external system)	Provision of Emergency Messages	Emergency action not requested when prevailing conditions require emergency action	All		Safety Critical	Outside the control of ETCS Emergency situations does not occur on a regular basis, therefore time at risk will be low.
EXT-4	Incorrect overall consist length provided by external device	Safe Consist Length, Confirmed Train Length	Incorrect train length information to ETCS On-board leads to incorrect Confirmed Train Length in the position report sent to RBC	All		Safety Critical	Overall Consist Length information shall be provided by external source with at least SIL2 quality[1]. If necessary to comply with required safety level in SM mode project specific mitigation should be applied either at ETCS on-board (depending on track access criteria (RINF), e. g. additional independent information with which the safe consist length can be deduced) or at trackside level (trackside

[1] Requirement is based on state of the art

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
							evaluation for train distancing function based on other external entities, e.g. axle counter)
EXT-5	Incorrect train integrity status provided by external source	Position report, Confirmed Train Length	Train integrity confirmed by external source when it is lost or unknown	All		Safety Critical	Train Integrity information shall be provided by external source with at least SIL2 quality. - Intended split: Trackside is informed about a change of the train length information. This information needs to be independent, possibly supported by means of driver validation or independent driver or shunter input.- Unintended Split: Based on the Risk Analysis provided in X2Rail-4 (Deliverable D6.1) the worst case for number of unintended train separations events

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
							in a year is 6,98 x 10-5 /h (per freight train) and 2,61 x 10-6 /h (per passenger train). These values can be used as barrier for the overall THR calculation.
DRV-1	Driver attempts to exceed indicated speed or distance	Safe speed and distance as known by ETCS	Driver attempts to exceed indicated safe speed or distance.	FS	Protected by supervision function of both speed and distance.	Safety Related	
			In OS, SR, SM and SH more responsibility is on the driver to ensure safety. In these modes ETCS does not have all the information about the line, for example unknown obstacles.	SR, SH	In SR and SH modes there is reduced protection. However the train is supervised to a maximum speed (both for SR and SH) and a maximum distance (only for SR and Level 2).	Safety Critical	National procedures need to direct driving in SR and SH mode.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
					Also, in SR or SH, the train is tripped on passing balises containing “Danger for SH”, “Stop if in SR” or balises not in the list given to the train.		
DRV-1 Continued				OS	In OS there is reduced protection; however the train speed and limited distance are supervised by the Dynamic Speed Profile.	Safety Critical	National procedures need to direct driving in OS mode.
			In LS the ETCS on-board equipment is responsible for the background supervision of the train movement to the extent	LS	In LS there is reduced protection; however the train speed and limited	Safety Critical	National procedures need to direct driving in LS mode.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			permitted by the information provided by trackside. The driver must observe the existing line-side information (signals, speed boards etc.) and National operating rules.		distance are supervised by the Dynamic Speed Profile.		
			In SM the ERTMS/ETCS on-board equipment is responsible for the train protection. However, the speed and distance monitoring function will rely on default Train Data.	SM		Safety Critical	The driver (possibly in collaboration with other staff on site or on-board the train) is responsible for - respecting the EOA When approaching an EOA with a release speed, - checking the track occupancy, when performing e.g. a joining operation
DRV-2	Incorrect Driver input of SR speed, Override	MRSP, DSP leading to incorrect	Driver inputs unsafe SR speed or distance.	SR	Prevailing conditions are such that the	Safety Critical	Data entry procedures To have a hazardous situation, also DRV-1

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
		supervision			driver can drive safely at the excessive speed.		needs to happen. This should be evaluation for an application.
			Driver overrides an EOA when not allowed		For override an EOA specific conditions must exist for the facility to be invoked; in particular train speed must be below the National limit for Override.	Safety Critical	Use of EOA is usually subject to Authorisation by trackside personnel, however if the driver decides to select the function, ETCS provides no protection Needs to be covered by national procedures.
DRV-3	Incorrect train data entered by driver	Train Data	The driver inputs incorrect train data into the MMI.	All,	Validation of train data required	Criticality depends on the data.	
DRV-3 (Continued)			Category - Tilting / non-tilting, if incorrect it is possible that the ETCS could allow	All, except SM	Driver vigilance can be claimed in noticing that the train is failing to	Safety Critical	Data entry procedure should protect against basic human error. In SM preconfigured default train data shall be

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			excessive train speed on bends not suitable for non-tilting trains.		tilt on bends.		used by the on-board.
DRV-3 (Continued)			Length - Potential for acceleration out of a change of speed profile too early if the length is understated. Potential derailment possibility on clearing a set of points There could be stopping location issues if train too long for platform. When used for reporting train integrity information RBC does not know that track is occupied. In SM overall consist length information from external source is used instead.	All, (except SM)	Due to acceleration performance of trains only a significant error in length would cause rear end overspeeding	Safety Related	Data entry procedure should protect against basic human error.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
						Safety Critical for train separation function in reporting of min safe rear end position	Interlocking (track occupancy) required to protect against the clearing of points, and collision hazards.
DRV-3 (Continued)			Traction/Brake parameters - The supervision function will be incorrect, and the train will fail to apply safe braking curves In SM preconfigured default train data shall be used by the on-board	All (except SM)	The parameters entered must be an overestimate of the trains braking capability.	Safety Critical	Data entry procedure should protect against basic human error Driver vigilance is presumed.
DRV-3 (Continued)			Maximum Train Speed - The driver inputs a maximum train speed in excess of that permitted for the train. In SM preconfigured	All (except SM)	Needs to be significant error to result in hazard Line speed profile in FS	Safety Critical	Data entry procedure should protect against basic human error. Driver vigilance is presumed

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			default train data shall be used by the on-board				
			Loading Gauge and Axle Load - Entry of incorrect parameters for the High speed network In SM preconfigured default train data shall be used by the on-board	All (except SM)		Safety Critical	Data entry procedure should protect against basic human error.
DRV-4	Incorrect additional data as part of driver input	Train Data	The driver inputs incorrect additional data into the DMI. Driver ID, ETCS Level, RBC ID/ Telephone No or Adhesion Factor.	All	Acknowledgement of data required.	Criticality depends on the data	Data entry procedure should protect against basic human error.
DRV-4 (Continued)			Driver ID - System acquires an incorrect ID, operational data only, not safety related	All		Not a Safety Function	
DRV-4 (Continued)			ETCS Level - System in incorrect level	All	The majority of the time the system will	Safety Related	Data entry procedure should protect against basic human error.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
					undergo a warm start-up and ETCS will only allow valid levels to be entered in accordance with the level transition tables. ETCS start-up procedures		Driver vigilance is presumed
			ETCS Level - During cold start-up the position will not be known and therefore conflict could exist	All	ETCS start-up procedures On passing the first balise group the position will be known	Safety Related	Driver vigilance is presumed,
			Train Running Number - Operational data only, not safety related.	All		Not a Safety Function	
			Radio Data – Network ID RBC ID/Telephone Number - System acquires an incorrect RBC Number	All	Upon start-up the on-board will contact the last known RBC, If unable to contact the RBC there	Safety Related	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
					will be a loss or no communication with RBC and the train will remain under the responsibility of the driver.		
					During a cold start-up, the on-board does not know its position or RBC area. An incorrect RBC could be contacted. For a MA to be provided to the train, the train has to provide a position report.	Safety Related	
DRV-4 (Continued)			Adhesion Factor - Driver fails to perceive that adhesion is, or might be lower and that	All		Safety Critical	Data entry procedure should protect against basic human error. Driver vigilance is

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			adhesion factor should be reduced. System acquires an adhesion factor that is greater than achievable under prevailing conditions. Adhesion factor affects braking curve.				presumed
DRV-5	Incorrect driver input (Override or non-leading, Override route suitability etc.)	Current Mode of Operation	Driver inputs unsafe information	Mode Specific	Transition table conditions have to be fulfilled in order to allow some mode changes	Safety Critical	Operating Rules should protect against human errors.
DRV-6	Incorrect Train Integrity confirmation	Position Report	Driver confirms Train integrity when it is unknown or lost	SB, FS, AD, LS, SR, OS, PT	Train integrity can only be confirmed by driver when train is at standstill and when there is valid Train Data	Safety Critical	Operating Rules should protect against human errors.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
MMI-1a	False acknowledgement of mode change to less restrictive mode	Current Mode of Operation	The DMI erroneously gives acknowledgement to Kernel with the consequence of entry to UN, RV, SN, SR, SH, LS or OS modes without driver knowledge	FS, PT, OS, LS, SB, SH, AD	A request to enter the less restrictive mode is needed. Also, ETCS mode transition table must be fulfilled (SRS ch. 4.6.2).	Safety Related	Driver vigilance is presumed
			The DMI fails to transmit the acknowledgment with the consequence that the driver is not prepared to take more responsibility		Service Brake is applied after 5 seconds		
			The DMI erroneously gives acknowledgement to Kernel with the consequence of entry to IS	all	Isolation status is shown to the driver	Safety Related	Driver vigilance is presumed Use of external switch to enter Isolation mode
MMI-1b	False command	Current Mode of	DMI erroneously issues	SB, SH,	Only possible to	Safety	Driver vigilance. is

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	to enter NL mode	Operation	command for entry to Non-leading. Rollaway protection is removed, brakes isolated and DMI screen still displays many items of FS/OS modes.	FS, LS SR, SM OS, AD	select Non-leading during standstill (see ETCS mode transition table).	Critical	presumes. Operating Rules should protect against human errors. Product specific safe-guarding of NL entry procedure
MMI-1c	False command of Override request	Safe speed and distance as known by ETCS	The DMI issues the command requesting passing of signal at danger without driver intending to do so.	FS, LS OS, SR, SB, SH, UN, PT, SN, AD	Procedures for Override must be fulfilled, kernel accepts the ack only when inside the "rectangle" (SRS ch. 5.8)	Safety Critical	Driver vigilance is presumed
MMI-1d	False acknowledgement of Level Transition	Current Level of Operation	The DMI erroneously gives acknowledgement to Kernel with the consequence avoid or release service brake	FS, LS OS, SR, SB, UN, TR, SH, AD, SN	Procedures for Level Transitions must be fulfilled (SRS ch. 5.10) ETCS mode transition table must be fulfilled (SRS ch. 4.6.2)	Safety Related	Driver vigilance is presumed.
			The DMI fails to transmit		Service brake is		

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			the acknowledgment with the consequence that the driver is not prepared to take more responsibility		applied after 5 seconds (SRS 5.10.4)		
MMI-1e	False acknowledgement of Train Trip	Safe speed and distance as known by ETCS		TR	ETCS mode transition table must be fulfilled (SRS ch 4.6.2).	Safety Related	Driver vigilance is presumed.
MMI-1f	False acknowledgement of Track Ahead Free	Safe speed and distance as known by ETCS The train can go into FS and receive new MA while section is occupied	The DMI sends a false track ahead free to the on-board kernel	SB, SR, OS, PT, LS	There needs to be an obstacle in front of the train for the situation to be dangerous.	Safety Critical	Driver vigilance is presumed Product specific safe-guarding of TAF procedure.
MMI-1g	False request for SH mode	Current Mode of Operation	Shunting initiated at an inappropriate location	SB, FS, LS, SR, OS, SM UN, PT, SN, AD	Shunting Request is only possible at standstill.	Safety Related	Driver vigilance is presumed. Product specific safeguarding of SH entry procedure
MMI-1h	False acknowledgement of undesired	Safe speed and distance as known by ETCS	The DMI erroneously gives acknowledgement to Kernel. Train Brakes	SH, FS, LS,SM, SR, OS,	Reinitializing of supervision function using	Safety Related	Driver vigilance is presumed

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	train movement (RAM, RMP, UDMP, SSS, PT distance and reversing distance)		are released unintentionally.	UN, PT, RV,	new train position		
MMI-1i	False request for SM mode	Safe speed and distance as known by ETCS	Driver is not prepared to take responsibility for Supervised Manoeuvre e.g. check track occupancy, respect EOA	SB, SM, FS, AD, LS, SR, OS, PT	On-board check of authorisation by RBC	Safety Critical	operational rules for driver product specific safeguarding of SM entry procedure
MMI-1j	False command to inhibit BTM alarm reaction	Safe speed and distance as known by ETCS	No reaction is applied when BTM alarm is activated. BG with safety information can be missed.	SB, SH, SR	Inhibition can only be performed when train is in standstill. Inhibition will be revoked when the maximum allowed distance is reached, or if OBU transits to another mode.	Safety Related	Driver is aware of inhibition due to icon displayed on DMI, so Driver vigilance is presumed.
MMI-2a.1	False presentation of	Information to driver	False presentation of the data on the DMI, relative	FS	Protected by on-board	Safety Related	Driver vigilance is presumed

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	train speed		to the data understood by the Kernel - Display of too low actual speed		Supervision and monitoring		
				Other modes than FS	See DRV-1	See DRV-1	See DRV-1
MMI-2a.2	False presentation of speed (except train speed) or distance, including supervision status	Information to driver	False presentation of the data on the DMI, relative to the data understood by the Kernel - Display of too high permitted speed/target speed/release speed/ First Line of Intervention - Display of too long target distance . Display of wrong supervision status	FS	Protected by On-board Supervision and monitoring	Safety Related	Driver vigilance is presumed
				Other modes than FS	See DRV-1	See DRV-1	See DRV-1
MMI-2b	False presentation of mode	Information to driver	False presentation of the data on the DMI, relative to the data understood by the Kernel	SH, SM, AD, LS, SR, OS,	Protected by On-board Supervision and monitoring	Safety Critical	Driver vigilance is presumed

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			- Display of mode that is of higher level of ETCS responsibility than is actually in operation.	NL, UN, PT, SN, RV, IS SB, TR, SF			
MMI-2c	False presentation of track adhesion factor	Information to driver	False presentation of track adhesion on the DMI misleads the driver.	SB, SM, FS, AD, LS, SR, OS, UN, TR, PT, SN, RV	Braking curve calculation by kernel	Safety Critical	Driver vigilance is presumed.
MMI-2d	Failure to present Entry in FS/OS information	Information to driver	Driver does not know that he has to observe speed limitation, because during entry FS/OS track description is not available for whole train length.	FS, OS		Safety Critical	Operational rules for driver
MMI-2e	False presentation of train data/ additional data	Information to driver	Train data are incorrectly displayed or driver is not / incorrectly informed about train data change from an external source	SB, FS, SR, LS, OS, UN, TR, SN, PT, RV, AD, SM	Depending on train data, see further Subset-079	Safety Critical	Operational rules for driver Depending on train data: Product specific safe-guarding

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
MMI-2f	Failure to display Override status including false enabling of override selection	Information to driver	Override is not activated, but active status is displayed	FS, OS, UN, SR, SN, AD, SB, LS, UN, PT, SN	Protected by On-board Supervision	Safety Related	Operational rules for driver
			Override is activated, but active status is not displayed		Kernel supervision of : - SR speed and distance - Override time, distance and balise passage.	Safety Critical	
			enabled override selection: shown when not expected		kernel accepts the request only when inside the "rectangle"(see conditions in SRS 5.8.2.1)	Safety Related	
MMI-2g	Failure to present acknowledge-ment message to a less restrictive mode	Information to driver	Failure to presentation an acknowledgement message on the DMI with the consequence that a transition to a less restrictive mode can happen without the driver being prepared to take over more responsibility.	SB, FS, AD, SH, OS, LS, PT	• kernel check of mode acknowl-edgement. Dependent on mode a) brake if no ack b) no mode	Safety Related	Driver vigilance is presumed.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
					change without ack • kernel monitoring of new mode		
MMI-2h	False presentation of TAF request	Information to driver	Movement authority may be erroneously updated by RBC after driver input	SB, SR, OS, LS, PT		Safety Critical	Operational rules for driver Product specific safe-guarding of TAF procedure
MMI-2i	Failure to present LX “not protected” information	Information to driver	LX “not protected” information is not shown to the driver. Driver could fail to reduce train speed	FS, OS, LS, SM, AD	Protected by On-board Supervision	Safety Related	Driver vigilance is presumed.
MMI-2j	False presentation of reversing allowed	Information to driver	"Reversing allowed" information is shown to the driver. Driver could try reversing against valid MA	FS, LS, OS, AD	Protected by On-board Supervision (UDMP)	Safety Related	Driver vigilance is presumed.
MMI-2k	False presentation of level transition announcement	Information to driver	Missing Level transition announcement prevents the driver from taking over more responsibility in time in case of	FS, LS, SR, OS, NL, UN, TR, PT, SN, AD	Acknowledgment within 5 seconds at level transition point	Safety Related	Driver vigilance is presumed..

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			transition to lower level or National System				
			Unexpected Level transition announcement misleads the driver.	FS, LS, SR, OS, NL, UN, TR, PT, SN, AD	Kernel Monitoring	Safety Related	Driver vigilance is presumed.
MMI-2l	Failure to present Entry in SM information	Information to driver	When the message is not shown driver does not apply manual routines for speed limitation	SM		Safety critical	Operational rules for the driver
MMI-2m	Failure to indicate BTM alarm reaction inhibition	Information to driver	Missing indication of BTM alarm reaction inhibition misleads the driver. OBU is still allowed to move over BMM without track condition stored. In case of real BTM failure, BG with safety information can be missed	SB, SR, SH	Inhibition will be revoked when the maximum allowed distance is reached, or if OBU transits to another mode.	Safety Related	Driver vigilance is presumed.
MMI-3	Falsification of driver's train data/ additional data input stored on-	Train data	Falsification of the driver's train data input to Kernel, without a possibility for the driver to	All		Safety Critical	Driver vigilance is presumed. MMI-3 can be further developed in a product

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	board		realise this				specific fault tree to obtain a less demanding tolerable failure rate for an individual MMI failure.
MMI-4	Falsification of SR speed/ distance data	exceedance of safe speed or distance	Wrong supervision of maximum staff responsible speed or distance due to falsified input.	SR		Safety Critical	Operational rules for driver
MMI-5	Falsification of train integrity confirmation input	Safe speed and distance as known by ETCS	RBC sends a train to an erroneous track due to wrong integrity information	SB, AD, SM, FS, LS, SR, OS, PT UN, SN	Application specific protection measures	Safety Critical	Driver shall notice the split and take safe action. Based on the Risk Analysis provided in X2Rail-4 (Deliverable D6.1) the worst case for number of unintended train separations events in a year is 6,98 x 10-5 /h (per freight train) and 2,61 x 10-6 /h (per passenger train).
MMI-6	Falsification of Virtual Balise Cover	exceedance of safe speed or distance	Wrong processing of balise groups due to falsified input.	SB		Safety Critical	Operational rules for driver

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
ODO-1	Incorrect standstill indication	Standstill Indication	Indicates Standstill when in motion	All	Detected upon passing a balise.	Safety Critical	Driver vigilance is presumed
ODO-2	Speed measurement underestimates trains actual speed	Determination of distance travelled, determination of train position relative to LRBG Position reporting, Provision of MA. Common mode error as it affects both the supervision and the display to the driver	Accuracy of speed known on-board, in ceiling speed monitoring, release speed monitoring and in target speed monitoring in case the compensation of the speed measurement inaccuracy is inhibited	All	In SR the train speed will be low (fixed national value) thus allowing time for driver vigilance.	Safety Critical	Driver vigilance is presumed
ODO-3	Incorrect actual physical speed direction	Determination of train position relative to LRBG	Incorrect train position leading to violation of MA	All	When going forward: ETCS-on-board will think the train is reversing and apply RMP/UDMP. This	Safety Related	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
					is not hazardous, but restrictive. If the forward movement is unintended, the RAP will be disabled. When going backwards: ETCS on-board will think the train is running forward and disable the RMP/UDMP. The error could be discovered when the first expected balise group is not detected, if linking is used.		
ODO-4	The confidence interval for distance measurement does not include	Incorrect determination of speed and position.	Over-estimation of position could result in a premature acceleration from a speed restriction	All	If linking is used, on passing the next balise group outside its expected window,	Safety Critical	The interlocking should prevent trains from occupying the same block

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	the real position of the train	Position Reports, Information to driver.			the balise group will not be accepted and the linking reaction will be invoked (dependent upon linking reaction). But if the error is large (develops quickly) before the next balise group the position of the train known by ETCS on-board is incorrect and potentially dangerous		
				SR	In SR the train speed will be low (fixed national value) thus allowing time for driver vigilance.	Safety Related	Driver is responsible for the movements of the train according to national procedures, therefore should be able to maintain it within safe distance.
ODO-5	Cold Movement	Unsafe train	On-board uses and	NP, SB	Application	Safety	Project specific analysis

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	not detected	position Undetected passing of BG Exceedance of safe distance Erroneously valid information	provides wrong information for train run (incorrect valid position) to RBC, which can provide wrong MA based on wrong position, stored information • EOLM information, • train position, • ETCS Level, • RBC ID, • table of trackside supported levels which is set to invalid when NP is entered is set to valid when cold movement is not detected		specific permissible maximum distance to move in NP is not exceeded. Tolerated non-zero movement will be added to the confidence Interval. In NP EB is permanently commanded.	Critical	for maximum distance which vehicle is permitted to move while being considered “not moved”
KERNEL-1	Balise linking consistency checking failure	Linking reaction	Balise linking consistency is a protective function against linking rules violation.	FS, OS, LS	There has to be another coincident failure for this to result in the ETCS Core Hazard.	Safety Related	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
KERNEL-2	Balise group message consistency checking failure	Provision of Data to on-board (balise message)	Balise group message consistency checking is a protective function against the receipt of inconsistent messages	All (except NP,SL, SF,IS)	There has to be another coincident failure for this to result in the ETCS Core Hazard.	Safety Related	Safety related balise transmission function is required.
KERNEL-3	Failure of radio message correctness check	Provision of Data to On-board (MA etc.)	Radio message correctness check is a protective function against the receipt of inconsistent messages	All (except NP ,SF,IS)		Safety Related	
KERNEL-4	Radio sequencing checking failure	Provision of Data to On-board (MA etc)	Radio sequencing check is a protective function	All (except NP ,SF,IS)	This function is an inherent protective function of ETCS	Safety Related	Message acknowledgement
KERNEL-5	Radio link supervision function failure	Provision of Data to On-board (MA etc)	Radio link supervision is a protective function against receiving the latest valid message later than a specified time. Failure to correctly manage a communication session could result in the loss of communications and a failure to receive	FS, OS, LS	This function is an inherent protective function of ETCS (Linking reaction, T_NVCONTACT)	Safety Related	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			more restrictive route information.				
KERNEL-6	Manage communication session failure	Provision of Data to On-board (MA etc)	Failure to correctly manage a communication session results in the loss of communications and a failure to receive more restrictive route information.	FS, OS, LS	This function is an inherent protective function of ETCS (Linking reaction, T_NVCONTACT)	Safety Related	
KERNEL-7	Incorrect LRBG	Determination of train position to LRBG	All position reports are based upon the LRBG. If the on-board reports an incorrect LRBG to the RBC, the train would appear to be at another location, e.g. the previous LRBG	All (except NP, SF, IS)	This is an inherent core function of ETCS.	Safety Critical	
KERNEL-8	Emergency Message Acknowledgement Failure	Emergency stop failure	On-board acknowledges receipt of message but does not take it into account	FS,OS, LS, SR, PT	This is an inherent core function of ETCS	Safety Related	
KERNEL-9	Speed calculation underestimates train speed	Determination of speed / location	As for ODO-2	All (except NP	This is an inherent core function of ETCS	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
				,SF,IS)			
KERNEL-10	Functional failure of standstill detection	Standstill indication and brake intervention	The on-board commands brake release prior to train being at standstill	All (except NP ,SF)	Driver acknowledgement is required to release brakes.	Safety Related	
KERNEL-11	Incorrect traction/braking model (e.g. brake use restrictions)	Dynamic Speed Profile	This is an inherent core function of ETCS	FS, LS, OS	This is an inherent core function of ETCS	Safety Critical	
KERNEL-12	Failure of standstill supervision	Protection against undesired movements	This is a protective function performed by ETCS	SB		Safety Critical	
KERNEL-13	Failure of reverse movement distance monitoring	Protection against undesired movements	This is a protective function performed by ETCS	PT, RV		Safety Critical	
KERNEL-14	Failure of unauthorised direction movement protection	Protection against undesired movements	This is a protective function performed by ETCS	FS, LS; SR,OS, PT,RV		Safety Critical	
KERNEL-15	Incorrect cab status (TIU failure)	Determination of train position relative to LRBG	Wrong desk reported open resulting in incorrect train position being	All (except NP	MA points in the allowed direction	Safety Critical	Interlocking must protect against track occupancy Operational rules

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			reported to Trackside.	,SF,IS)			
KERNEL-16	Incorrect train status TIU sleeping/cab status	Current Mode of Operation Standstill protection (KERNEL-12)	Detects sleeping	All	ETCS mode transition table must be fulfilled (SRS ch 4.6.2)	Safety Critical	
KERNEL-17	Wrong Acceptance of MA	Provision of Data to On-board (MA etc)	On-board accepts incomplete MA information from trackside	All (except NP ,SF,IS)	This is an inherent core function of ETCS	Safety Critical	
KERNEL-18	Failure to manage RBC/RBC handover	Provision of Data to On-board (MA etc)	Failure to manage the RBC/RBC handover will result in a loss of communications and the on-board being unable to receive more restrictive route information.	All	On-board has current valid MA Maximum time between radio communications, T_NVCONTACT	Safety Related	
KERNEL-19	Failure of train trip supervision in OS, LS and FS	Supervision of EoA / LoA	Failure of train trip monitoring, unable to trip on demand	FS, OS, LS	Inherent protective function of ETCS	Safety Critical	
KERNEL-20	Failure of train trip supervision, shunting and SR	Supervision of train trip.	Failure of train trip monitoring	SH, SR	Inherent protective function of ETCS	Safety Critical	
KERNEL-21	Incorrect	Supervision of	Failure of train trip	SR	Inherent	Safety	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	supervision of stop in SR	EoA / LoA	monitoring		protective function of ETCS	Critical	
KERNEL-22	Incorrect current EoA	Supervision of EoA / LoA Provision and revocation of emergency messages	Incorrect internal data within on-board system leading to the erroneous assumption that the emergency stop position lies beyond the current EoA. Thus the train overruns the emergency stop location	FS, OS, LS		Safety Critical	
KERNEL-23	Incorrect train position / train data sent from on-board to trackside	Report train position Report train valid data Report confirmed train length	The effect of incorrect train data is analysed at DRV 3, ENG-4 and EXT-4 An incorrect train position report could result in the RBC formulating an incorrect MA or the erroneous establishment of an RBC / RBC handover process In case of train separation function, the RBC could send wrong MA to	All		Safety Critical	Protection must be provided by the interlocking and associated train detection methods A quality corresponding SIL-4 for confirmed train length has to be achieved. This can be reached for example when Train Integrity and Train Length are acquired fully independently, or with driver validation of

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			following train based on wrongly determined confirmed train length sent by on-board The event deals with the age of speed and location (timestamp) sent to RBC. The position report might include an “old” timestamp for the associated train location. This also implies the violation of clause 5.3.1.3 included in Subset-041				Train Length or additional information of Train Length from driver/shunter.
KERNEL-24	Failure of message acknowledge-ment	Provision of Data to On-board	Message acknowledgement is a protective feature and is used to ensure that the on-board has correctly received transmitted information RBC receives acknowledgement in error, ATP or driver is not aware of the emergency.	FS, LS	Inherent protective function of ETCS	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
KERNEL-25	Incorrect traction/braking model (Acceleration only)	Braking Intervention Maximum train speed calculation	On traction cut-off, there is a delay until when the train stops accelerating Brake intervention times will be incorrect	SH,FS, LS, OS, SR,UN, RV	Inherent safety function of ETCS	Safety Critical	
KERNEL-26	Deleted						
KERNEL-27	Incorrect System Data (e.g. current level)	Current mode of Operation	ETCS enters incorrect unsafe mode for conditions, i.e. less restrictive mode	All	Inherent core function of ETCS	Safety Critical	
KERNEL-28	Incorrect confidence interval	Determination of distance travelled Determination of train position to LRBG	Train is outside train calculated confidence interval. The confidence interval determines the max front/rear position of the train. The confidence interval increases in relation to the distance travelled from the last location reference depending on the accuracy of odometry	All (except NP,SF, IS)	When passing a balise group, which will (if the error is sufficiently large) be receivedoutside the expectation window, this will prompt activation of the link reaction.	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			equipment.				
KERNEL-29	Failure to shorten MA	Supervision of EOA/LOA	On-board fails to implement MA reduction following co-operative shortening. Only leads to a hazard if the RBC receives information that the on-board has agreed with the shortening.	FS, OS, LS	Inherent core function of ETCS	Safety Related	
KERNEL-30	Incorrect shortening of MA	Supervision of EOA/LOA	On-board applies insufficient shortening of MA	FS, OS, LS	Inherent core function of ETCS	Safety Critical	
KERNEL-33	Wrong processing of MA information	Supervision of EOA/LOA Supervision of train speed	Although the information received from trackside is correct, the on-board fails to establish the correct distance or timers when processing the related MA information	FS, OS, LS	Inherent core function of ETCS	Safety Critical	
KERNEL-34	Incorrect supervision of MA time-outs	Supervision of EOA/LOA Supervision of	on-board applies insufficient shortening of MA following timeout of	FS, OS, LS	Inherent core function of ETCS	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
	(sections and overlaps)	train speed	any timer In case of this event leading to GATE RS, only overlaps time-outs shall be considered for release speed supervision				
KERNEL-35	Incorrect supervision of odometry errors for distance measurement	Check of odometer accuracy thresholds. Storage of accumulated underestimation / overestimation in measuring the movements over a defined total distance	The on-board does not apply safe reaction in case the accumulated underestimation/overestimation in measuring the movements over the defined total distance travelled exceeds the safety threshold.	All (except NP, IS, SF)	Inherent core function of ETCS	Safety Critical	
KERNEL-36	Incorrect relocation of location based information	Determine EoA/LoA. Determine MRSP (based on location based information) Report train	On-board fails to relocate location data in case no linking is available. Wrong distance calculated to EoA/start and end location of MRSP.	All (except NP, SB, PS, SL, NL, TR, PT, SF, IS)	Inherent core function of ETCS	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
		position					
TI-1	Service brake / emergency brake not commanded when required	Brake control function	Unable to apply brakes on demand.	All (except IS, SL, NL, PS)		Safety Critical	
TI-2	Service brake / emergency brake release commanded when not required	Brake control function	Brakes released too early.	All (except IS)		Safety Critical	Brake release is initiated by driver according operational rules.
TI-3	Inappropriate sleeping request	Standstill protection	Inappropriate entry to Sleeping, with loss of Standstill protection as a consequence.	SB	Cabin must be closed and the train must be at standstill.	Safety Critical	Driver vigilance is presumed.
TI-4	Incorrect brake status (TIU failure)	Any	Service Brake indicated ON when OFF	All		Safety Related	Driver vigilance is presumed. A project specific analysis is only necessary in case the brake pressure is used for safety purposes related to service brake

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
							feedback. Otherwise it is a RAM issue. It is not relevant for emergency brake, considering 2.3.2.2 from subset 034, v3.1.1
TI-5	Incorrect direction controller position report (TIU failure)	Rollaway protection, protection against undesired movements, backwards distance monitoring	In case Dir Ctrl position changes direction: • Rollaway protection changes direction. In case Dir Ctrl position reported as forward/backward instead of neutral: • Loss of Rollaway protection in one direction.	All		Safety Critical	Driver vigilance is presumed.
TI-6b	Wrong Cabin considered as Active	See KERNEL-15	See KERNEL-15	All		See KERNEL-15	See KERNEL-15
TI-7	Inappropriate passive shunting request	Standstill protection	At desk closure on-board ETCS switches in PS Mode instead of SB. Standstill protection is not	SH	”Continue Shunting on desk closure” function must be active.	Safety Critical	Driver vigilance is presumed. Driver has to ensure the standstill (e.g. by

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			provided in this mode.				applying the parking brake) before leaving the cab
TI-8	Inappropriate Non Leading permitted signal received	Supervision of EOA/LOA Supervision of train speed	On-board switches to NL mode after driver selection when not required with a loss of supervision as consequence.	SB, SH, FS, LS, SR OS	Train must be at standstill and Driver selects NON LEADING on DMI. NL mode is displayed on the DMI.	Safety Related	Driver vigilance is presumed.
TI-10	Falsification of train data received by External Source	Supervision of train speed	• False Cant Deficiency Information (higher than real) • False Other International Train Categories • False train length • False loading gauge • False axle load available on-board Results in supervision of wrong SSP or entering of a track which is not	All (except IS, SL, NL, PS, RV)	Driver must confirm changed train data via DMI (project specific)	Safety related	Infrastructure planning has to prevent that tilting infringes the allowed gauging. Product specific safe-guarding Operational rules for the driver Project specific safety analysis is needed when acquisition of Train Length Information and related external source cannot be realised with

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
			suitable for the train RBC uses false Confirmed Train Length for MA to other trains so that the train distancing function may turn unsafe				the highest safety integrity level Project specific mitigation should be applied either at ETCS on-board or at trackside level
TI-11	Traction Cut-Off not commanded when required	Supervision of EOA/LOA Supervision of train speed	Traction Cut-off command not transmitted to the train	All (except IS, SL, NL, PS, SH, SN, RV)	For traction cut-off at warning limit, the criticality could be safety critical.	Safety critical	Product specific safe-guarding
					If the ETCS on-board is not configured for “traction cut-off at warning limit” the criticality would be none.	None	
TI-12	Inappropriate Trian Integrity Confirmed Status received	Position Report, Confirmed Train Length	Train integrity confirmed when it is lost or unknown	All		Safety Critical	Train Integrity information shall be provided by external source with at least SIL2 quality.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
							Based on the Risk Analysis provided in X2Rail-4 (Deliverable D6.1) the worst case for number of unintended train separations events in a year is 6,98 x 10-5 /h (per freight train) and 2,61 x 10-6 /h (per passenger train). These values can be used as barrier for the overall THR calculation. Driver vigilance (notice split and take action)
TI-13	Falsification of Overall Consist Length Information received by External Source		Incorrect train length information to ETCS on-board leading to incorrect confirmed train length in the position report sent to RBC	All		Safety Critical	Overall Consist Length information shall be provided by external source with at least SIL2 quality[2]. If necessary to comply with required safety level in SM mode project specific mitigation should be applied such as

[2] Requirement is based on state of the art

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
							- Trackside specific measures based on other external entities (e.g. Axle Counter) - Additional independent source of information needed by On-board to determine Safe Consist Length (e.g. the number of axles), in case the RINF requires Safe Consist Length information with SIL4 to enter the line.

Fault Tee Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Notes
TRACK-1	Incorrect gradient (track description)	Release Speed, DSP	Engineering Data incorrect. Incorrect gradient will result in an incorrect traction/braking model. Trackside equipment failure	Note: In the functionally oriented perspective of the Fault Tree in Part 1, the TRACK events define how erroneous data can lead to the ETCS Core Hazard. Here in Part 2, we are less interested in the detail of the data but more interested in the failure modes of equipment that can create this erroneous data. This is necessary in order to be able to apportion hazard rates to equipment in Part 3. Therefore, the TRACK-events are not analysed further, but instead merged into the TRANS-events, defined to indicate the failure mode and also the transmission channel (Balise or Radio) that could be responsible for the failure. A further splitting of the TRANS-events into constituents and more fine-grained failure modes are done in Subset 088 part 3. However, the FMEA-tables here in Part 2 are not carried out to that level of detail.
TRACK- 2	Incorrect Adhesion Factor “slippery rail”	DSP	Trackside equipment failure.	
TRACK-3	Incorrect Signalling related speed restriction	MRSP, DSP	Engineering Data Incorrect. Trackside equipment failure Level 1 issue only	
TRACK-4	Incorrect MA data	MRSP DSP	Engineering Data Incorrect from RBC Trackside equipment failure	
TRACK-5	Incorrect system data. V_NVREL	MRSP DSP	Engineering Data Incorrect. Trackside equipment failure	
TRACK-6	Incorrect track description (level transition orders)	Determination of Current Level	Engineering Data Incorrect. Trackside equipment failure	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
TRANS-BALISE-1 (was TRANS-1)	Incorrect balise group message received by on-board Kernel functions as consistent. (Corruption)	Provision of Data to on-board (balise message)	Corruption of balise group message	All	Message consistency check.	Safety Critical	
TRANS-BALISE-2 (was TRANS-2)	Balise group not detected by On-board Kernel functions (Deletion)	Provision of Data to on-board	On-board fails to receive data from balise and failure to detect any of the balises in the group.	All	If only one balise is missed, consistency checking is mitigation. If all balises in a group are missed, linking is mitigation.	Safety Critical	The criticality of this failure is dependent upon the information missed within the unlinked balise group. Having two (or more) balises in the group can mitigate the hazard of deletion. In situations where deletion is critical, single balise groups are not appropriate.

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
TRANS-BALISE-3 (was TRANS-3)	Inserted balise group message received by On-board Kernel functions as consistent. (Insertion)	Provision of Data to On-board (balise message)	Cross-talk of balise group message	All	Message consistency check. Balise group linking.	Safety Critical	
TRANS-OB/RADIO-1 (was TRANS-4)	Incorrect radio message received by the On-board Kernel functions as consistent. (Corruption)	Provision of Data to on-board (MA data etc.)	Incorrect data includes corruption, late, repeated, etc.	All	Message consistency check has to fail. Messages are key coded to ensure authenticity and contain a timestamp to check sequencing and delay.	Safety Critical	Emergency messages are not covered by the MAC code and therefore there is no mitigation. If the on-board can decode the message as an emergency message the message will be acknowledged by the on-board to the RBC

TRANS-OB/RADIO-2 (was TRANS-5)	Radio message not received by the On-board Kernel functions (Deletion)	Provision of Data to On-board (MA data etc.)	Deletion in the communications channel resulting in the on-board being unable to receive a more restrictive MA. The on-board will be unable to receive emergency messages, no protection afforded against the loss of conditional emergency messages. However, this is conditional upon an emergency message being transmitted to the train.	All	Train should be shortened via co-operative MA shortening. For shortening by an emergency message mitigation is provided by the radio link supervision. This ensures messages are received no later than a specified time (T_NVCONTACT) which should be limited to a safe default value defined by each railway. Section timeouts will also provide mitigation.	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
TRANS-OB/RADIO-3	Inserted radio message received by the on-board kernel functions as consistent. (Insertion)		Erroneous MA received by the on-board resulting in an exceedance of speed / distance	All	Message sequencing, time stamping and addressing as recommended by Cenelec 50159 render this event as non hazardous	Safety Critical	
TRANS-TS/RADIO-1 (was TRANS-6)	Incorrect radio message received by RBC Kernel functions as consistent. (Corruption)	Provision and revocation of emergency messages. Provision of data to the on-board		All	Message consistency check Messages are key coded to ensure authenticity and time stamped as per Cenelec 50129-2 to check sequence and delay.	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
TRANS-TS/RADIO-2	Radio message not received by the RBC Kernel functions (Deletion)		Loss of train reports and / or message acknowledgements	All	Train retains existing MA. Protection is afforded at the application level with transmission repeats	Safety Critical	.
TRANS-TS/RADIO-3	Inserted radio message received by the RBC kernel functions as consistent. (Insertion)				Message sequencing, time stamping and addressing as recommended by Cenelec 50159 render this event as non hazardous	Safety Critical	

RBC-1	Radio message deleted in the RBC Kernel in an undetectable way	Provision of Data to On-board (MA data etc.)	Errors in the RBC kernel functions resulting in the on-board unable to receive a more restrictive MA. The on-board will be unable to receive emergency messages, no protection afforded against the loss of conditional emergency messages. However, this is conditional upon an emergency message being transmitted to the train.	All	Train should be shortened via co-operative MA shortening. For shortening by an emergency message mitigation is provided by the radio link supervision. This ensures messages are received no later than a specified time (T_NVCONTACT) which should be limited to a safe default value defined by each railway. Section timeouts will also provide mitigation.	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
RBC-2	Incorrect RBC radio message sent from the RBC kernel functions, such that the message appears consistent	Provision of Data to On-board (MA data etc.)	Errors in the RBC kernel resulting in erroneous messages to the Euroradio trackside function.	All	Message consistency check. Messages are key coded to ensure authenticity, Sequencing and Timestamp.	Safety Critical	Messages via the high-priority channel are not covered by the MAC code and therefore there is no mitigation. If the on-board can decode the message as an emergency message the message will be acknowledged by the on-board to the RBC.
RBC-3	RBC misinterprets a message from an adjacent RBC causing an incorrect message to be sent to the on-board	Provision of Data to On-board (MA data etc.)	Errors in the kernel of the RBC. Incorrect data includes corruption, late, repeated, etc.	All	Message consistency check. Messages are key coded to ensure authenticity, Sequencing and Timestamp.	Safety Critical	

Fault Tree Base Event	Fault Tree Base Event Description	Affected ETCS Functions or Data	Explanation	Mode	Mitigation Condition	Criticality	Exported Conditions
RBC-4	Erroneous message sent from RBC to an adjacent RBC	Provision of Data to RBC	Errors in the kernel of the RBC. Incorrect data includes corruption, late, repeated, etc.	All	Message consistency check. Messages are key coded to ensure authenticity, Sequencing and Timestamp.	Safety Critical	

6.1 Functional Analysis of Virtual Balise Cover Function

6.1.1 Introduction

6.1.1.1 The purpose of this FMEA is to derive proposed Engineering Rules (ENG RULE) and Operational Rules (OP RULE) in relation to the Virtual Balise Marker function defined in section §3.15.9 of SUBSET-026 v3.4.0, v3.6.0 and 4.0.0. It is assumed that the infrastructure owner derives and implements these rules.

6.1.1.2 It is furthermore assumed that the infrastructure owner defines correct Virtual Balise Cover orders and supplies the driver with these orders in a process that guarantees the correctness and timeliness of the order.

6.1.1.3 Normally, the FMEAs in UNISIG only concern the information at the interoperable interfaces of ETCS. In order to fulfil the above purpose, however, this FMEA also analyses some ERTMS/ETCS on-board internal failure modes and some operational situations.

The analysis is then still performed for the information flowing on the interfaces; however, this shall then be understood as the handling of this information inside ERTMS/ETCS on-board all the way into the execution of the function using it.

6.1.1.4 DMI failures modes are included, using SUBSET-079 as input. Driver failures are however not analysed here.

6.1.1.5 This FMEA analyses the two information packets “VBC marker” and “VBC order”. They are given the ERTMS/ETCS on-board in different ways:

- The VBC marker analysed in chapter 6.2.1 can only be given from a balise, as Packet 0 from trackside with version X=2 and Packet 200 from trackside with version X=1, Y=1.
- The VBC order analysed in chapter 6.2.2 can either be given from a balise, as Packet 6, or from the driver as DMI input.

6.1.1.6 The analysis in cases 6.2.2.2.3.x uses the failure cause “The T_VBC is set to a value which doesn’t exceed the maximum time of train operation inside the LUC”. Therefore, it is here assumed that T_VBC is rather set too long instead of too short, and that the driver will systematically have to manually check all applicable VBCs once at SoM[3] inside this area. The assumption is further elaborated and defined in the FMEA, see OP RULE 1 and OP RULE 2.

6.1.1.7 Compatibility with baseline 2: a B2 ERTMS/ETCS on-board equipment will be stopped due to system version check if entering a LUC B3 X=2 area; in a B3 X=1 LUC area a B2 ERTMS/ETCS on-board equipment will not be protected by version check and will not consider VBC information included in balise groups. So external protections are necessary to avoid a B2 ERTMS/ETCS on-board equipment entering such area.

[3] It is further assumed that commissioning of the LUC is not done with trains operating in traffic inside it.

6.1.2 FMEA

6.1.2.1 Virtual Balise Cover Marker

Ref ID	Macro Function Data Item	Failure Mode	Failure Cause	Operation Mode	Failure Effects			Proposed External Protection / Mitigation Barriers	Severity	Internal Barriers
					Local	Intermediate	Initial End Effect			
6.1.2.1.1-1----------	NID_VBCMK	**DELETION**	Engineering error in non-commissioned balises (e.g. VBC marker forgotten)	Any but NP	The ERTMS/ETCS on-board will not ignore the balise telegram in the LUC	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	ENG RULE 1: The setting of a VBC marker needs to follow a safe process	Catastrophic	-
6.1.2.1.1.2			Any failure of the non-trusted transmission system	Any but NP	As above	As above	As above	-	Catastrophic	The Eurobalise code protects against losing a packet inside a balise telegram. If the whole telegram is lost, there is no hazard.
6.1.2.1.2.1		**CORRUPTION**	Engineering error in non-commissioned balises (e.g. wrong NID_VBCMK programmed)	Any but NP	In case the balise telegram should have been ignored: The ERTMS/ETCS on-board will not ignore the balise telegram	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	ENG RULE 1: The setting of a VBC marker needs to follow a safe process	Catastrophic	

Ref ID	Macro Function Data Item	Failure Mode	Failure Cause	Operation Mode	Failure Effects			Proposed External Protection / Mitigation Barriers	Severity	Internal Barriers
					Local	Intermediate	Initial End Effect			
6.1.2.1.2.2					In case the balise should not have been ignored: The ERTMS/ETCS on-board will ignore the balise telegram if there is a VBC order pointing to the new "wrong" NID_VBCMK	H2: Balise information (potentially restrictive) intended for traffic will be ignored	Exceedance of safe speed or distance	ENG RULE 1: The setting of a VBC marker needs to follow a safe process	Catastrophic	It is not certain that there is a VBC order pointing to the new "wrong" id. Ignoring all balise telegrams in a group can lead to a linking reaction.
6.1.2.1.2.3			Any failure of the non-trusted transmission system	Any but NP	As above (both cases)	As above (both cases)	As above (both cases)	As above (both cases)	Catastrophic	The Eurobalise code protects against corruption

6.1.2.1.3.1		**INSERTION**	Any failure of the non-trusted transmission system, i.e. cross-talk	Any but NP	If a VBC marker is cross-talked, the ERTMS/ETCS on-board will ignore the balise telegram according to rules in SUBSET-026 v3.4.0	None	None		'	

6.1.2.2 Virtual Balise Cover Order

Ref ID	Macro Function Data Item	Failure Mode	Failure Cause	Operation Mode	Failure Effects			External Protection / Mitigation Barriers	Severity	Internal Barriers
					Local	Intermediate	Initial End Effect			
6.1.2.2.1.1	Q_VBCO, NID_VBCMK, NID_C, T_VBC	**DELETION**	Any failure of the non-trusted transmission system	Any but NP	Intended setting of VBC order is not performed (in case Q_VBCO=1 was intended)	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	ENG RULE 2: A balise group giving a VBC order shall consist of at least two balises	Catastrophic	
6.1.2.2.1.2					Intended removal of VBC is not performed (in case Q_VBCO=0 was intended)	H2: Balise information (potentially restrictive) intended for traffic will be ignored	As above	As above	Catastrophic	As above

Ref ID	Macro Function Data Item	Failure Mode	Failure Cause	Operation Mode	Failure Effects			External Protection / Mitigation Barriers	Severity	Internal Barriers
					Local	Intermediate	Initial End Effect			
6.1.2.2.1.3			ERTMS/ETCS on-board internal failure	Any but NP	As above	As above	As above		Catastrophic	Product specific safeguarding to SIL4[4]
6.1.2.2.1.4			ERTMS/ETCS on-board memory buffer full	Any but NP	As above	As above	As above		Catastrophic	The number of memorised VBCs on-board is defined in SUBSET-040 v3.3.0 and v3.4.0 §4.3.2.1.1w (and must thereby be respected by trackside). For transitions between countries/regions, the previous VBCs are deleted when a balise group with a new country/region identifier (NID_C) is received, see SUBSET-026 v3.4.0 and v3.6.0 §3.15.9.5d.

[4] For DMI function failures, the SIL4 safety is expected to be built up by an entry+validation process, as in the case of e.g. train data entry.

Ref ID	Macro Function Data Item	Failure Mode	Failure Cause	Operation Mode	Failure Effects			External Protection / Mitigation Barriers	Severity	Internal Barriers
					Local	Intermediate	Initial End Effect			
6.1.2.2.1.5			The VBC order never reaches the ERTMS/ETCS on-board because the train has been moved into a LUC in a mode where balises are not read (NP, IS and SF)	Any but NP	As above	As above	As above	OP RULE 1: Driver needs to “re-enter and validate” or “remove” VBCs at each SoM inside a LUC to be sure the onboard uses the correct set of VBCs	Catastrophic	-

6.1.2.2.1	**CORRUPTION**	Any failure of the non-trusted transmission system	Any but NP	Intended setting of VBC order is not performed (in case Q_VBCO=1 was intended)	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	None needed	Catastrophic	The Eurobalise code protects against corruption in the transmission channel
6.1.2.2.2				Intended removal of VBC order is not performed (in case Q_VBCO=0 was intended)	H2: Balise information (potentially restrictive) intended for traffic will be ignored	As above	As above	Catastrophic	As above
6.1.2.2.3		ERTMS/ETCS on-board internal failure	Any but NP	As above (both cases)	As above (both cases)	As above (both cases)		Catastrophic	Product specific safeguarding to SIL4[5]. Specifically for corruption of T_VBC, special considerations are needed, and the case is analysed separately below, see B.2.2.2.3.x.

[5] For DMI function failures, the SIL4 safety is expected to be built up by an entry+validation process, as in the case of e.g. train data entry.

6.1.2.2.3.1	T_VBC	**CORRUPTION**	Train is **outside** LUC 1. The T_VBC is set to a value which doesn't exceed the maximum time of train operation inside the LUC. 2. ERTMS/ETCS on-board internal failure (e.g. clock) 3. External failure (e.g. UTC)	All	Timer expires and VBC order removed earlier than intended (hazardous case is only if it happens before commissioning of LUC).	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	ENG RULE 3: Balise group giving VBC order shall be placed at all entries to a LUC and need to correctly reflect the status of the LUC at all times, both setting valid VBCs and removing non-valid[6] VBCs and to define adequate T_VBC (long enough)	Catastrophic	
6.1.2.2.3.2					Timer expires and VBC order removed later than intended.	H2: Balise information (potentially restrictive) intended for traffic will be ignored	As above	As above	Catastrophic	

[6] The remove VBC order should be enforced until the need for using the same VBC code again arises.

6.1.2.2.3.3			Train is **inside** LUC with ERTMS/ETCS on-board **powered off** 1. The T_VBC is set to a value which doesn't exceed the maximum time of train operation inside the LUC. 2. ERTMS/ETCS on-board internal failure (e.g. clock) 3. External failure (e.g. UTC)	NP	Timer expires and VBC order removed earlier than intended (hazardous case is only if it happens before commissioning of LUC).	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	OP RULE 1 Driver needs to "re-enter and validate" or "remove" VBCs at each SoM inside a LUC to be sure the onboard uses the correct set of VBCs	Catastrophic	

6.1.2.2.3.4					Timer expires and VBC order removed later than intended.	H2: Balise information (potentially restrictive) intended for traffic will be ignored	As above	OP RULE 2: For every vehicle, driver needs to remove the VBC orders at the first SoM inside a LUC after the commis-sioning of the LUC [7]	Catastrophic	

[7] To cover the case of erroneously too long T_VBC, the manual removal needs to be done once per vehicle after the commissioning:. thus it is not enough to enforce this procedure only up to commissioning date + T_VBC days

6.1.2.2.3.5			Train is **parked inside** LUC with ERTMS/ETCS on-board **powered on** [8] 1. The T_VBC is set to a value which doesn't exceed the maximum time of train operation inside the LUC. 2. ERTMS/ETCS on-board internal failure (e.g. clock) 3. External failure (e.g. UTC)	Any but NP	Timer expires and VBC order removed earlier than intended (hazardous case is only if it happens before commissioning of LUC).	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	As ENG RULE 3 above. In addition: the balise groups need to be placed also where trains are normally parked with ERTMS/ETCS on-board powered. If this is not possible, OP RULE 1 and 2 can be applied also in other situations than SoM [9].	Catastrophic	

[8] Since the ERTMS/ETCS On-board is powered on the whole time, the Start of Mission procedure is not executed and therefore barrier OP RULE 1 is not effective.

[9] If this barrier is pursued, situations to be considered shall include using a vehicle that has been parked with ERTMS/ETCS On-board in SL mode, since it could be hazardous to receive e.g. erroneous National Values and Level Transition Orders, which will be used later when the vehicle becomes the leading vehicle.

6.1.2.2.3.6					Timer expires and VBC order removed later than intended.	H2: Balise information (potentially restrictive) intended for traffic will be ignore	As above	As above	Catastrophic

6.1.2.2.3.7			Train is running **inside** LUC with ERTMS/ETCS on-board **powered on** 1. The T_VBC is set to a value which doesn't exceed the maximum time of train operation inside the LUC. 2. ERTMS/ETCS on-board internal failure (e.g. clock) 3. External failure (e.g. UTC)	Any but NP	Timer expires and VBC order removed earlier than intended (hazardous case is only if it happens before commissioning of LUC).	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	The time at risk is small. see further B2.3.1.3.	Catastrophic	
6.1.2.2.3.8					Timer expires and VBC order removed later than intended.	Not an applicable scenario. A LUC is not commissioned when there is traffic inside it.	n.a.	n.a.	None	n.a.

6.1.2.2.4.1		**INSERTION**	Any failure of the non-trusted transmission system; i.e. cross-talk	Any but NP	If a correct VBC order is cross-talked, the ERTMS/ETCS on-board will use it and - set the VBC (in case Q_VBCO=1) or - remove the VBC (in case Q_VBCO=0)	None, since the VBC order is correct	None		'	
6.1.2.2.4.2			ERTMS/ETCS on-board internal failure	Intended setting of VBC order is not performed (in case 'set VBC' is inserted)	H1: Balise information (potentially permissive) only intended for test purposes will be used in traffic	Exceedance of safe speed or distance	None needed	Catastrophic		Product specific safeguarding to SIL4[10].
6.1.2.2.4.3				Intended removal of VBC order is not performed (in case 'remove VBC' is inserted)	H2: Balise information (potentially restrictive) intended for traffic will be ignored	As above	As above	Catastrophic		As above

[10] For DMI function failures, the SIL4 safety is expected to be built up by an entry+validation process, as in the case of e.g. train data entry.

6.1.3 Notes

6.1.3.1 Notes of ENG RULE 1: The rule says that the setting of a VBC marker needs to follow a safe process. This could be perceived as redundant to the general rule in SUBSET-091 called EXT_SR01 that requires the preparation of the ETCS Trackside Data to be of a quality that is appropriate to the required safety level. However, in a construction area the data (e.g. balise telegrams) is not commissioned and can therefore not be expected to have gone through all safety processes. Even so, safety reliance is placed on balise telegrams in the construction area; therefore ENG RULE 1 is necessary.

6.1.3.2 Notes on OP RULE 1 and 2:

- The use of the VBC function requires the driver to validate that ERTMS/ETCS on-board has the correct set of VBCs in many operational situations, at least connected to the technical procedure Start of Mission inside a LUC. In some of these situations it is clear that the validation is not merely a double check of a list that should already be valid, but that the driver will be expected to actually correct the set of VBCs (if not using VBC orders from balises at all, the driver will need to enter the VBC codes even more frequently). The effect of a failure to do so correctly might have catastrophic consequences. Therefore, the operational procedure which shall guarantee that the driver can take this responsibility must be elaborated with great care, taking into account the aspects of human failures given the ergonomics of the VBC set and remove function specified in ERA_ERTMS_015560 “ERTMS/ETCS, ETCS Driver Machine Interface”.
- It needs to be made sure that the timer is restarted when the driver checks the VBC. Therefore, OP RULE 1 must contain the instruction to go through the set and validation procedure for each VBC that is required for operation in the LUC.

Notes on ERTMS/ETCS on-board timer function:

- The timer related to the VBC function shall be active also when ERTMS/ETCS on-board is powered off. This implies that ERTMS/ETCS on-board must make itself reliant upon external sources of time, most likely with unknown safety properties. The timer at power off shall therefore not be considered as a safety function, but must be mitigated with external barriers; see further cases B.2.2.2.3.x.

6.1.3.3 For the case of erroneously releasing a VBC timer while running inside a LUC, there are no operational mitigations. The driver will not be given any warning on the DMI if a VBC timer expires, but the ERTMS/ETCS on-board will simply start processing the balise telegrams that should have been ignored in the LUC. However, it is believed that the time at risk for such an event will be limited since the train will at some point in time go outside the LUC. Therefore, any accuracy and safety requirements imposed by this scenario will highly likely be bounded by accuracy and safety requirements imposed by

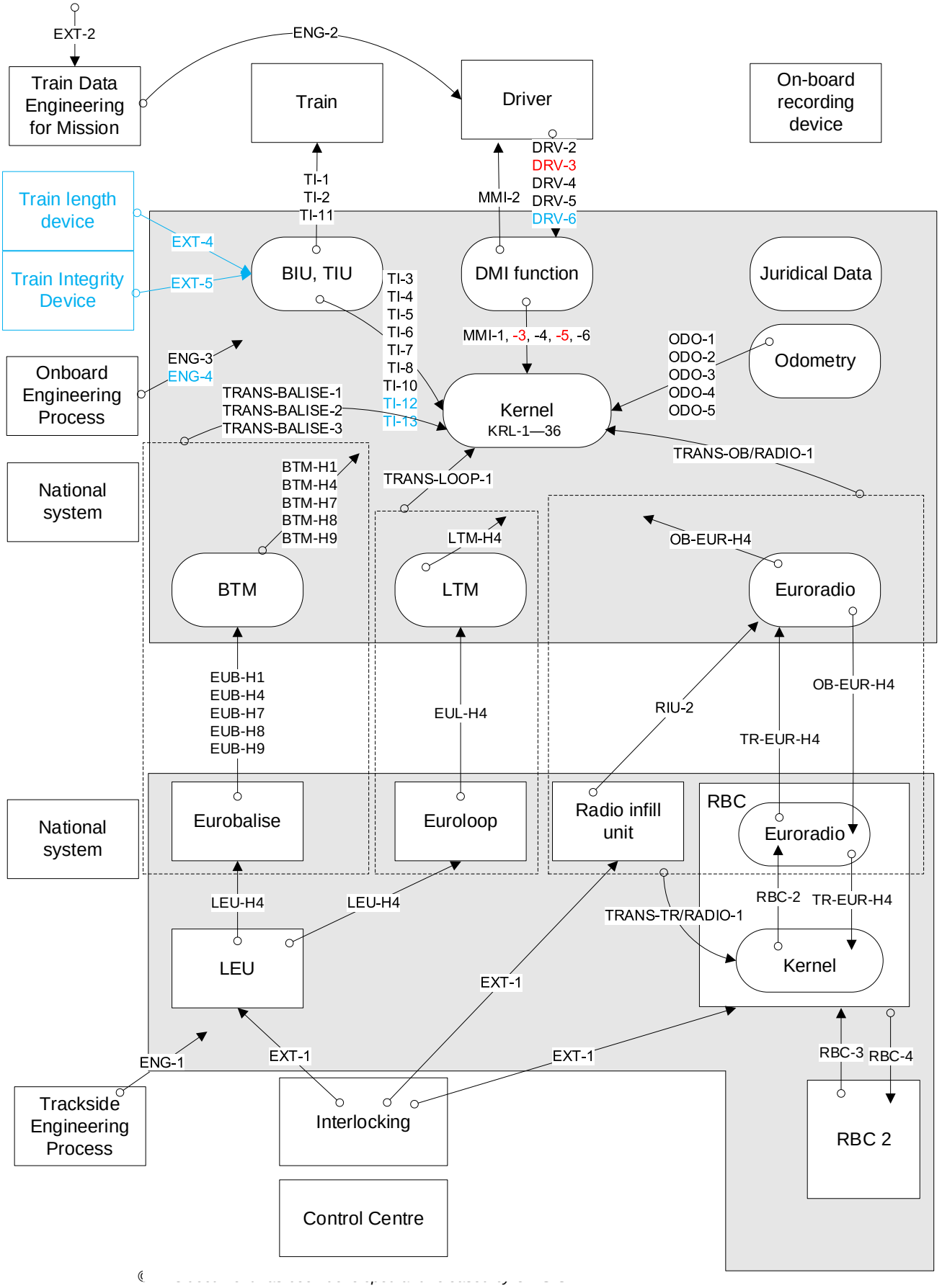
other scenarios involving the ERTMS/ETCS on-board clock with ERTMS/ETCS on-board powered, e.g. MA timer.

7. TRANSMISSION CHANNEL EVENTS

7.1.1.1 Each TRANS-ENTITY-X event in section 6 consists of several different transmission related events, each belonging to exactly one constituent and one functional element within that constituent. Identification of these events to allow proper allocation to each constituent will be undertaken in SUBSET-088 Part 3 as part of the process of apportioning the ETCS THR.

8. GRAPHICAL REPRESENTATION OF HAZARDOUS EVENTS

8.1.1.1 The figure below illustrates the hazardous events of section 6 in relation to the ERTMS/ETCS UNISIG Reference Architecture.


EXT-2
ENG-2
Train Data Engineering for Mission
Train
Driver
On-board recording device
DRV-2
DRV-3
DRV-4
DRV-5
DRV-6
TI-1
TI-2
TI-11
MMI-2
Train length device
Train Integrity Device
EXT-4
EXT-5
BIU, TIU
DMI function
Juridical Data
TI-3
TI-4
TI-5
TI-6
TI-7
TI-8
TI-10
TI-12
TI-13
MMI-1, -3, -4, -5, -6
ODO-1
ODO-2
ODO-3
ODO-4
ODO-5
Odometry
ENG-3
ENG-4
Onboard Engineering Process
TRANS-BALISE-1
TRANS-BALISE-2
TRANS-BALISE-3
Kernel
KRL-1—36
TRANS-OB/RADIO-1
National system
BTM-H1
BTM-H4
BTM-H7
BTM-H8
BTM-H9
TRANS-LOOP-1
LTM-H4
OB-EUR-H4
BTM
LTM
Euroradio
EUB-H1
EUB-H4
EUB-H7
EUB-H8
EUB-H9
EUL-H4
RIU-2
OB-EUR-H4
TR-EUR-H4
National system
Eurobalise
Euroloop
Radio infill unit
RBC
Euroradio
LEU-H4
LEU-H4
RBC-2
TR-EUR-H4
TRANS-TR/RADIO-1
LEU
Kernel
EXT-1
ENG-1
EXT-1
EXT-1
RBC-3
RBC-4
Trackside Engineering Process
Interlocking
RBC 2
Control Centre