Innovative technical solutions for improved train DYNAmics and operation of longer FREIGHt Trains

D3.1 – Functional requirements of radio controlled traction and braking

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EXECUTIVE SUMMARY

The main objective of DYNAFREIGHT Task 3.1 is to analyse the operational and technical requirements of long trains in order to specify the functional requirements of radio remote control systems for distributed power in mainline freight operations.

The long train concept in this report refers to a train consist of up to 1,500m, with at least 2 traction locomotives, one at the front of the train, being the master locomotive (with driver) and a slave locomotive (without driver) in the middle of the train or other position. The slave locomotive is remote controlled from the master.

The report contains an overview of related standards that can serve as reference for the operation of long trains with radio control in main line service. It establishes the functional requirements of the radio remote system, focusing on the radio and the traction system.

A safety analysis is done as well as allocation of the safety level for each relevant function.

Finally a very generic overview on the radio system is given.

DYNAFREIGHT project is a complementary project of Future Freight Locomotive for Europe – FFL4E project. Both consortiums have collaborated in the use cases definition, on the FBS and system requirements and preliminary hazard analysis. However, in the end DYNAFREIGHT has not provided the radio system for the FFL4E demonstrator to be run in August 2018 (as was foreseen at the beginning of the project) and this has reduced the scope of DYNAFREIGHT Task 3.1 to the above mentioned activities.

Both consortium have also closely collaborated in other DYNAFREIGHT tasks, especially the simulations done in Task 3.2 and the infrastructure analysis in Task 3.3.

ABBREVIATIONS AND ACRONYMS

BCU	Brake Control Unit
BP	Brake Pipe
COTS	Commercial Off The Shelf
DBCU	Distributed Brake Control Unit
DPCU	Distributed Power Control Unit
DPS	Distributed Power System
EVN	European Vehicle Number
FBS	Functional Brakedown Specification
FFL4E	Future Freight Locomotive for Europe (S2R-CFM-IP5-03-2015)
FRA	Federal Railroad Administration
FRS	Functional Requirement Spefication
GMS-R	Global System for Mobile Communications – Railway
IM	Infrastructure Manager
MCB	Main Circuit Breaker
RU	Railway Undertaking
TCMS	Train Control Management System
TU	Traction Unit (A locomotive or the compilation of locomotives that are connected and steered via an UIC-line (at least one locomotive is equipped with a DPS))
VSC	Valid System configuration: concrete train using DPS defined by train configuration, number and position of TU and train length

TABLE OF CONTENTS

Shift2Rail
Grant Agreement Number: 730811

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Long trains, up to 1,500 meters, are an important feature to explore in order to improve freight transport capacity and to achieve the objectives of the EU White Paper on Transport 2011, which states that by 2030 a shift of 30% of road freight over 300km to rail, or a doubling of the freight transport by rail compared to 2005, should be achieved.

The main technical challenge in the long train freight concept is the risk of damage and derailment at certain braking scenarios, in particular involving lack of radio communication, and at certain wagon and payload compositions. This challenge is addressed in DYNAFREIGHT WP3, in Task 3.2. Safety precautions in train configuration and brake application, where multiple simulations of different long train scenarios with randomly distributed total masses of the wagons have been done in order to produce guidelines on derailment risk reduction.

Within Task 3.1 the main objective is to analyse the operational and technical requirements of long trains in order to specify the functional requirements of radio remote control systems for distributed power in mainline freight operations. These requirements are aligned with the results of the long train simulations.

Chapter 2 of this deliverable gives an overview on the possible use cases of a distributed power and brake control system. The use cases and general requirements have been developed by a joined team of FFL4E and DYNAFREIGHT consortiums. References to some deliverables of FFL4E are given along this report.

Chapter 3 establishes the functional requirements of the radio remote system, focusing on the radio and the traction system, so no other system is analysed in this report. It start with a review of current standards, providing an overview of the DPS architecture and continues defining the requirements of the radio and traction systems, identifying the functions that have to be transmitted from the master to the slave locomotive/s (or vice versa) for the operation of long trains, i.e., implemented by the DPS system.

Once the needed functions have been identified, Chapter 4 makes a safety analysis of the radio and traction functions.

Finally, Chapter 5 gives a very generic overview on the radio system. Because of a change in the scope of DYNAFREIGHT Task 3.1, the reader is encouraged to read FFL4E deliverables in order to find out details on the final radio solution integrated in the locomotive and on the interface description between the radio and the locomotive.

Conclusions are clear in terms of the need of having a new standard for the operation of long trains with DPS.

2. LONG TRAIN USE CASES. GENERALITIES

This chapter describes the possible use case configurations of long trains with distributed power and brake control system.

The long train basic concept in this project refers to a train consist of up to 1,500m, with at least 2 traction locomotives, where at least two freight trains of up to 750 m length each are coupled together with a leading master locomotive (with driver) and a slave locomotive (without driver) in the middle of the long train. The master locomotive controls the slave locomotive through radio communication. The next figure shows this basic configuration, which is also the same concept of Marathon project.

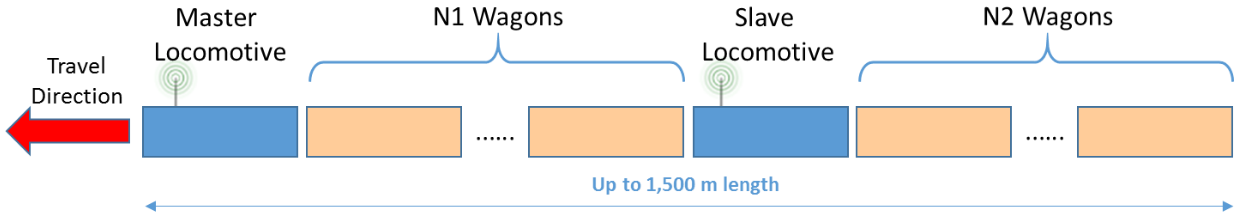

Figure 1: Long train basic concept

Within this basic concept of distributed traction via radio control several configurations are possible, as more locomotives can be involved and their position can vary along the train consist. The cooperation between FF4LE and DYNAFREIGHT teams led to the definition of a wider long train concept, named VSC 3[1] (Valid System Configuration). The following figure defines the schematic representation of possible train configurations:

[1] FFL4E projects considers VSC 1 as the demonstrator case: train of 530 m with 2 locomotives using DPS. The VSC 2 refers to the operation of DPS in 740 m trains, specially as pushing action in heavy trains.

Grant Agreement
Number: 730811

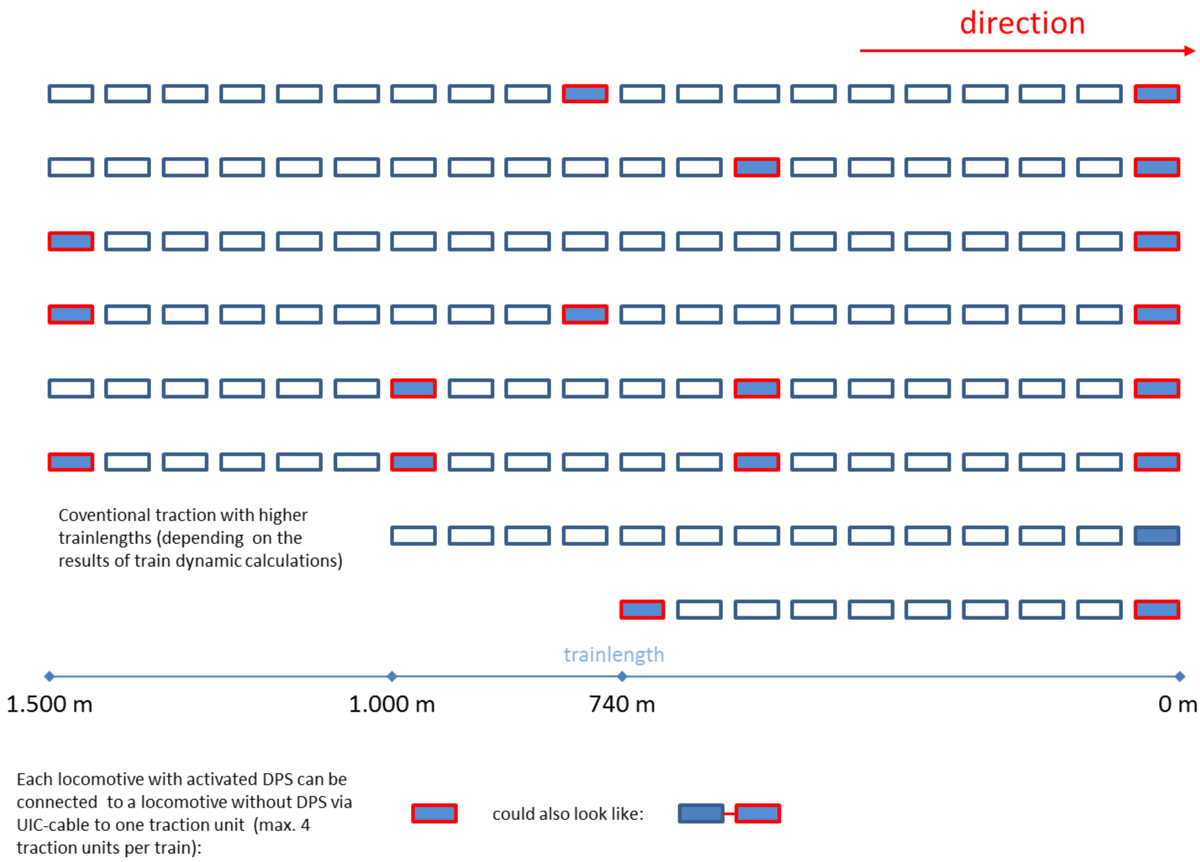

Figure 2: Schematic representation of possible long train configurations
[Source: FFL4E project: D5.2 Functional and system requirements specification]

In this long train concept, initially, up to four TUs must be able to work. The positions of the TU are operationally based on the train lengths of the train units assembled for a VSC. The restrictions of the positions of the TU must be identified from a train dynamic perspective.

Deliverable D5.2 Functional and system requirements specification of complementary project FFL4E contains more information of the use cases and its requirements which are important to consider for the operation of long trains.

3. FUNCTIONAL REQUIREMENTS OF THE RADIO REMOTE SYSTEM FOCUSED ON THE RADIO AND THE TRACTION SYSTEM

The present chapter describes:

- The starting point for the analysis and functional definition of radio remote systems: A summary of the reference systems and standards used for the system definition and the main conclusions extracted from these documents is given.
- Description of the architecture of the system and main use cases considered.
- Functional and main system requirements of the radio and traction components of the system.

3.1 State of the art. Overview of related standards

The first step in the development of the functional requirements of a new radio remote system intended for the operation of the long train concept defined in Chapter 2 is the analysis of similar solutions and related standards which may be used to develop the requirements.

In terms of similar solutions, today we find radio remote systems used for the same purpose outside Europe. These products do not fulfil European standards, including the methodology used for the development of safety related systems and therefore have not been considered in this analysis, although some conclusions of some FRA studies have been taken into account in this document. These systems are used today mainly in freight trains in USA, Canada, Australia or South Africa.

Radio remote systems used for shunting purposes are the closest products developed according to European standards, these systems are using a radio to control a locomotive. These products are based on the EN50239. This standard covers well the functional definition of the system, however it is intended for very precise use cases (low speed, small distances, shunting tracks, etc.) which are not similar to the ones needed in main line operation for the long train concept defined, therefore the functional and safety requirements cannot be used for DYNAFREIGHT project.

UIC647 is a standard intended to describe the functional model of distributed traction trains and therefore it can be used as the basis of the system that this document intends to describe. UIC647 categorizes 4 groups for the different functions:

- CT1: Mandatory control functions
- CT2: Train allows control with selective traction unit operation
- CT3: Train includes speed control

- CT4: Train includes control with interactive procedures

The functional scope of the system depends on the use cases and the assumptions considered during the project. These assumptions must be aligned with those used for the simulations of the long trains performed during DYNAFREIGHT project. By doing this the operational use cases will be limited but a homogeneous and predictable performance backed with theoretical analysis is ensured. Otherwise it would be impossible to cover all the possible operational cases within the scope of this project.

After these considerations the functional scope of the project regarding the functional categories stated in UIC647 can be defined. Selective control of the traction unit is not allowed as one of the main assumptions is that all the traction units are controlled in the same way at the same time. Neither the option of a speed control has been considered in the main assumptions. Therefore the scope defined in the present document covers only the categories CT1 and CT4 of the functions defined in the UIC647 and they will be developed in the next chapters.

In United States, where the use of remote control system (known as RCL) in long train is relatively common, the FRA (Federal Railroad Administration) has analysed the use of such systems with focus on safety; the most interesting conclusions are summarised here:

- The report presented in 2006 is focused on the use of RCL system in classification (marshalling) yards, equivalent to the use of the remote control systems in Europe.
- The application to main tracks is also considered, however the conclusions were that technologically speaking the existent systems can be used for shunting operations but they cannot guarantee a safety operation in main tracks due to the excessive number of variables to be taken into account. DYNAFREIGHT conclusion is similar: the integrity of the train and the limitation of the train forces cannot be guarantee unless the variables are limited. This is the reason to fix some assumptions in order to reduce these variables.
- The report of the FRA also raises some doubts about the problems due to the delay in the transmission and application of the orders in the traction units. These doubts are translated into some proposed limitations of the use cases for RCL trains: low speeds (15mphs), short train lengths (1000 feet) and only 8 traction axles are some of the limitations of the report for the use of RCL trains in main tracks.
- Finally the FRA report emphasizes the importance of the training of the drivers, even estimates a minimum duration of 2 weeks for experienced drivers in order to learn the complexities of the use of RCL trains.

Grant Agreement Number: 730811

As explained there is no specific standard related to radio remote systems for use in long trains, though radio remote systems would have to fulfil the main European standards, especially the technical specifications for interoperability like TSI OPE or TSI CCS.

- TSI CCS is focused on the signalling system of the vehicle. Recent versions of the ETCS (Baseline 3) have prepared the use of long trains by allowing train lengths of more than 1500m. Only two possible conflict aspects between the TSI CCS and the DPS systems would be: interference between radio systems (between DPS radio and Cab radio or Data Radio) and possible impact in the braking curve calculations of the performance of a DPS train.

- Regarding TSI OPE, and in line with the conclusions of the FRA report, the integration of a DPS system in a vehicle would mean that the driver's rule book must be updated with the new operational rules and procedures defined by the IM and the RU for the use of DPS trains.

  These procedures must cover at least the preparation of the DPS trains, the initialisation, inauguration, operation and end of service phases.

  New cases should be included in Annex B of TSI OPE.

  Clear Operational rules must be defined for the composition of the DPS trains.

  The problem of the train integrity with long trains must be assessed to guarantee a safe traffic management, there are synergies with the TSI CCS and the ETCS about this issue which can be used to define a solution acceptable for all parts.

  Finally, perhaps a new level of competence must be defined for the RU staff for DPS trains.

3.2 General overview of the generic system

The radio remote system, which will be referred as DPS from now on (Distributed Power System), has the following main components:

- DBCU (Distributed Brake Control Unit): brake unit performing the brake functionality of the system. It can be integrated in the main brake panel. This unit will be controlling the brake on the slave locomotive.

- Radio: Component of the system which provides the communication channel between the locomotives.

Grant Agreement Number: 730811

- DPCU (Distributed Power Control Unit): Component of the system performing the main logic of the system. It can be integrated in the TCMS of the locomotive as shown in the figure below.

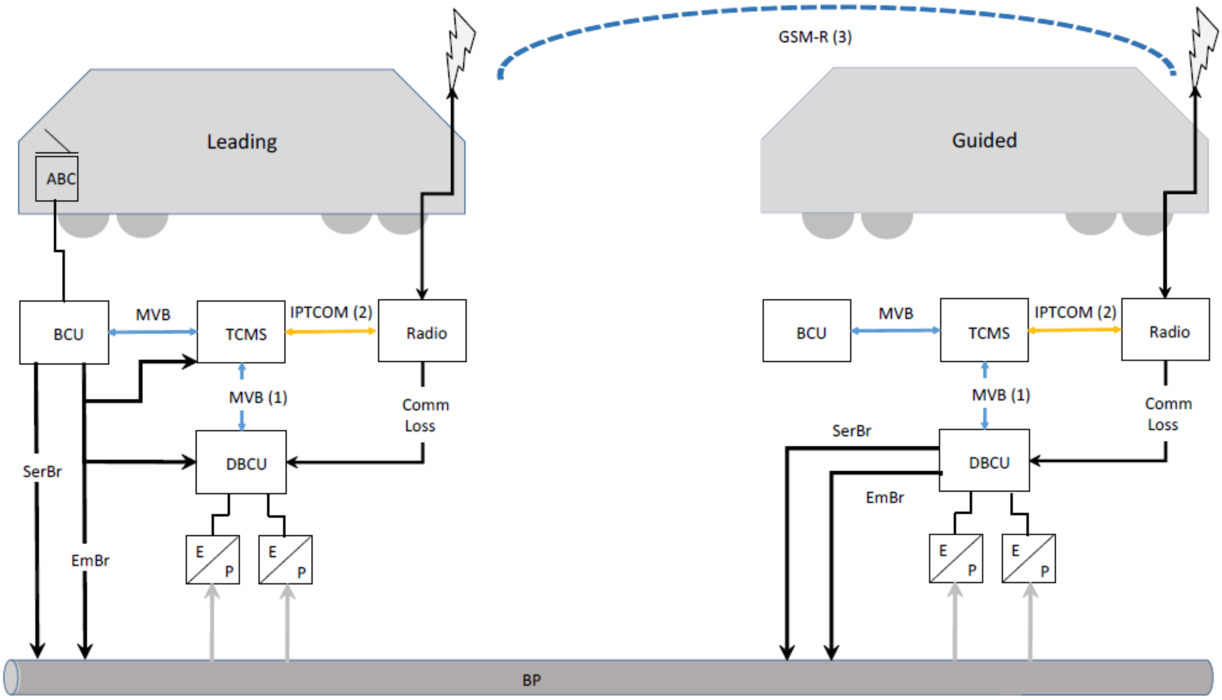

Figure 3: Overview of the DPS architecture [source: FFL4E]

The present document will focus on the radio and traction functions and therefore no description of the DBCU and its functionality is done. The analysis and requirements are focus on the radio component and the DPCU.

3.3 SYSTEM AND OPERATIONAL DESCRIPTION FOCUSED ON THE RADIO AND TRACTION SYSTEM

In order to set up a list of system and operational requirements of the traction and radio components of the DPS system, a top-down process in terms of requirements to clear the process of definition is done..

3.3.1 MAIN REQUIREMENTS OF LONG TRAINS WITH DISTRIBUTED POWER

There are two main requirements of the long trains equipped with a DPS system:

- Keep the train under safe conditions
- Maximize the operation of the train by using distributed traction

Grant Agreement Number: 730811

3.3.2 Main system requirements of DPS systems

These two main requirements lead to some generic requirements of the DPS system:

- Based on a standard technology
- Solutions compatible between different suppliers
- Safe and predictable performance; the fact that a long train in whatever configuration and with DPS systems of different suppliers has a predictable performance allows the use of simulation as a back-up to guarantee the safety of the operation.
- COTS components

In order to keep the train under safe conditions the variables of the system need to be reduced, as described in the conclusions of Chapter 3.1. This is recommended at least in a first step of development, until the use of such DPS systems have been proved in long term demonstrations as safe under different conditions.

- At least 2 locomotives in the train; one master and one slave locomotive. This restriction is aligned with the simulations performed during DYNAFREIGHT project.

  Train compositions with up to 4 locomotives are accepted in Europe (e.g. in Switzerland) depending on national rules, but some considerations have to be taken into account:

  - Simplification of the traction/brake control; casuistry increases with the number of locomotives but simulations have revealed that two locomotives are not always sufficient with lengths over 750m.
  - Increase of performance is not significant as there are other rules limiting the performance of the locomotives, for example the EN50388 limiting the maximum current drained by the train and therefore limiting the total effort of the train.

- Train lengths up to 1500m. Main assumption of the project which has the goal to allow operation of long trains in Europe.

3.4 Functional requirements of the radio and traction system

A first step in the development of the setup of functional requirements of the DPS system is the determination of the functions to be performed by the DPS system.

In order to do that, an analysis of the Functional Brake down Description (FBS) of the EN15380-4 was done by DYNAFREIGHT partners together with FFLE4 partners.

Shift2Rail
Grant Agreement Number: 730811

The result of the analysis, as seen in the image below, is a list of functions as defined in EN15380-4 which have to be implemented by the DPS system for operation in long trains.

All the functional analysis of the FBS can be seen in Annex 1.

EN 15380-4 levels					Train function	consolidation	Level 4 subfunction	Level 5 subfunction
G					Accelerate, maintain speed, brake and stop	YES		
G	B				Provide acceleration	YES		
G	B	B			*Configure propulsion system*	*YES*		
G	B	B	B			*YES*	Configure propulsion system according to operational modes/limits	
G	B	B	B	B		*YES*		Forward/Reverse selection according train orientation for guided TU
G	B	B	B	C		*YES*		Ensure F/R traction according train
G	B	B	C			*YES*	Configure propulsion system according to internal status	
G	B	B	D			*YES*	Apply power limits	
G	B	C			*Acquire propulsion demand*	*YES*		
G	B	C	B			*YES*	*Command Traction Cutout to guided TU's in DPS mode*	
G	B	D			*Manage traction system within mode*	*YES*		
G	B	D	B			*YES*	Manage traction direction	

Table 1: Extract from FBS analysis of a DPS system

Shift2Rail
Grant Agreement Number: 730811

The related functions to traction and radio that are needed for the operation of long trains according to the analysis made are:

- **GBB**: Configure propulsion system (traction)
- **GBC**: Acquire propulsion demand (traction)
- **GBD**: Manage traction system within mode (traction)
- **GBG**: Generate tractive effort (traction)
- **GDB**: Manage sanding (traction)
- **HCB**: Inaugurate train network (radio)
- **HCC**: Manage train network operation (radio)
- **HEC**: Manage propulsion and brake demand traction (traction)

The control of the pantograph and MCB are not considered within the scope of this report as they are not considered part of the traction or radio functions (which is the focus of this report). However these functions and others shall also be considered for the complete analysis.

The mentioned radio and traction functions are explained here:

Inauguration of radio channel (HCB): The inauguration is the procedure followed during the start-up of the system to guarantee that the master locomotive is leading the slave locomotives of its own train, also that the slaves only accept orders from the right master and finally that the master is in possession of all the parameters from the slaves needed to perform the service.

As part of the operational procedures the ID of the different slaves must be introduced in the master locomotive (the ID could be the EVN number, which is a unique number for every locomotive) and the ID of the master must be introduced in the slaves. This process is needed in order to guarantee that the master only send orders and receive information of the authorized slaves and that the slaves only accept orders and send information to the authorized master locomotive.

Static properties and initial status of the slave locomotives are sent during this process. Main static properties regarding traction and radio functions are:

- Order in the composition (master is number 1), the order is introduced in every slave during the data entry procedure,
- Position/distance to the master locomotive of each slave,
- Maximum traction effort,

Grant Agreement Number: 730811

- Catenary current consumption when maximum effort applied.

The locomotives must be capable to record the introduced ID's so in case there is a reset of the network it is not necessary to re-introduce the ID's in the slave locomotives.

Manage train network operation (HCC): Radio component must be capable to handle the communication between the different units. Length of the messages will be determined by the functions performed by the system (for example in Marathon project 9 bytes were used and in FFL4E demonstrator 30 bytes are previewed). The function of the radio component is just to transmit the information without modifying it, manage the conflicts of the network and be able to detect communication loss.

Encryption system using keys similar to other railway systems using radio like ETCS seems suitable for the radio system in order to guarantee the safety of the communication.

Direction of travel (GBB, GBD): The direction of travel must be configured in the slave locomotives of the train according to the direction defined by the master locomotive. The locomotives configure the direction of travel regarding the travel direction switch and the active cab, but the master locomotive needs to know how each slave is oriented in relation with his active cab. The proposed solution is that the driver must introduce, as one parameter of the data entry, which cab of the slave locomotive is oriented towards the master during the configuration of the DPS system in the slave. In this way the master locomotive stablishes the relative orientation of each slave locomotive. In return the slave locomotives must send to the master the status of the direction.

As a double check it is proposed to perform a traction test to check that the directions are aligned. In order to perform such a test the yard must allow the train composition to move some meters.

Management of diesel engine (GBG): In case of diesel locomotives, the master locomotive sends the request to start/stop the diesel engine during at least one second. Two different signals, one for start and one for stop. Once the master sends the order, if the conditions are correct, the slave will apply it and the engine will be in this status until a new order arrives. If the engine in the slave needs a preheating then the start order will launch the preheating and the cranking will be applied just after the preheating. If both start and stop orders are sent by the master then the slave applies a shutdown in case the engine is running. Slave sends to the master the status of the engine and its speed.

Traction Management (GBC, HEC): There are several strategies which can be applied for the long trains using DPS systems. For example, today in Germany the trains using distributed traction use a configuration with two locomotives, one in the head and another in the tail with drivers in both locomotives. The traction strategy in this case is to apply different levels of traction in the head and the tail.

The strategy must be as simpler as possible in order to reduce the variability. The current proposal is aligned with UIC647 and with the dynamic simulations performed during DYNAFREIGHT project: all the locomotives apply the same traction effort although some delay between the transmission and application of the effort must be taken into account in the slave locomotives (which in nominal conditions is less than 2seconds). In order to apply the same effort level during the inauguration each slave locomotive must inform the master about the maximum efforts at maximum traction effort and current consumptions for such efforts. During service the slave locomotives must send updated information to the master about maximum effort for the maximum traction request. The master will then send back to each slave locomotive the traction request in % in order to assure the same level of effort applied in all the locomotives. The slave locomotives in return send to the master the traction % applied and the current drained from the catenary (this is not applicable for diesel locomotives). UIC647 warns about the difficulty to assure an equal distribution of the effort when using different types of vehicles so special attention must be put to solve this problem.

Different strategies can be implemented in some specific cases in order to reduce the risk level of certain situations. For example, simulations carried out in Task 3.2, show that in some cases it could be positive in a brake situation allow a certain level of traction in the master, while the rest of the train is braking (stretch braking). A careful analysis must be taken before implementing these kind of solutions, in this case for instance as the stopping distance will be modified and it has a direct impact on the security and the performance of the signalling systems.

The master locomotive must take into account the current limitation and other possible effort limitations and calculate for each locomotive the traction request % to maximize the performances of the train.

During a communication loss, a new strategy is needed to allow that each slave locomotive acts independently when there is no communication with the master. The solution proposed by UIC647 seems appropriate: if the slave receives a non-valid value or no value then keeps the last valid traction request during 1 second and if the communication is not re-established then start to ramp the traction request to 0 within 5 seconds. This strategy was implemented successfully for Marathon project although some validation through simulations is needed for confirmation. The time values can be adjusted depending on the results of the simulations.

The value suggested by the UIC647 is one second but for radio remote controlled vehicle this value must be defined with the help of some specific simulations.

Besides the automatic response of the DPS system on the master and slave locomotive, driver is warned in the master and a procedure must be defined to be followed in these cases.

Traction Cutout (GBB): The master locomotive must command the activation/deactivation of the traction through a direct command and the slave locomotive must send to the master the status of traction.

Shift2Rail
Grant Agreement Number: 730811

Sanding (GDB): The master sends to the slaves the request of manual sanding (apply/not apply). The slaves send to the master the status of the sanding (applied/not applied).

4. SAFETY ANALYSIS OF THE RADIO REMOTE SYSTEM FOCUSED ON TRACTION AND COMMUNICATION FUNCTIONS

The purpose of this chapter is to perform a safety analysis of the radio and traction functions defined as applicable to the DPS systems in Chapter 3.

During the project development DYNAFREIGHT and FFL4E partners developed a safety plan for the demonstrator to be performed by FFL4E partners. The safety plan proposed the SIRF as the method for the functional analysis of the system. Therefore in this chapter the German SIRF procedure has been applied to the functions defined in Chapter 3 as applicable to DPS systems.

4.1 HAZARD IDENTIFICATION

The first step in the safety analysis is the hazard identification, which has been performed with FFL4E partners in some dedicated meetings. In this chapter the focus is put on the hazards related to three main functions: train composition, train functions and communication loss (these three blocks the ones covering the aspects of the traction and radio functionality).

Hazards applicable to each of the functions defined in chapter 3.4 have been identified, though not all the functions have a specific hazard, some hazards are common to several functions and some functions have several hazards.

Hazards taken into account in this analysis have been defined during a workshop organised together with FFL4E partners, based on commonly known accidents and the underlying hazards and generalized causes:

- Accident
    - Underlying Hazard
        - Generalized cause
- Collision
    - Train does not stop within giving brake distance
        - Insufficient Brake force in wagons due to delayed propagation of brake command in BP (emergency brake)
        - Traction active against brake command (service brake, emergency brake)
- Derailment

Shift2Rail
Grant Agreement Number: 730811

    - Sideward forces derail wagons (due to increased (out of bounds) longitudinal forces
        - Delayed brake or traction in guided loco
        - Wrong brake or traction in guided loco
- Fire
    - Unmanaged fire in guided loco
        - Not transmitted fire alarm
- Impact
    - Impact with catenary

The hazards applicable to each of the functions defined in chapter 3.4 are explained bellow:

Traction Management (GBx)

- Function: to apply traction forces (limited according to the positions and distances of locomotives)
    - Hazard: high longitudinal forces (compression) lead to a derailment
        - Cause: guided locomotive applies higher traction than master
    - Hazard: Oscillation in the train (compression/stretch) lead to a derailment / Train separation
        - Cause: interference between signal transmission times and control cycles
    - Hazard: high longitudinal forces (stress) lead to a train separation and subsequent collision of separated parts
        - Cause: guided locomotive applies lower traction than master

Function: Direction Configuration of all connected locos (GBB,GBD)

- Hazard: Stretch of train into both directions, approx. 20 meters (train separation is deemed to be impossible)
    - Cause: locomotives pull into different directions
    - Limited severity, because this will happen in a protected area only (very low speed / no speed, but dedicated freight yard)
- Hazard: too high compression forces between the locomotives lead to a derailment or turnover of wagon

    - Cause: locomotives push towards each other
    - Limited severity, because this will happen in a protected area only (very low speed / no speed, but dedicated freight yard)

Function: To set up the train: locos and wagons (Inauguration) (HCB)

- Function: to determine Train ID, ID of master loco, ID of guided loco(s)
    - Hazard: Unintended control of a loco that is not physically connected to the train
        - Cause: Master loco accepts wrong guided loco
        - Cause: Guided loco accepts wrong master loco
- Function: to exchange parameter between locos
    - Hazard: wrong traction forces / brake forces
- Function: to set parameters for the train (total train length, locomotive distances, positions, number of wagons between locomotives and their weight) initially
    - Hazard: wrong setting of traction force in the guided loco (too high forces) lead to a derail of wagons
    - Hazard: BP control affected (timing for re-filling) delayed brake forces in parts of trains → collision

Function: Configuration of DPS in a loco to master / guided (HCB)

- To isolate DPS on master locomotive and to isolate locomotive brake panel on guided locomotives
    - Hazard: conflicting BP control (no hazard, because both panels try to control the same)
        - Cause: Non-isolated DPS on master locomotive
        - Cause: Non-isolated locomotive brake panel on guided locomotive
    - Hazard: no BP control from guided locomotive
        - Cause: Isolated DPS on guided locomotive
    - Hazard: no BP control from master locomotive
        - Cause: Isolated locomotive brake panel in the master locomotive

Function: Protection of set DPS parameters for a confirmed train configuration (HEC)

- To protect parameters for the train (total train length, locomotive distances, positions, number of wagons between locomotives and their weight) against spuriously change

Shift2Rail
Grant Agreement Number: 730811

- Hazard: wrong setting of traction force in the guided locomotive (too high forces) lead to a derail of wagons
    - Cause: Wrong tractive effort or brake force limitation due to spuriously changed parameters in the guided locomotive or the master one
- Hazard: delayed brake forces in parts of trains due to BP control affected (timing for re-filling) lead to a collision
    - Cause: Wrong tractive effort or brake force limitation due to spuriously changed parameters in the guided locomotive or the master one

Manage Train Network Operation: Communication Loss Case (HCC)

It has been identified that the loss of radio communication between master and guided locomotives is a use case that needs to be considered, therefore the above listed functions have been discussed (and hazards identified were obvious) for the effect of loss of communication while a specific function is executed (for example to brake). This task needs to be finalized also for the change of a function (i.e. change from “to apply traction” to “to brake”).

- Function: to apply traction
    - Hazard: longitudinal forces (stretch, compression) lead to train separation and derailment
    - Concept: a limitation of pushing/pulling force is needed
    - Concept: keep tractive effort constant for 1 sec, then ramp down to zero in 5 seconds (acc. UIC 647) when communication is back use the currently transmitted value (ramp up)

Next table shows the SIRF analysis of the traction and radio communication functions for the operation of long trains with distribute power system.

Shift2Rail
Grant Agreement Number: 730811

	Explanation of the function	S_A	*Damage number*	S_V	Damage – degree of injury	*W*	Entry probability	*E*	Exposition time	*V*	Avoidance	*I*	Security request level (SAS)
Traction	• GBB: Configure propulsion system "Direction of travel "	5	Several persons can be affected (≤ 10)	4	At most, serious injury can be expected	1,7	Loss of function does not necessarily lead to serious injury	1	Short-term	1	Persons cannot escape	34	1
	• GBC: Acquire propulsion demand "Traction Management "	5	Several persons can be affected (≤ 10)	4	At most, serious injury can be expected	1,7	Loss of function does not necessarily lead to serious injury	1,3	During the entire stay	1	Persons cannot escape	44,2	2
	• GBD: Manage traction system within mode "Direction of travel "	5	Several persons can be affected (≤ 10)	4	At most, serious injury can be expected	1,7	Loss of function does not necessarily lead to serious injury	1	Short-term	1	Persons cannot escape	34	1
	• GBG: Generate tractive effort "Management of diesel engine "	3	A maximum of 1 person can be injured	2	Minor injuries may occur	1,7	Loss of function does not necessarily lead to serious injury	1,3	During the entire stay	1	Persons cannot escape	13,26	0
	• GDB: Manage sanding	5	Several persons can be affected (≤ 10)	4	At most, serious injury can be expected	1,7	Loss of function does not necessarily lead to serious injury	1	Short-term	1	Persons cannot escape	34	1
Radio	• HCB: Inaugurate train network "Inauguration of radio channel "	5	Several persons can be affected (≤ 10)	4	At most, serious injury can be expected	1,7	Loss of function does not necessarily lead to serious injury	1	Short-term	1,7	Persons can escape	20	0
	• HCC: Manage train network operation	5	Several persons can be affected (≤ 10)	4	At most, serious injury can be expected	1,7	Loss of function does not necessarily lead to serious injury	1,3	During the entire stay	1	Persons cannot escape	44,2	2
Traction	• HEC: Manage propulsion and brake demand traction "Traction Management "	5	Several persons can be affected (≤ 10)	4	At most, serious injury can be expected	1,7	Loss of function does not necessarily lead to serious injury	1,3	During the entire stay	1	Persons cannot escape	44,2	2

Table 2: SIRF analysis of the Traction and Radio fucntions

Shift2Rail
Grant Agreement Number: 730811

Considerations and explanations on the SIRF analysis are given below:

- Persons that can be affected:
  - Several persons can be affected: This option is selected when the hazard can occur/affect not only the staff of the locomotive. This can affect to other train in the line or persons in the stations.
  - A maximum of one person can be injured: this option is selected when the hazard only affect the staff.
- Damage degree:
  - Minor injuries may occur from pressure fluctuations.
  - At most, serious injury can be expected.
- Entry Probability:
  - Loss of function does not necessarily lead to serious injury: the failure will not always cause the hazard.
- Exposition Time:
  - During the entire stay: the failure can ocurr at any time of the service.
  - Short-term: the hazard can only ocurr during a limited period or activity (start of the service)
- Avoidance:
  - Persons can not escape
  - Persons can escape

After the analysis of each of the functions, the safety level must be assumed for the different equipment's of the locomotive. A decomposition of the overall system has been done to allocate the safety requirements of each component (see in figure 4 below the system decomposition of a locomotive equipped with a DPS system).

Shift2Rail
Grant Agreement Number: 730811

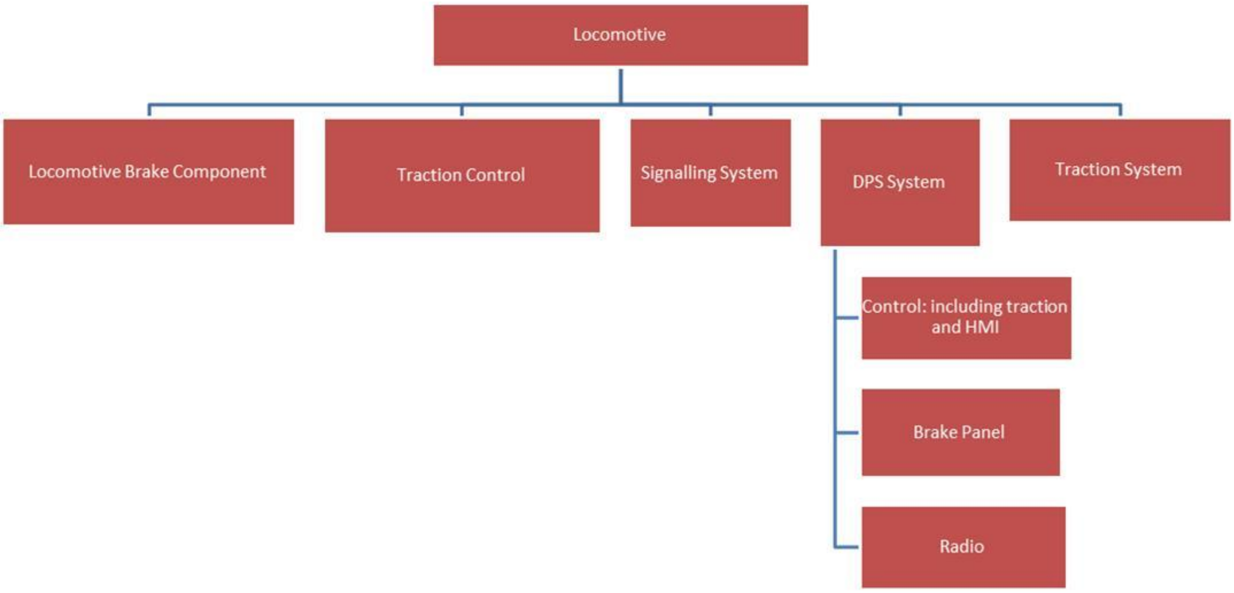

Figure 4: System decomposition

4.2 SAFETY REQUIREMENTS OF RADIO FUNCTIONS

After the establishment of the different safety level for the vehicle functions where the radio is involved, a breakdown of this safety level taking into account the locomotive architecture is detailed:

- Direction of travel (GBB, GBD) → SAS 1

  In the process of selecting the direction of the different locomotives the radio will only send the signal of which direction is selected (Lead to guided) and send the feedback of which direction is selected (Guided to lead).

  In a first step the responsibility lies on the driver who is responsible to configure the orientation of each locomotive.

  To achieve a SAS 1 in this function the DPCU of the master or guided locomotive must check the different signals transmitted by the radio and in case of signal lost or contradictory signs the DPCU must active an alarm. Therefore the safety of the function relies on the DPCU unit performing the logic of the DPS function.

- Traction Management (GBC, HEC) → SAS 2

  In the process of applying traction the radio will only send the signal of the quantity selected (Lead to guided) and send the feedback of which quantity selected is selected (Guided to lead).

  To achieve a SAS 2 in this function the locomotive must check the different signals transmitted by the radio and in case of loose the signal or contradictory signs active an alarm. Therefore the safety of the function relies on the DPCU unit performing the logic of the DPS function.

- Management of diesel engine (GBG) → SAS 0

  This function is not safety relevant, as can be seen in the SIRF analysis table.

- Sanding (GDB) → SAS 1

  The function of avoiding the automatic sanding in low speed, must be independent of each locomotive.

- Inauguration of radio channel (HCB) → SAS 0

  This function is not safety relevant, as can be seen in the SIRF analysis table.

- Manage train network operation (HCC) → SAS 2

  The function of the radio component is only to transmit the information without modifying it, to manage the conflicts of the network and to be able to detect communication loss.

  So the radio system has not safety requirements, therefore only the operational requirements are needed.

5. DESCRIPTION OF THE RADIO SYSTEM IMPLEMENTED FOR THE DEMONSTRATOR

5.1 DESCRIPTION ON COMMUNICATION TECHNOLOGY

Under the consideration of cross boarder operation, and having in mind standard radio technology as well as no or very little additional ground based hardware supporting the radio communication, a study of which is the right frequency range and radio transmission technology for a DPS system was made.

Common radio frequencies in harmonised and unlicensed radio bands in the EU are not suitable for a DPS system as either the maximum permissible output power is too low or the channel access time is too limited to support the timing requirements for a safe reaction over the radio channel.

For radio channels requiring a license there is no common radio in available in EU countries. With almost every border crossing the radio frequency has to be changed. In addition, it is expected that under critical radio environment such as tunnels and cuttings addition ground based infrastructure has to be implemented to guarantee the critical timing for DPS systems.

As a solution GSM-R was selected as derived from the requirements of ETCS a channel availability of 99% is guaranteed and GSM-R is already implemented on the dedicated main routes for DPS operation.

5.2 Interface Description between the Radio System and the Vehicle

As mentioned in the Executive Summary, DYNAFREIGHT project is a complementary project of Future Freight Locomotive for Europe – FFL4E (S2R-CFM-IP5-03-2015). WP5 Long Trains of FFL4E aims to establish solid and consistent specifications for technological solutions that enable longer and heavier trains to be operated and to define the architecture bringing together the different technologies, including the development of the prototype.

DYNAFREIGHT was supposed to develop and provide the radio system as well as providing support in commissioning of the FFL4E demonstrator (as stated in the Collaboration Agreement of both projects, among other things). However, due to the large process on the specifications of the radio system (discussed between DYNAFREIGHT and FFL4E partners), the new radio firmware needed for the locomotive integration (which DYNAFREIGHT LAIRD partner would have done from scratch) and the pressure on FFL4E to start the demonstrator and to present concrete outcomes at the Innotrans 2018, FFL4E took the decision to continue the development with an already existing Bombardier supplier, who has already implemented the locomotive interface (IPTCOM) and has GSM-R modems in its portfolio. Therefore DYNAFREIGHT did not provided the radio system for the demonstrator and this task cannot be described in this deliverable.

The reader is encouraged to read the following deliverables of FFL4E in order to find out details on the interface description between the radio and the locomotive and the final solution integrated in the locomotive:

- D5.5 – Risk management and trains dynamics
- D5.7 – System integration on two locomotives
- D5.8 – Demonstration report

Shift2Rail
Grant Agreement Number: 730811

Among the different goals of the technical file was the definition of the maximum duration of a blackout leading to a communication loss. As DYNAFREIGHT is no longer providing the radio system for the demonstrator a precise determination of the maximum duration of the blackout has not been stablished. However the communication loss has been considered in the functional analysis, assuming a duration of x seconds.

6. CONCLUSION

The present document gives a general view of the main system and functional requirements of a DPS system for the operation of long trains, up to 1,500m.

Main system requirements of DPS systems point to the need of a clear definition of the main characteristics of DPS systems to allow the compatibility between DPS suppliers and vehicle manufacturers. Characteristics like radio technology, radio protocols, format of the information, traction strategies, etc. must be agreed.

Feasibility of long trains have been stablished with MARATHON project or by the coming demonstrator of the project FFL4E. Now is time to collect all the information from both projects and find a consensus about the main requirements and operational limitations of long trains, some of them already proposed in this document. A new standard has to be written to allow to all possible suppliers to produce safe, profitable and compatible products for long train operation with DPS. A set of clear and unambiguous specifications must be produced using the experience of similar projects in Europe like ERMTS to avoid compatibility problems. Clear generic procedures and operational rules must be defined to be used in the definition of new rule books for the IM and RU. Possible impact in other standards and technical specifications like TSI OPE could be expected.

Simulations performed during DYNAFREIGHT project have also shown that long trains need to pay a price in terms of degree of freedom. Operational rules must be agreed in this new standard to avoid all the unsafe configurations founded in the simulations.

Use cases derived from the operational limitations must be backed up with simulations and the simulation tools must be validated with the results of the already performed and future test.

Grant Agreement Number: 730811

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APPENDIX

The functional analysis of the FBS is included in the Excel document:

Annex 1 FBS DPS.xls

Grant Agreement Number: 730811