OCORA

Open CCS On-board Reference Architecture

ATO Demonstrator - Case Study S2R IP 5 ARCC lessons learned and best practices for OCORA platform development

Document ID: OCORA-TWS15-010

Version: 2.00

Release: Delta

Date: 30.06.2021

Revision history

Version	Change Description	Initial	Date of change
2.00	Official version for OCORA Delta Release	BJ	30.06.2021

Table of contents

Table of figures

References

Reader's note: please be aware that the numbers in square brackets, e.g. [1], as per the list of referenced documents below, is used throughout this document to indicate the references to external documents. Wherever a reference to a TSI-CCS SUBSET is used, the SUBSET is referenced directly (e.g. SUBSET-026). OCORA always reference to the latest available official version of the SUBSET, unless indicated differently.

[1] OCORA-BWS01-010 – Release Notes

[2] OCORA-BWS01-020 – Glossary

[3] OCORA-BWS01-030 – Question and Answers

[4] OCORA-BWS01-040 – Feedback Form

[5] OCORA-BWS03-010 – Introduction to OCORA

[6] OCORA-BWS04-010 – Problem Statements

[7] OCORA-TWS15-020 – CCS-TCMS-Interface-ETCS-Functionality

[8] OCORA-TWS15-030 – CCS-TCMS-Interface-ATO-Functionality

[9] TSI CCS: 02016R0919 - EN - 16.06.2019 - 001.001 - 1: COMMISSION REGULATION (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union, amended by Commission Implementing Regulation (EU) 2019/776 of 16 May 2019 L 139I

1 Introduction

1.1 Purpose of the document

The purpose of this document is to provide an overview of the lessons learned and ensuing best practices to be used in the development of OCORA from the Shift2Rail IP 5 “Automated Rail Cargo Consortium Demonstrator Concept”.

This document is addressed to experts in the CCS domain and to any other person, interested in the OCORA concepts for on-board CCS. The reader is invited to provide feedback to the OCORA collaboration and can, therefore, engage in shaping OCORA. Feedback to this document and to any other OCORA documentation can be given by using the feedback form [4].

If you are a railway undertaking, you may find useful information to compile tenders for OCORA compliant CCS building blocks, for tendering complete on-board CCS system, or also for on-board CCS replacements for functional upgrades or for life-cycle reasons.

If you are an organization interested in developing on-board CCS building blocks according to the OCORA standard, information provided in this document can be used as input for your development.

1.2 Applicability of the document

This document is specifically and only applicable for the prototyping project carried out by DB Cargo AG and delivers feedback from field tests into the OCORA collaboration.

It is in no way intended to replace any S2R IP5 ARCC project and design documents, that need to be delivered by e.g. the system or subsystem suppliers.

1.3 Context of the document

This document is published as part of the OCORA Delta release, together with the documents listed in the release notes [1]. Before reading this document, it is recommended to read the Release Notes [1]. If you are interested in the context and the motivation that drives OCORA we recommend to read the Introduction to OCORA [5], and the Problem Statements [6]. The reader should also be aware of the Glossary [2] and the Question and Answers [3].

1.4 Document Context

This document provides basic background information on the integration of ATO Grade of Automation level 2 (GoA 2) into the ETCS OBU and the test vehicle, the combination of which constitutes the ARCC GoA2 Demonstrator. The document also briefly describes necessary actions to ensure a safe and reliable operation of the demonstrator on the Swiss railway network tracks.

The Shift2Rail (S2R) project “Automated Train Operation” (ATO) – which is ongoing within the “Automated Rail Cargo Consortium” (ARCC) – aims to demonstrate the viability of safe, efficient and reliable automatic freight train operation according to GoA 2 regime. Therefore, the S2R IP5 Automatic Train Operation Module (ATO module) has been developed, the aim of which is to fulfil the operational timetable in the most energy-efficient way by calculating the ideal speed profile for the vehicle and by controlling its traction and brake control accordingly.

The GoA2 regime, as is well known, supposes that an ETCS system that is fully independent from the ATO system, ensures safe operation at any time, while the automated driving mode is supervised by a driver.

The goal of the ARCC GoA2 Demonstrator is to:

- understand and test the functional deployment of an ATO system within a full operational environment;

- provide empirical feedback with regard to ATO design to support upcoming S2R ATO development projects, e.g. X2Rail1 WP 4 (GoA4 Development) to improve design, engineering, test preparations and execution.

DB Cargo AG, an OCORA core member, is leading ARCC GoA2 Demonstrator activities and envisages to ensure consistency and coherence between the S2R IP5 project and the ongoing OCORA development, with the specific intent to find maximum synergy between the two initiatives.

2 ARCC GoA2 Demonstrator objectives

2.1 Objectives of ATO testing from the OCORA perspective

From the point of view of OCORA, the prime goal of the ARCC GoA2 Demonstrator is to test and analyse to what extent GoA2 functionality would support Railway Undertaking objectives for the different modes of transportation, e.g. national and international long distance passenger traffic, regional and urban passenger traffic and heavy haulage freight transportation. These objectives include:

- **Ensuring (network) interoperability (interface standardization between ATO – TS (SBB) and various ATO on-boards):** The DB Cargo locomotive used as the mobile testbed of the ARCC GoA2 Demonstrator (a TRAXX AC 1 locomotive) has been tested on an operational ERTMS L2 test track which is part of the operational Swiss rail network (SBB). The vehicle is equipped with ATO OB systems from various suppliers. Data exchange with trackside equipment is executed according to SUBSET 126 (version 0.1.16) requirements.
- **Establishing interchangeability (interface standardization between proprietary vehicle TCMS and various ATO on-boards):** the ATO OB provided by the involved suppliers, were connected to the vehicle Train Control Management System (TCMS) via the standardized interface SUBSET 139. Furthermore, these units were connected to the ETCS SUBSET 026 version 2.3.0d compliant on-board unit via the standardized interface SUBSET 130 (SUBSET 130 has been realized by ETCS to ATO proprietary gateway).
- **Solving human factor:** Test sequence output provides e.g. information on and indications for improvement of automated driving style and vehicle guidance requirements as handled by the human today. Test results can be used to enhance driver handling of ETCS and ATO enabled rolling stock in general and the ATO equipment specifically.
- **Increasing specification maturity:** Test output will allow to improve the robustness, quality, correctness and completeness of the ATO specification which will support a harmonized demand by RU's to the supply industry, reducing the need to design and engineer specialty solutions.

2.2 S2R and OCORA interaction

The Shift2Rail IP 2 "X2Rail 2/4 ATO GoA2" work stream has delivered the basis for the ATO-OB to TCMS interface (SUBSET 139). OCORA has checked the consistency between OCORA CCS-TCMS work stream and the SUBSET 139 document, resulting in the OCORA-40-007-Beta-CCS-TCMS-interface – ATO Functionality specification scope.

The actual ATO-OB to TCMS interface design for the ATO demonstrator is based on the X2Rail 2/4 ATO GoA2 specification workstream, taking account of the OCORA-40-007-Beta-CCS-TCMS-interface – ATO Functionality requirements. The intention is to check consistency where possible the output of both work streams for the actual ARCC GoA2 Demonstrator project, and to achieve a harmonised approach and requirement specifications for future ATO functionality development initiatives.

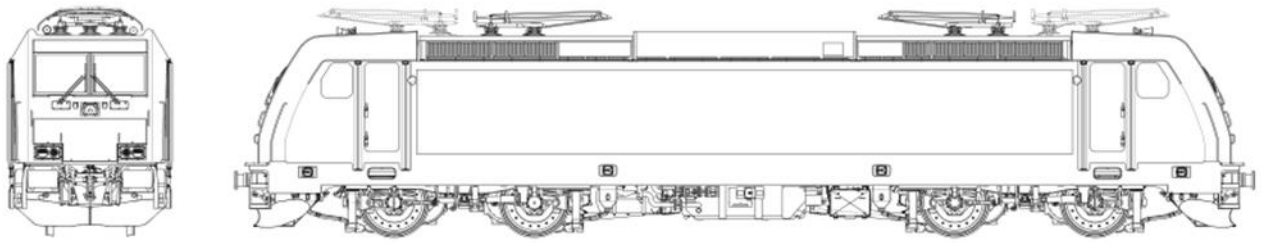
The ensuing, specific vehicle integration of the ARCC GoA2 Demonstrator – that required a few specific modifications that needed to be implemented in the TRAXX AC 1 system – is suitable for retrofitting on existing Multi Vehicle Bus systems, identified by the Shift2Rail X2Rail3 WP10 work stream.

3 ARCC GoA2 Demonstrator test configuration

To execute the test itself, a test locomotive with fixed technical arrangements was equipped repeatedly with ATO on board units of four different suppliers to analyse if the ATO equipment could be installed without the need to adapt the vehicle configuration and if the resulting combination would perform according to operational requirements. Below an overview is provided of the test configuration.

3.1 Test Vehicle

The vehicle used for testing is a BR 185.1 CH TRAXX F 10 AC which is equipped with ETCS according to SUBSET 026 version 2.3.0 d. For the details, see Figure 1.



Operator:	DB Cargo
Length:	18,900 mm
Width:	2,977 mm
Weight:	approx. 85 tons
Max. Speed:	140 km/h
System voltage:	AC 15 kV/16.7 Hz, AC 25 kV/50 Hz
Max. traction power:	5.6 MW
Starting tractive effort:	300 kN

Figure 1 BR 185.1 CH TRAXX F 10 AC details

For the S2R IP5 ATO demonstrator project, the BR 185.1 (German vehicle class code), respectively Re 485 (Swiss vehicle class code) from Bombardier Transportation (BT) is used. The vehicle UIC number is 9180 6185141-9. From here on, the vehicle will be referred to as BR 185.1.

The operational use of the locomotive is limited to Switzerland and Germany. For operation of German legacy infrastructure in Germany, the vehicle is equipped with the national Class B train protection system LZB80/16 (Linien Zug Beeinflussung) and for Swiss legacy infrastructure with ZUB262ct INTEGRA/SIGNUM. Additionally, the vehicle has been retrofitted with Trainguard®200 (ETCS Level 0 and 2, according to UNISIG Baseline 2.3.0d) with the system release CHP 03.02. and consequently can operate on ETCS levels 0 and 2.

The BR 185.1 CH TRAXX F 10 AC is currently deployed by the following RUs:

- DB Cargo AG;
- DB Cargo Rail Switzerland AG;
- BLS Cargo AG, SBB Cargo AG;
- SBB Cargo International AG.

Operating approval (German: “Betriebsbewilligung”) for the BR 185.1 has been issued by BAV under number *CH 512015006* and has been provided to DB Cargo. The approval for the ATO test runs (German: “Versuchsbewilligung”) has been issued by BAV under number CH5120200033.

3.2 Test ATP System (Existing System)

The control, command and signalling subsystem on BR 185.1 consists of the following essential building blocks:

- Trainguard®200 OBU;
- LZB 80/16 (No ETCS equipment);
- GSM-R SIM card;
- GSM-R data transmission.

The ETCS on-board consists of an EVC (European Vital Computer), an NVC (non-vital Computer), balise or loop antenna, distance pulse generator, radar, ETCS display, isolation switch, reset button and JRU.

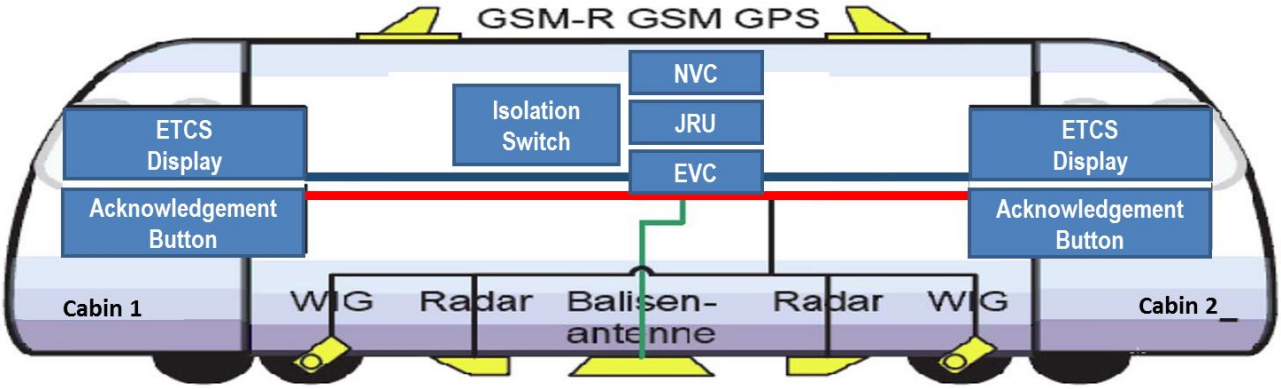


Figure 2 TRAXX AC 1 BR 185.1 CH ETCS subsystem equipment

The ETCS subsystem equipment of the locomotive is illustrated in **Figure 2**. The core of the ETCS vehicle equipment is the European Vital Computer (EVC). The non-vital computer (NVC) is used for communicating via GSM-R with the track infrastructure. The NVC includes the Communications Base System (CBS) software and has two GSM-R-Data-Mobiles. The NVC establishes a connection to a radio block centre (RBC), using the CBS software and GSM-R data modems via the GSM-R roof antennas, as far as this is required by the operated ETCS level. In addition to the time signal, the data recorder (JRU) retrieves and stores data that need to be registered (e.g. travel data) module according to SUBSET 027 requirements and which are conveyed via the MVB vehicle bus and a wired connections input.

EVC, NVC, GSM-R data radio and JRU are mounted in an ETCS cabinet on the vehicle. Data transmission from track based eurobalises to the vehicle is realized via the balise antenna. The ETCS vehicle system uses two radar sensors and two wheel speed sensors for distance and speed measurement.

For vehicle control and driver signalling, the vehicle's cabins are equipped with an ETCS display. The ETCS system has direct control to the braking system as well as to the traction system for cut off.

The GSM-R data radio module ensures the ETCS data transfer with the GSM-R trackside network using the CBS software, to the EVC. The on-board GSM-R radio device contains two independent radio modems.

In Germany, the ETCS vehicle system is always isolated during operation (country switching). The protection function is then carried out by the LZB80 / 16. The switchover from the national protection system to ETCS occurs at the national boarders by the country switchover vehicle control automatically. The switching between ETCS and ZUB is carried out via a proprietary (non-standardized) wire interface. ZUB / Signum is activated via a nationally defined interface in parallel to the activation of ETCS level 0. The status of the ETCS isolation switch is controlled by the vehicle I / O modules and is sent to the vehicle controller via MVB. The information for ETCS isolation switch actuation is recorded by the JRU.

The single state is responsible for the particular "ETCS Class B" specification and train protection technology. These components were only considered when there were effects or interactions due the European requirements of TSI CCS, see ref. [9].

The ARCC test setting will allow to perform tests with the ATO on-board equipment provided by four different suppliers, each of which is interfaced to the same unique configuration of ETCS on-board unit, vehicle and trackside environment via standardizes

- ATO OB – TCMS interface (SUBSET 139)
- ATO OB – ETCS OBU interface (SUBSET 130) supported via a converter logic within that specific implementation
- ATO OB – ATO TS interface (SUBSET 126/125).

Figure 3 gives an overview of these interfaces.

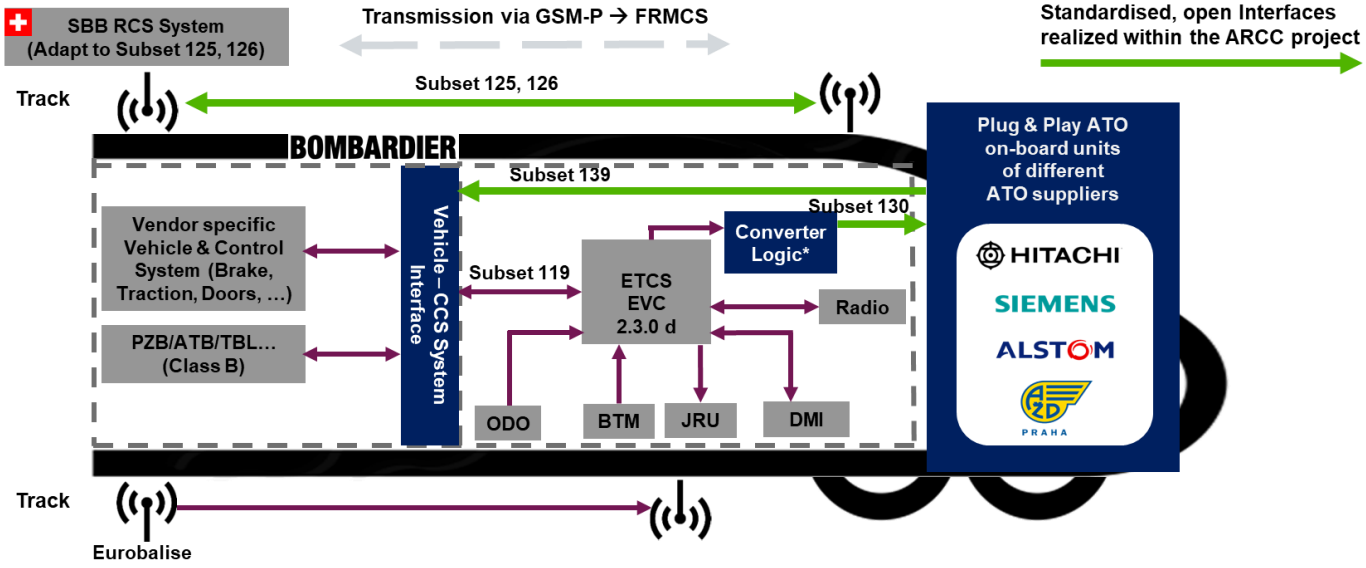


Figure 3 ATO on-board Test Configuration overview

4 Test Cases

To date, the development of the ARCC GoA2 Demonstrator test configuration specifically addressed the issue of the technical feasibility of exchangeability of ATO equipment of different suppliers in a stable vehicle configuration. Naturally, the next phases of the project will include extensive operational testing of the test configurations.

4.1 Freight Specific Test Cases

Freight specific test cases will be tested with hauled trains consisting of 14 wagons, covering a length of240 m and weighing 1274 tons. All stops and starts are required to emulate human driver behaviour and style to avoid e.g. ETCS emergency brake interventions, wheel flats, stretching of the train set incl. coupler and dangerous behaviour of the train set incl. load.

Stop testing includes:

- Stopping at ETCS Stops;
- Stopping at ATO stopping point;
- Start with ATO.

4.2 General Test Cases

Goal of the generic test cases is to test the functional behaviour of the ATO on-board as defined in SUBSET 125 and 126. Also, the robustness and usability of the interfaces SS 139 and SS 130 will be scrutinized.

5 Freight specific challenges within automation

Following freight specific challenges due to the fact that heavy loaded and long loco-hauled train will have completely different brake, dynamic behaviour than a EMU/DMU. Since EMU/DMU does not need to deal with different length, loading, coupler, different brake systems, … . E.g. freight trains has mostly 3 brakes (dynamic, direct and indirect air brake), which will be applied by today human according national rules and environmental conditions.

Violation or wrong handling of freight specific challenges within automation may lead to (safety-)critical situation such as derailment or train separation!!!

5.1 Generic dynamic control:

A major challenge for freight trains is the speed control of the heavily loaded trainset. It is unclear if this depends on the composition and loading of the train, i.e. the number and characteristics of the wagons.

Therefore, it is a question if the ATO-OB would need to know about the number, weight, and other parameters of the wagons, and if this is then sufficient to determine the real resistance of the train.

As opposed to a passenger trainset with a defined length and a weight within certain limits, the running resistance of a freight train can vary a lot. That means every new train composition will have an individual characteristic that needs to be controlled by the ATO OB.

A freight train set composition incl. the coupler and wagons must be understood as dynamic control of a spring-mass-damper system.

Supplier needs to consider the freight train as dynamic control of a spring-mass-damper system: consider the mass-spring-damper system in4. Spring k_2 and damper b_2 are attached to the wall and mass m2. Mass m2 is also attached to mass m1 through spring k1 and damper b_1. Mass m_2 is affected by the disturbance force f_2. The system is controlled via force f_1 acting on mass m_1.

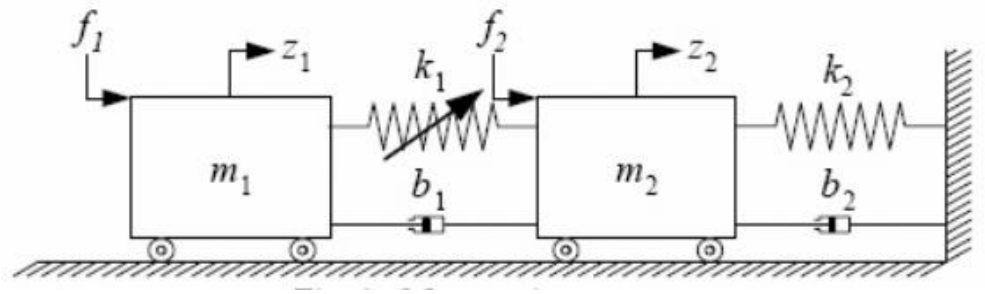


Figure 4 Freight train set dynamic control of a spring-mass-damper system

Though important influence factors for the running resistance, e.g. the track gradients profile, the length, composition, and weight of the train, other important influence factors are unknown, such as the real running resistance of each wagon. These constraints need to be taken into account for ATO freight product deployment.

5.2 Hill-start:

This use case is challenging due to the complex interaction between train characteristics, brake status, and control of brake and traction.

5.3 Status of the indirect brake:

To deploy an ATO system in productive operation an important step is to improve the control of the pneumatic braking system, i.e. the indirect brake.

Unfortunately, with today's freight trains, usually, no electro-pneumatic brakes are available. This adds a high level of complexity to ATO. Future use of the Digital Automatic Coupler could remove many of the problems associated with control of the indirect air brake (status of the brakes, brake reaction time). In theory, the use of the Digital Automatic Coupler will allow better ATO stopping accuracy and go some of the ways to allow starting in a slope, especially in combination with the airbrake.

5.4 Challenges with the realization of the braking function:

The main challenge in a loco-hauled freight train is the control of the indirect brake. As opposed to Electrical Multiple Units, where already many ATO tests were carried out in the past and where also projects in commercial service exist, a freight train usually does not have an electro-pneumatic brake. For the ATO-OB it is not possible to know when the brakes of the wagons are released and when traction can be applied. If traction would be applied too early with one or more wheelsets of the train still braking, a flat spot could occur.

Such behaviour can lead to the separation of the train.

For this project, it was therefore decided to wait 30 seconds between the signal from TCMS that the indirect brake is released and the application of traction. This time is called brake release delay time.

The main challenge was the implementation of the braking functions, especially the holding brake. According to Subset 125 when the train comes to a stop in AD mode the ATO-OB requests the "Train Holding Brake" application to the rolling stock and disengages.

Due to the realization of the vehicle software, this behaviour could not be achieved. If the ATO-OB disengages it does not have any influence on the vehicle anymore and the vehicle uses the manual brake handles as input. Therefore, after disengaging the brakes would be released by the vehicle when equipped with a common driver's brake valve with operation according to position as was the case with the loco used in the tests. To prevent the rolling of the train, the driver had to apply the brake manually in this project.

5.5 Control of train dynamic application and environmental influence

National rules and train driver experience must be considered within the specification:

For example, there should be the possibility to influence the brake and traction behaviour of the train with respect to tracking location and environment. During the tests it was observed that ATO applied higher electrical braking forces than allowed, which could in the worst-case lead to a derailment e.g. in front of a switch.

5.6 Operational rules regarding the limitation of longitudinal forces in switches and crossings

Presently most railways have operational rules for the train driver regarding the limitation of longitudinal forces in switches and crossings as not observing them could lead to derailment: e.g. limiting the use of the electrodynamic braking force when the locomotive is braking alone in switches and crossings. During the tests ATO didn't respect these rules, forcing the test drivers to intervene. Most operational rules have 3 aspects:

they specify a speed limit until which a certain braking or traction force limit in switches and crossings must be respected. Defining switches and crossings in the segment profile is currently neither implemented nor wanted as it would render the segment profile safety-relevant.

6 Lessons learned from the ARCC GoA2 Demonstrator project

The current phase of the ATO Demonstrator activities will be completed by 10th of December 2020. Therefore, a formal report describing the findings and the lessons learned will be delivered after finalizing the ATO Demonstrator activities, and after delivery of the official report in Q1/2021. A next OCORA report will take due account of this information.

The experience made thus far, allow to conclude to the following lessons learned:

- A consistent, complete and detailed system architecture, supported by unambiguous and complete interface documentation, is a prerequisite for even understanding the basic requirements for designing, engineering and installing an ATO on-board in an effective and reliable manner in any given, stable ETCS and Class B equipped rail vehicle configuration.
- All design documents should be reviewed carefully and frequently, like in the incumbent case by all applicants for supplying the ATO on-board equipment.
- After thoroughly scrutinizing the documentation by all partners in the project, a general design freeze is necessary to enable progress. Nevertheless, it is inevitable that inconsistencies, quality issues or missing elements will be found during the implementation phase. To mitigate the impact, strict documentation and version management and agreed procedures to manage abnormalities during the implementation phase is imperative.
- Smart requirements management tools and platforms are necessary to ensure full transparency and traceability during the design and integration phases.
- It's never enough to perform communication tests in the laboratory only. Also, static and dynamic functional tests need to be confirmed ideally on a track to ascertain the robustness and quality of the specification and implementation.
- Completeness and quality of the specification needs to be proven in a test environment prior to field testing.
- Dynamic integration tests need to be performed before going in the field. Special attention needs to be paid to test the integration of legacy systems as part of the overall system.
- Proof of correct functional behaviour between vehicle system and ATO should be performed in a lab environment.
- Easy understandable, unambiguous, clear structured specifications, combined with easy and indiscriminate access to such specifications for all stakeholders, is the key for a successful integration and lasting stability of the system.
- Adapt the system as far as possible to the manual driving style (brake and traction application by humans) and vehicle guidance in an ATO project. It's not just about logical functions but human factors and human experience need to be integrated for maximum operational performance.
- The automation function needs to be understood as an end-to-end process from TMS via ATO, ETCS, TCMS to the automated train functions and backward. TMS can only provide good input to ATO, if the train and line configuration, capabilities, and deficiencies are sufficiently updated and communicated. Train control quality and safety depend on the full implementation of these constraints, especially covering operational rules. Therefore, an allocation of related functions and their comprehensive specification in the end-to-end process is essential.

Prior to even considering starting an ATO procurement and installation process, try and apply the lessons learned summarised above.

7 Proposal for further development of GoA 4 Freight Specification

7.1 Next steps

I. Requirements from RU Driving/Brake dynamic and vehicle guidance need to be taken into account.

II. ATO OB- Train interface specification is to be completed with respect to „Plug & Play“-requirements also for existing vehicle design (e.g. consider OCORA proposal for the functional vehicle adapter).

III. ATO specifications need to be further enhanced e.g. in field tests to achieve the necessary maturity for procurements. Specifications should be adequately tested in different operation modes (in particular freight) and this also needs to be considered for TSI 2022.

IV. The advantage of proven state-of-the-art technology must be taken into account for further development.

V. The human factor, social impact, and acceptance by society need to be seriously taken into the analysis.

VI. The holistic approach of railway automation and traffic management needs to be further analyzed to ensure end–to–end solutions.

VII. Roles and responsibilities e.g. between RU, IM, CCS supplier, Vehicle supplier, … need to be stressed and analyzed also from the view of the holistic end–to–end approach.

7.2 Taking advantage of a proven technology (AFB) for further development of the ATO

The automatic driving and braking control (abbreviation: AFB) is a technical system that is used in locomotives to support the driver in his work. The system takes on the driver task of accelerating or braking the vehicle and the train to a speed (Vsoll (german) – Vshall) pre-selected by the driver and maintaining the speed. Such systems are referred to as Automatic Train Operation without connection to the TMS.

For this purpose, the driver specifies a speed using a Vsoll adjuster (see figure 16); the AFB then automatically sets the necessary traction and braking forces: To do this, it uses the engine brake as well as the continuous train brake. The amount of traction can be influenced via traction control, while braking always takes place with deceleration values. The driver always retains control of the vehicle and can intervene at any time by switching off the traction or manually braking with the driver´s brake valve. The AFB is then temporarily deactivated, just as it can completely be switched off at any time.

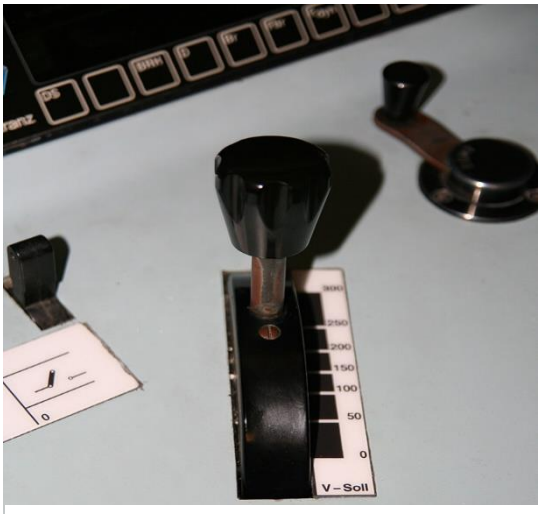


Figure 5 AFB Vsoll adjuster of ICE 1

The AFB is mainly found in modern vehicles, such as the Intercity Express, Class 101 locomotives, and others. Some subway systems also use AFB. For driverless railway systems, AFB is a basic requirement.

The Class 103 engines, introduced in the mid-1960s, were the first locomotives in Germany to be equipped with automatic speed control.

In combination with effective line train control (LZB) (Figure 5), the AFB can automatically control the speed of a train (Figure 19), taking into account the LZB guide sizes, in such a way that it never exceeds the permissible speed of Vmax, if the vehicle is equipped with appropriate equipment. The system can automatically accelerate again after braking, but it does not detect scheduled stops if they are not signaled.

As with manual control, the driver always retains full responsibility for the safe performance of the train journey. Since automatic driving with AFB and LZB on many routes with fully designed traction force and Vsoll actuators (then Vsoll=Vmax applies) leads to very dynamic handling of the train (unnecessarily strong accelerations and delays, no predictive driving), train drivers usually switch traction force and Vsoll completely only if it makes sense. In addition to higher driving comfort, energy savings can be achieved in particular. (source: Automatische Fahr- und Bremssteuerung – Wikipedia)

Figure 6 LZB Data Entry via Display

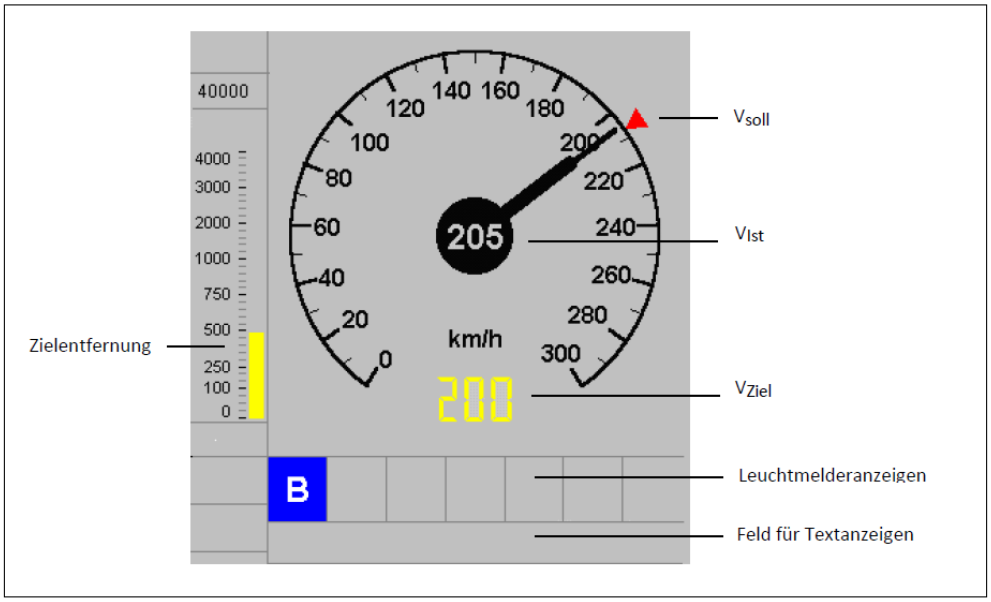


Figure 7 LZB command speed variable in a modern driver desk

The new generation of AFB has been already started ran into acceptance test with DB already in June 2018 and will be installed in the newest locomotives e.g. TRAXX AC 3.

See short explanation of the new generation of AFB:

Term	Meaning
ATO-AFB	Designed to fit DB AFB requirements, involves the following features: - Automatic management of traction and dynamic brake force set-point and mechanical brake force (using brake pipe control) to regulate the speed in a way that the speed set-point set by the driver using the Automatic Speed Controller (ASC) [019] {-TD.A23/24-A02} is reached and the ATP brake curves are not exceeded. - Driver assistance functions (train stretching and holding brake)
ATO-E	Speed regulation using an automatic management of the traction and dynamic brake force set-point, without control of the brake pipe and automatic regulation intervention based on ATP brake curves
ATO-WE	Washing mode, based on ATO-E with adapted parameters for regulating the speed at low values, with higher resolution of the set-point and without control of the brake pipe (no possibilities to stop the train at the end of the washing run without the intervention of the driver on pneumatic brake)
ATO-LoaMod	The loading mode ATO-LoaMod is designed for a very slow run through a freight loading terminal. For regulating speed, both traction and ED-Brake shall be available. In contrast to normal mode, ED-Brake effort up to 240 kN shall be available for speeds larger than 0.5 km/h.

Summary: this section has been described as a very high mature legacy automatic driving and braking control of the locomotive and in particular a heavy freight train, which has further developed in the last decades. This means there is already massive engineering experience and understanding of controlling a heavy loaded and long freight by automatic driving and braking control system. Of course, this legacy system is not connected to the Traffic Management System and therefore not understand as a GoA 2 standard. But, GoA 2 standards should use the advance of an existing legacy automatic driving and braking control system to deliver high mature GoA 2 specifications and products to the market and ensure acceptance and rollout of the ATO technology in particularly for freight. The idea of such a technology approach in particular concerning existing vehicle design will be considered in the next section with the Functional Vehicle Adapter.

7.3 Functional Vehicle Adapter as legacy vehicle design solution

The current ATO GoA 2 vehicle interface would be easy to integrate into a new vehicle design.

For existing vehicle designs the gap is typically much larger. To achieve the objective of defining a fully Generic interface between the ATO Onboard and the vehicle there will always be a requirement for an “adapter” solution. This is the most economical way to realize the Plug & Play integration of an ATO GoA 2 system – see figure 19.

An economical solution for existing vehicle designs is highly needed today for freight RU´s. At DB AG RU a retrofit solution for ETCS & ATO is estimated to be required for 80 % of the fleet.

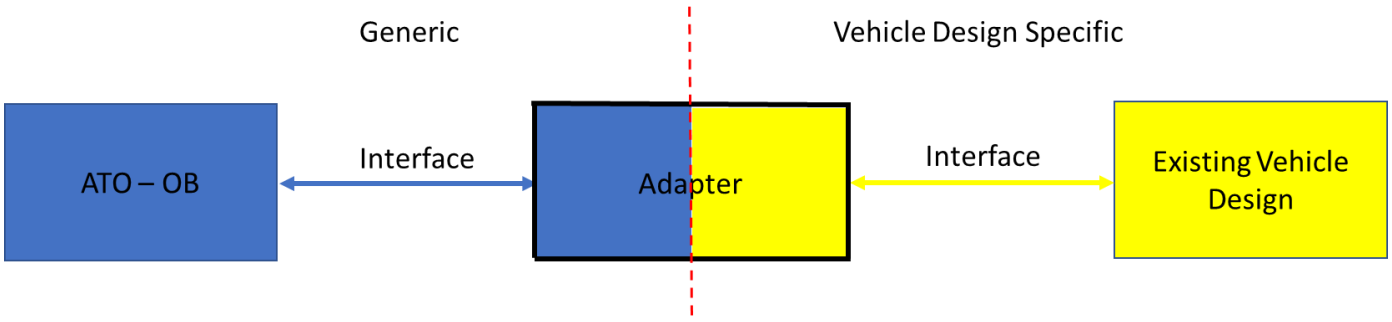


Figure 8 Adapter between generic ATO and Existing Vehicle Design

The proposed Functional Vehicle Interface as a common standard can be understood as a solution for ATO retrofit for all generations of vehicles including the continued use of legacy automatic driving and braking control systems such as AFB.

One important goal of this solution is to provide on the one hand a common solution for adaptation functions to Existing Vehicle Design and on the other hand to use the advantage of highly matured legacy automatic driving and braking control systems – see figure 20. For legacy vehicles, this can in many cases be a better solution than to try and “reinvent” the wheel by fine-tuning the low-level control loops of the ATO onboard.

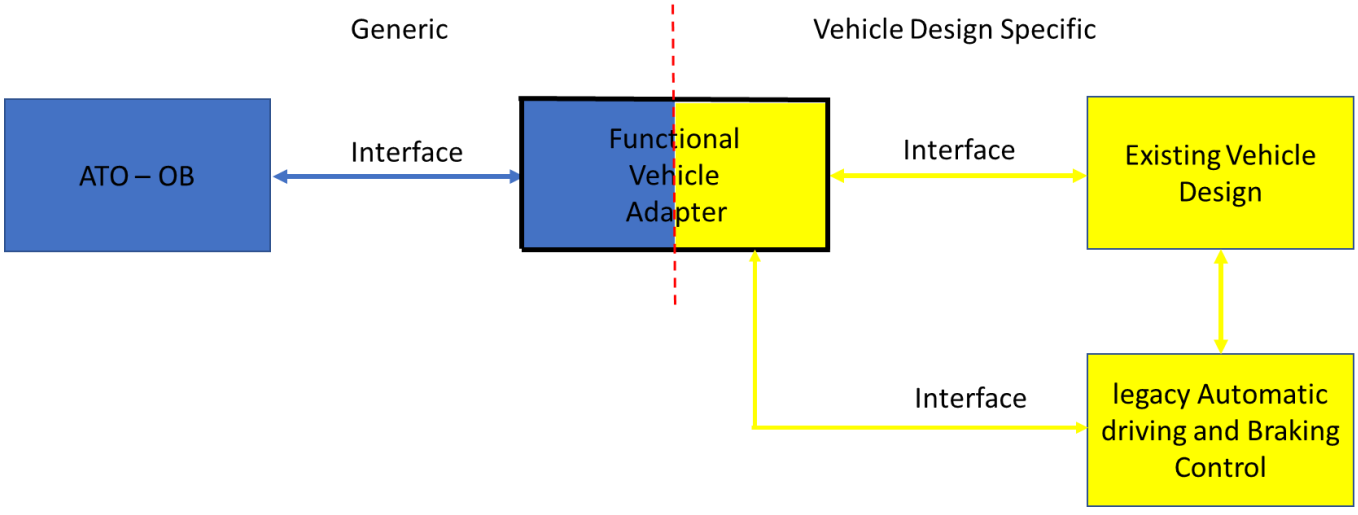


Figure 9 Use of FVA with Existing Vehicle Design and Legacy Automatic Driving and Braking Control

Summary: the FVA proposal can be a solution to overcome the challenge of the Plug & Play interface for existing vehicle design while continuing to use the highly matured existing legacy automatic driving and braking control systems. A strategic discussion to be held on sector level to support the quick ATO rollout and migration of RU fleet in particularly freight is required to define and roll- out such a solution.

7.4 Human Factor, Social Impact and Acceptance of the ATO technology as critical path

Since the ATO GoA2 and also GoA 3/4 with Remote Control for degraded mode is completely changing today job profile of today train driver the human factor issue needs to be taken in serious consideration. In particularly the effect of the human and its courtesy in relation to the automation of operation will become a significant impact. The following diagrams describes the reaction times with respect to the grade different grades of automation.

Longer reaction times in seconds to critical stimulus in the driver's cab (immediate braking required) with automatic speed control (GoA2) vs. manual speed control (GoA1) during a 2-hour trip (see figure 21).

(source: Brandenburger, N., Naumann, A., & Jipp, M. (2019). Task-induced fatigue when implementing high grades of railway automation. *Cognition, Technology & Work, 52*, 1-11.)

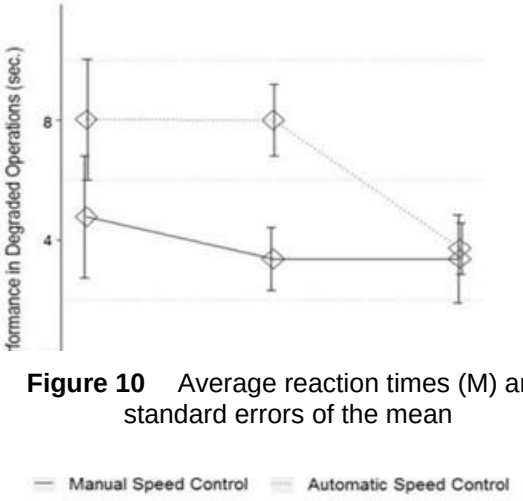


Figure 10 Average reaction times (M) and standard errors of the mean

Stronger increase in subjective fatigue in GoA2 (measured with Karolinska Sleepiness Scale (KSS)) compared to GoA3 after 2 hours of work (see figure 22).

(source: Brandenburger, N., Naumann, A., & Jipp, M. (2019). Task-induced fatigue when implementing high grades of railway automation. Cognition, Technology & Work, 52, 1-11.)

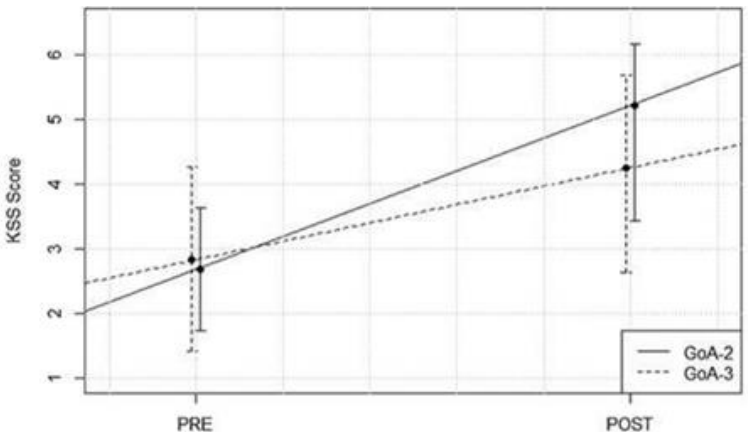


Figure 11 Effects of the Grades of Automation (GoA) on the Karolinska Sleepiness Scale scores over the course of the study.

Since driver has the full responsibility of the operation with ATO GoA 2 the acceptance of the system by the human is very critical. So called “acceptance of innovation the customer is the key”. The result of the ARCC is challenging this topic as it could noticed 7 ETCS emergency brake interventions and 110 driver interactions during the test phase to avoid critical operational or safety situation from the fully educated test driver point of view.

Further investigation on that topic and results future ATO development in particularly within the specification and testing methodology is necessary to avoid and serious issue with human factor and social impact.

7.5 Roles and Responsibilities of future Full Automated Operation (GoA 4)

The following benefits and potential expected from the automation of the railway system e.g.

- Improve quality of operation
- Increase reliability
- Improve recovery time
- Improve reaction time
- Improve capacity
- Improve cost and efficiency
- Reduce energy consumption
- Increase productivity
- Deliver flexibility in planning
- Having more flexible customer service

To ensure the listed benefits a holistic approach of railway automation needs to take into consideration as described in figure 23 .

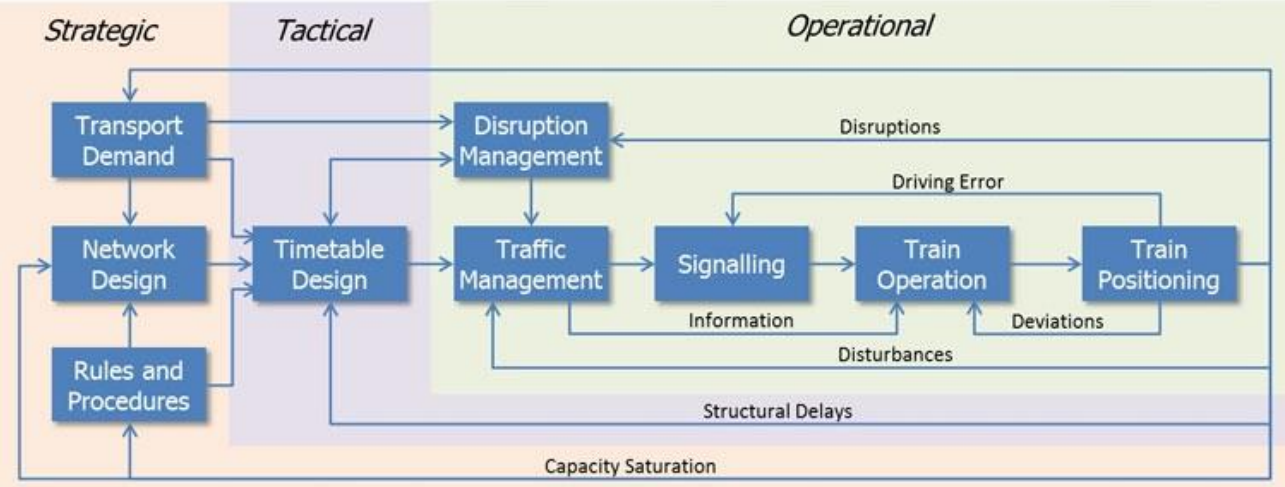


Figure 12 Railway Traffic System

(source: Trends and developments in the automation of heavy rail operations (globalrailwayreview.com))

For that purposes also the roles and responsibilities of

- Infrastructure Manager
- Railway Undertaking
- CCS Supplier
- Vehicle Supplier

needs clearly identified in such an “holistic” approach of automated system and need to be discussed and elaborated within further development of ATO.

7.6 Iterative approach and prototype

The ARCC tests has demonstrated the need for having real field tests and prototyping to evaluate the applicability and quality of current specifications ready for further refinement. It is also highly recommended to

test every release of the specification in such field tests before it becomes part of the TSI regulation and applicable for procurement. For the ARCC test a specification design freeze specification from 08/2018 has been applied which was not foreseen for procurement purposes. Results from the tests needs to be discussed (see figure 1 in section 2) and tests needs to be repeated with respect to the further developed specification until the necessary quality and robustness for procurement puroposes can be proofed to avoid further uncertain investment. The following figures 24 and 25 will illustrate the state of the at methodology of such iterative testing approach in relation with the design cycles process and prototypes steps.

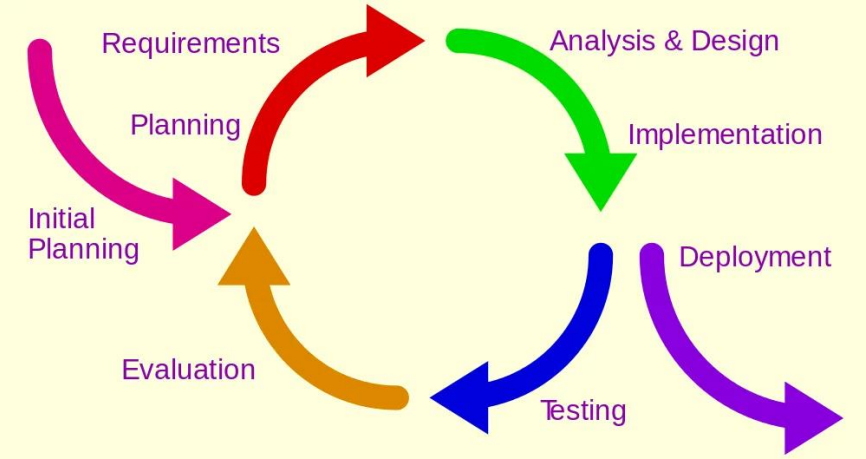


Figure 13 Cycle in a design or development process

(source: Design iteration brings powerful results. So, do it again designer! | Interaction Design Foundation (IxDF) (interaction-design.org))

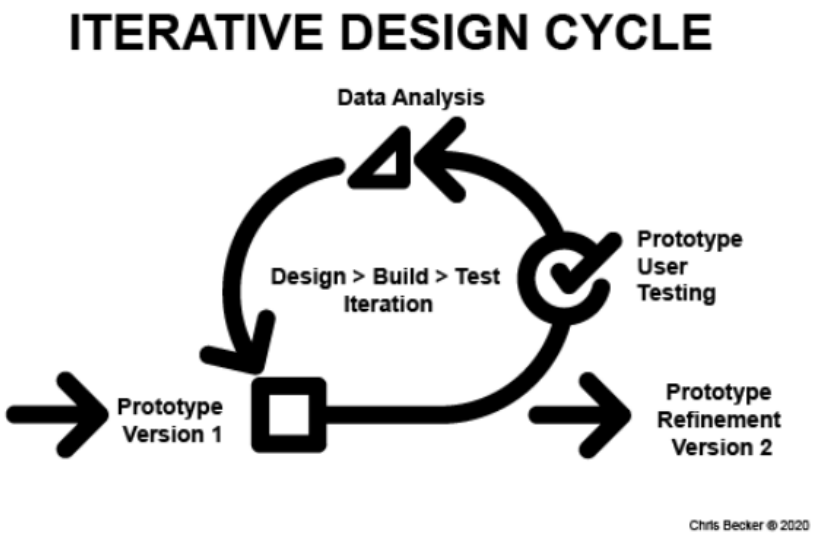


Figure 14 Iterative design with prototypes

(source: Learn Human-Computer Interaction, Christopher Reid Becker)

7.7 GoA 4 driver task analysis

For further development of the ATO GoA4 functionality a driver task analysis has been delivered by DB AG as proposal to further discussion within the specification workstreams, tasks and initatives e.g. S2R X2Rail4 GoA 4, TAURO, EUROPE´s Rail … . The list will be attached to that document in the ANNEX A

Annex A Driver Task Analysis

ID	Function according to EN15380-4	Sorting criteria	Current system according to EN 15380-5	Driver Task	Automation (ATO function = combination of trackside and onboard function)	Reference document	Chapter in Ref
DT001	HBED Provide control command information	Driving		Speed and distance monitoring and Symbol "Traction inhibition"	UIC 612-0, Appendix L Automatic Speed Control (ASC)	ERA_ERTMS_015560 FprEN 16186-3 prEN 16186-2:2015 [E]	7 Table A.1 Table B.2
DT002	HBED Provide control command information	Driving		[Train position information and] Release Speed Monitoring (RSM)	Exact train positioning, e.g.: Balise, Virtual Balise, Satellite, ...	ERA_ERTMS_015560	7.5; 8.4.4; 13.9
DT003	HBED Provide control command information	Brake		Emergency Brake Intervention [results in standstill]	Indicate Emergency Brake and reason for Emergency Brake to ATO trackside function (see ERA_ERTMS_015560 chapter 15.1 and others). Release of Emergency Brake according to list of criteria (based on ERA_ERTMS_015560 chapter 15.1 and others). Cancellation of traction cut-off according to list of criteria (based on ERA_ERTMS_015560 chapter 15.1 and others).	ERA_ERTMS_015560	8.2.2.3; 15.1
DT004	HBED Provide control command information	Brake		Service Brake Intervention [may not result in standstill]	Indicate Service Brake and reason for Service Brake to ATO trackside function (see ERA_ERTMS_015560 chapter 15.1 and others). Release of Service Brake according to list of criteria (based on ERA_ERTMS_015560 chapter 15.1 and others). Cancellation of traction cut-off according to list of criteria (based on ERA_ERTMS_015560 chapter 15.1 and others).	ERA_ERTMS_015560	8.2.2.3; 15.1
DT005	HBED Provide control command information	Driving		Track Ahead Free information	Automatic Track Ahead Free Information from Infrastructure (and/or Information from Obstacle detection function).	ERA_ERTMS_015560	8.2.3.3; 13.9
DT006	HBED Provide control command information	Driving		Orders and announcements of track conditions	see Subset-026, list of automated actions and protocols to be specified.	ERA_ERTMS_015560 FprEN 16186-3	8.2.3.5; 8.2.3.6; 8.3.4; 13.5 5.2.4.7.6 ff
DT007	HBED Provide control command information	Driving		Adhesion Factor Indication	Adhesion Factor Setting related to route sections provided by ATO trackside function (based on forecast models, TMS, …).	ERA_ERTMS_015560	8.2.3.7; 11.2.3
DT008	HBED Provide control command information	Level Crossing		Level Crossing “not protected” [due to degraded situation] Indication [standstill at LX]	Obstacle Detection System, warning (horn) and initiate driving.	ERA_ERTMS_015560	8.2.3.8
DT009	HBED Provide control command information	Level Crossing		Level Crossing [regularly] “not protected” Indication [no standstill at LX]	Warning and Obstacle Detection System.	ERA_ERTMS_015560	8.2.3.8

DT010	HBED Provide control command information	Driving		Gradient profile	Traction/braking force setting by ATO trackside function (from TMS)	ERA_ERTMS_015560	8.3.5
DT011	HBED Provide control command information	Driving		Speed profile discontinuity information	Traction/braking force setting by ATO trackside function (from TMS)	ERA_ERTMS_015560	8.3.6
DT012	HBED Provide control command information	Radio		Safe radio connection indication	Degraded situation to be managed (scenarios tbd).	ERA_ERTMS_015560	8.4.1
DT013	HBED Provide control command information	Time		Local time	Synchronized time for European Railway system.	ERA_ERTMS_015560	8.4.3
DT014	HBED Provide control command information	Level NTC		Level NTC out of scope, only ATO over ETCS	-	ERA_ERTMS_015560	9
DT015	HBED Provide control command information	Train inaugoration		Data entry windows [after train composition] and Button "Train integrity"	Trigger for train inaugoration is any change of train data (e.g.: train composition, brake status, …) Result of train integration to be provided to ETCS and ATO trackside function automatically. Perform automatic cross-checks and plausibility checks.	ERA_ERTMS_015560	10.3; 11.2.3
DT016	HBED Provide control command information	Start Mission		Button "Start"	Enabling conditions (according to chapter 11.2) completed by futher criteria neccessary for "train ready message" (MA request) to be sent to RBC	ERA_ERTMS_015560	11.2
DT017	HBED Provide control command information	Shunting		Buttons "Shunting", "Maintain Shunting" and "Exit Shunting"	ETC-shunting in ATO economically not feasible. Exception: predefinend movements and train compositions supported by obstacle detection function.	ERA_ERTMS_015560	11.2
DT018	HBED Provide control command information	Leading		Button "Non-Leading"	Result of train inaugoration.	ERA_ERTMS_015560	11.2
DT019	HBED Provide control command information	Radio		Button "Radio Data", "Contact last RBC", "Use short number", "Enter RBC data" and "Rado network ID"	Connection with correct RBC/Network (criteria tbd).	ERA_ERTMS_015560	11.2
DT020	HBED Provide control command information	Override		Button "EOA" [override function]	Automatic override according to list of criteria.	ERA_ERTMS_015560	11.2.2; 11.2.5
DT021	HBED Provide control command information	Staff Responsible		Button "SR speed/distance"	Fixed setting by ATO trackside function.	ERA_ERTMS_015560	11.2.3
DT022	HBED Provide control command information	VBC		Button "Set VBC" and "Remove VBC"	Automatic setting by ATO trackside.	ERA_ERTMS_015560	11.2.4

DT023	HBED Provide control command information	Reversing		Reversing permitted indication	Automatic system for reversing (e.g.: identification of hazard by obstacle detection function, interpretation by remote camera access, …) (trigger tbd)	ERA_ERTMS_015560	8.4.2
DT024	HBED Provide control command information	ETCS modes and levels		Manual mode and level transitions	Automatic mode and level transitions triggered by ATO trackside function, Subset-026	ERA_ERTMS_015560	13.2; 13.3
DT025	HBEJ Provide diagnostic information	Diagnostic		Exterior lighting diagnostic	Automatic diagnosis to be sent to ATO trackside (list of critical situations tbd).	FprEN 16186-3	5.1.2.4
DT026	HBEJ Provide diagnostic information	Troubleshooting		Symbols "Fault overview" and "Provide remedy"	Automatic troubleshooting and/or debugging performed by ATO function (derive troubleshooting options from list of possible faults (Table A.1 and others).	FprEN 16186-3	Table A.1
DT027	HBEB Provide train status information to the crew	Washing		Symbol "Washing run"	Automatic trigger of washing run by ATO trackside function.	FprEN 16186-3	Table A.1
DT028	HBEB Provide train status information to the crew	Sanding		Symbol "Automatic sanding"	Sanding to be performed by ATO onboard function (time critical) if in area of permitted sanding (provided by ATO trackside function). UIC 612-0 UIC 612-2	FprEN 16186-3 prEN 16186-2:2015 [E]	Table A.1 Table B.1
DT029	HBEB Provide train status information to the crew	Switched-on	TCMS	Symbol "Start diesel engine" and "Wait for heating up"	Automatic trigger of Switched on-mode of train by ATO trackside function.	FprEN 16186-3 UIC 612-1	Table A.1 Table A.1
DT030	HBEB Provide train status information to the crew	In service	TCMS	Symbol "Start diesel engine" and "Wait for heating up"	Automatic activation of traction system (In service mode) of the train by ATO trackside function (independent of traction system).	FprEN 16186-3 UIC 612-1	Table A.1 Table A.1
DT031	HBEB Provide train status information to the crew	Driving	TCMS	Symbol "Start diesel engine" and "Wait for heating up"	Automatic trigger of Driving mode of the train by ATO trackside function.	FprEN 16186-3 UIC 612-1	Table A.1 Table A.1
DT032	HBEB Provide train status information to the crew	Driving	TCMS	Symbol "Traction supply system"	Automatic trigger of transition between traction supply systems by ATO trackside function (according to FprEN 16186-3 Annex F, Table F.1)	FprEN 16186-3	Table A.1
DT033	HBEB Provide train status information to the crew	Driving	TCMS	Symbol "Traction inhibition due to external power supply"	Automatic inhibition of traction when connected to external power supply cable by ATO trackside function	FprEN 16186-3	Table A.1
DT034	HBEB Provide train status information to the crew	Brake	TCMS	Symbol "Brake test" and "EP brake test"	Automatic trigger of brake test by ATO trackside function.	FprEN 16186-3	Table A.1 Table A.2
DT035	HBEB Provide train status information to the crew	Coupling	TCMS	Symbol "Ready for Coupling"	ATO trackside function triggers Coupling Operation (see UIC 612-1 chapter 3.1.6.2)	FprEN 16186-3	Table A.1
DT036	HBEB Provide train status information to the crew	Coupling	TCMS	Symbol "Coupled"	Automatic update of train data to ATO trackside.	FprEN 16186-3	Table A.1

DT037	HBEB Provide train status information to the crew	Coupling	TCMS	Symbol "Uncoupling"	ATO trackside function triggers Coupling Operation (see UIC 612-1 chapter 3.1.6.2)	FprEN 16186-3 prEN 16186-2:2015 [E]	Table A.1
DT038	HBEB Provide train status information to the crew	Coupling	TCMS	Symbol "Uncoupled"	Automatic update of train data to ATO trackside.	FprEN 16186-3	Table A.1
DT039	HBEB Provide train status information to the crew	Driving	TCMS	Symbol "Head-light"	not required or part of Obstacle detection.	FprEN 16186-3	Table A.1
DT040	HBEB Provide train status information to the crew	Driving	TCMS	Symbol "Status of external front and tail lights"	see DT025.	FprEN 16186-3	Table A.1
DT041	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Fire"	Automatic alarm to ATO trackside function.	FprEN 16186-3	Table A.1
DT042	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Fixed fire fighting equipment in operation"	Automatic alarm to ATO trackside function.	FprEN 16186-3	Table A.1
DT043	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "No service brake"	see DT025.	FprEN 16186-3	Table A.1
DT044	HBEJ Provide diagnostic information	Passenger Alarm	TCMS	Symbol "Passenger alarm" and "Passenger alarm test"	Automatic alarm to ATO trackside function. Driver acknowledgement to be cancelled. Passenger communication to be established with control center. All other functions of Passenger Alarm remain unchanged.	FprEN 16186-3	Table A.1 Table A.2
DT045	HBEJ Provide diagnostic information	Passenger Alarm	TCMS	Symbol "Passenger-alarm initiated brake application"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT046	HBEJ Provide diagnostic information	Passenger Alarm	TCMS	Symbol "Remote reset of Passenger alarm"	Automatic reset by ATO trackside function.	FprEN 16186-3	Table A.1
DT047	HBEJ Provide diagnostic information	Passenger Alarm	TCMS	Symbol "Passenger alarm not operational"	see DT025.	FprEN 16186-3	Table A.1
DT048	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Open door alarm"	Automatic alarm to ATO trackside function and Service / Emergengy Brake. Automatic warning to Passenger. Automatic back up system for door lock.	FprEN 16186-3	Table A.1
DT049	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Suspension alarm" and "Bogie instability"	Automatic alarm to ATO trackside function. If needed: Automatic speed reduction.	FprEN 16186-3	Table A.1
DT050	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Hot box warning"	Automatic alarm to ATO trackside function. Automatic stop at next suitable stopping point.	FprEN 16186-3	Table A.1
DT051	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Hot box alarm", "Blocked axle" and "Unintentionally applied parking brake"	Automatic alarm to ATO trackside function. Automatic Service brake.	FprEN 16186-3	Table A.1
DT052	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Unintentionally applied parking brake" and	Automatic alarm to ATO trackside function. Automatic back up for brake release if needed. Otherwise: Automatic Service brake.	FprEN 16186-3	Table A.1

				"Unintentionally applied brake"			
DT053	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Pantograph not nominal"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT054	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Data communication fault"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT055	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Fire monitoring fault"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT056	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Train line supply fault"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT057	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "WSP fault"	Automatic information to ATO trackside function. Change of brake mode and speed restriction if needed.	FprEN 16186-3	Table A.1
DT058	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Low fuel"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT059	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "EP brake fault", "Dynamic brake fault"	Automatic update of train data to ATO trackside function.	FprEN 16186-3	Table A.1
DT060	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Air supply fault"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT061	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Pantograph down by ADD"	Automatic alarm to ATO trackside function. Automatic Emergency brake.	FprEN 16186-3	Table A.1
DT062	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Diesel engine fault", "MCB unintentionally off"	Automatic information to ATO trackside function. Automatic reset if possible.	FprEN 16186-3	Table A.1
DT063	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Low battery warning"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT064	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Emergency brake"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT065	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Call for aid" and "Call for aid acknowledged"	Automatic information to ATO trackside function. Driver acknowledgement to be cancelled. Passenger communication to be established with control center.	FprEN 16186-3	Table A.1
DT066	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Remote reset of Call for aid device"	Automatic reset by ATO trackside function.	FprEN 16186-3	Table A.1
DT067	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Call for aid not operational"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1
DT068	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Communication request from passenger", "Communication request acknowledged" and "Cancel communication to passenger"	Automatic information to ATO trackside function. Driver acknowledgement to be cancelled. Passenger communication to be established with control center.	FprEN 16186-3	Table A.1
DT069	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Communication device function not operational"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.1

DT070	HBD Ensure display of information	Brake	TCMS	Symbol "Brake position according to EN 14198" Brake mode changeovers	Automatic setting of brake mode. Automatic update of train data to ATO trackside. According to: EN 15734 EN 14198 UIC 612-0 ETCS subset 034 (FFFIS TIU)	FprEN 16186-3 prEN 16186-2:2015 [E]	Table A.2
DT071	HBD Ensure display of information	Driving	TCMS	Symbol "Slope starting"	Automatic function of ATO function.	FprEN 16186-3	Table A.2
DT072	HBD Ensure display of information	Brake	TCMS	Symbol "Brake pipe overcharge"	Automatic function of ATO function.	FprEN 16186-3	Table A.2
DT073	HBD Ensure display of information	Doors	TCMS	Symbol "Door open" and "Door closed"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.2
DT074	HBD Ensure display of information	Doors	TCMS	Symbol "Driver's access door open" and "Driver's access door closed"	Automatic information to ATO trackside function if "Technical cabinet access door open".	FprEN 16186-3	Table A.2
DT075	HBD Ensure display of information	Degraded situation	TCMS	Symbol "Interior lighting off"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.2
DT076	HBEE Provide passenger information system information	Passenger Information	TCMS	Symbol "Passenger information system"	Automatic information to ATO trackside function. Automatic control of PIS by ATO trackside function.	FprEN 16186-3	Table A.2
DT077	HBEE Provide passenger information system information	Passenger Information	TCMS	Symbol "Passenger stop request"	If available: Automatic ATO function.	FprEN 16186-3	Table A.2
DT078	HBEJ Provide diagnostic information	Driving	TCMS	Symbol "Diesel engine is running at low temperature	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.2
DT079	HBEJ Provide diagnostic information	Driving	TCMS	Symbol "Traction motor off"	Automatic information to ATO trackside function.	FprEN 16186-3	Table A.2
DT080	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol "Warning lights"	If available: Automatic ATO function.	FprEN 16186-3	Table A.2
DT081	HBEJ Provide diagnostic information	Degraded situation	TCMS	Symbol" Brake pipe leakage"	Automatic alarm to ATO trackside function.	FprEN 16186-3	Table A.2
DT082	FB, FDB	Driving	TCMS	Pantograph/Diesel engine	Automatic function of ATO trackside function. According to: EN 50206 UIC 612-0 UIC 612-2 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT083	FB	Driving	TCMS	Main Circuit Breaker / Power transmission	Automatic function of ATO trackside function. According to: EN 60077 UIC 612-0 UIC 612-2 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1

DT084	FB	Driving	TCMS	Train Power Supply	Automatic function of ATO trackside function. According to: UIC 612-0 UIC 612-2	prEN 16186-2:2015 [E]	Table B.1
DT085	FBB, G, HEC	Driving	TCMS	Combined traction/dynamic brake controller with integrated driver activity control push button	Automatic setting of traction and brake force by ATO trackside function. According to: EN 15734 EN 14198 UIC 612-0 UIC 612-2 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT086	DBB	Doors	TCMS	Door control: left/right doors-release and cancel release	Automatic door control commanded by ATO trackside function. According to: EN 14752	prEN 16186-2:2015 [E]	Table B.1
DT087	CDB	Doors	TCMS	Door control: central closing all doors	Automatic door control commanded by ATO trackside function. According to: EN 14752	prEN 16186-2:2015 [E]	Table B.1
DT088	HEC	Driving	TCMS	Train lighting	Automatic train lighting controlled by ATO function. According to: EN 13272 UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT089	G	Brake	TCMS	Release (loco) brake	Automatic function commanded by ATO trackside function. According to: EN 15734 EN 14198 UIC 612-0 UIC 612-2 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT090	HEJ, KB	Driving	TCMS	External front/tail light	Automatic function commended by ATO trackside function. According to: EN 15153-1 UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT091	G, HEC	Brake	TCMS	Driver's automatic brake controller (automatic brake)	Automatic function commanded by ATO trackside function. According to: EN 15734 EN 14198 EN 16334 UIC 612-0 UIC 612-2 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT092	GDB	Driving	TCMS	Direction of travel “Forward”, "Neutral" and "Reverse"	Automatic function commanded by ATO trackside function. According to: UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT093	G	Brake	TCMS	Direct brake	Automatic function commanded by ATO trackside function. According to: EN 15734 EN 14198 UIC 612-0 UIC 612-2	prEN 16186-2:2015 [E]	Table B.1

DT094	HEJ	Horn	TCMS	External warning horn	Automatic function commanded by ATO function. According to: EN 15153-2 UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT095	CCC	Windscreen	TCMS	Windscreen wiper and windscreen washer (may be divided into two devices) and Windscreen heating	Optional automatic function in ATO onboard function. According to: EN 15152 EN 16186-1 UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT096	-	Diagnostic	TCMS	Diagnosis socket	According to: UIC 557 UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT097	-	Brake	TCMS	Isolation of driver's automatic brake controller	Automatic function commanded by ATO trackside function. According to: EN 15734 EN 14198 UIC 612-0 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT098	G	Brake	TCMS	EP brake	Automatic function commanded by ATO trackside function. According to: EN 15734 EN 14198 UIC 612-2 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT099	G	Brake	TCMS	Manual application/release of the parking brake	Automatic function commanded by ATO trackside function. According to: EN 15734 EN 14198 UIC 612-0 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT100	G	Brake	TCMS	Automatic brake release device	Automatic function of ATO function. According to: EN 15734 EN 14198 UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT101	G	Brake	TCMS	Brake isolating cock	Automatic function commanded by ATO trackside function. According to: EN 15734 EN 14198 UIC 612-0 ETCS subset 034 (FFFIS TIU)	prEN 16186-2:2015 [E]	Table B.1
DT102	-	Doors	TCMS	Override of traction cut-off in case of an open door	Automatic function commanded by ATO trackside function. According to: EN 14752 UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT103	-	Driving	TCMS	Preparation/shut-down	Automatic function of ATO trackside function. According to: UIC 612-0	prEN 16186-2:2015 [E]	Table B.1
DT104	-	Degraded situation		Line Safety Switches (LSS), Motor Safety	Replaced by automatic switches. DT029-030		

				Switches (MSS), Isolation Cocks, …			