



## Shift2Rail IP 5

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## EXECUTIVE SUMMARY

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The present document represents the issue of Deliverable D1.7 “Documentation and evaluation of test results, a proposal of next steps. Performance of functional GoA2 freight ATO demonstrator in specified testing scenarios”. It describes the project ATO Cargo Demonstrator in which semi-automatic test runs with a locomotive-hauled freight train was carried out. During this project, a locomotive was equipped with the necessary devices for Automatic Train Operation (ATO) with a Grade of Automation of 2 (GoA2). The test runs took place in Switzerland between Sion and Sierre. The project was a cooperation of two Shift2Rail projects, the Automated Rail Cargo Consortium (ARCC) and X2Rail-3 WP 10. The primary goals of the test runs were:

- To investigate the applicability of the ATO system as described in the system specification Subset 125/126 for operation on a heavily loaded freight train from a freight RU point of view.
- To show the interoperability and interchangeability of the interface between the ATO On-Board unit and TCMS as described in Subset 139.
- To show the possibility to deploy ATO over ETCS into an existing vehicle that only has ETCS Baseline 2 equipment instead of Baseline 3 via a Subset 130 adapter solution.

The tests showed the general viability of the tested concept but also challenges in some areas, such as the dynamic control of the train.

Some of the deficiencies in automatic control of the train gave reasons for safety and malfunction concerns that resulted in test driver interventions as mitigation actions.

Those reasons have to be further investigated. Especially it has to be clarified, which of the train control responsibilities will sit in which part of the railway system (TMS, ATO, ETCS, TCMS, RST functions). For the RST and TCMS related control functions requested for automatic operation, no ATO compatible specifications exist up to now.

For the full automation of railway systems is recommended to provide a comprehensive control process end-to-end from the TMS where the timetable is constructed based on the current train capabilities (including degraded situations) up to control functions of the train interfacing with the TCMS. The same applies for the return path back from train functions via TCMS, ETCS, ATO into TMS for adjustment of timetable settings according to the real train and infrastructure capabilities. Only the specification of the comprehensive end-to-end process will allow a clear allocation of functions in the entire railway system. This also means that clear roles and responsibilities between IM's, RU's, CCS and Vehicle suppliers need also to be defined.

Chapter 5, 6, 7 and 8 will deliver details about the results, recommendation, conclusions, next steps and lessons learned.



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## ABBREVIATIONS AND ACRONYMS

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Abbreviation	Explanation
AD mode	Automatic driving mode
AoE	ATO over ETCS
ARCC	Automated Rail Cargo Consortium
ATO	Automated Train Operation
ATO-OB	ATO Onboard (unit)
ATO-TS	ATO Trackside (unit)
ED	Electro dynamic
EoA	End of Authority
ETCS	European Train Control System
EVC	European Vital Computer
GoA2	Grade of Automation 2 – semi-automated train operation
JP	Journey Profile
MA	Movement Authority
MVB	Multifunction Vehicle Bus
SP	Segment Profile
SSEM	Supervised Speed Envelope Management
SS	Subset
TCMS	Train Control Management System
TMS	Traffic Management System
TP	Timing Point
UNISIG	Union Industry of Signalling
AFB	Automatische Fahr- und Bremssteuerung (legacy automatic driving and braking control of the locomotive)



## 1. BACKGROUND

---

Within the European rail research and development initiative Shift2Rail, one of the major topics is the development, specification, and testing of Automatic Train Operation (ATO) under the European Train Control System (ETCS). There were several workstreams within the Shift2Rail projects series X2Rail (-1, -3, and -4) to develop the specification of ATO over ETCS (AoE), with a Grade of Automation of 2 (GoA2).

The project described in this report intends to test the applicability of the ATO over ETCS specification in freight trains. The results of this project are intended to validate the specifications and to provide feedback for possible improvements.



## 2. OBJECTIVE / AIM

The Automated Rail Cargo Consortium (ARCC) was established within Shift2Rail's Innovation Programme 5 (Technologies for Sustainable & Attractive European Rail Freight) to demonstrate the applicability of the ATO over ETCS specifications on freight trains in collaboration with X2Rail3 WP10 as the ATO OB supplier. The major project goals of the ARCC project are:

- Proof of concept to deploy ATO over ETCS functions on a freight train in a real environment
- Proof the ATO specification with respect to
  - Interchangeability
    - Proof of interchangeability of Subset 139, in which the communication on the application layer between ATO-OB and TCMS is specified for DB Cargo BR 185.1 TRAXX AC 1.
    - And the application for other retrofit projects.
  - Interoperability
  - Human factor
  - Performance potential (e.g., stopping accuracy, drive close to system limits, etc.)
  - Maturity (is the specification ready for procurement?)
- Provide feedback for the ATO over ETCS specification, see Figure 1. Since specification **freeze from 08/2018** were used for that tests and specification has been further developed and refined.

This document gives an overview of the used system, the project organization, the test cases, and the achieved test results.

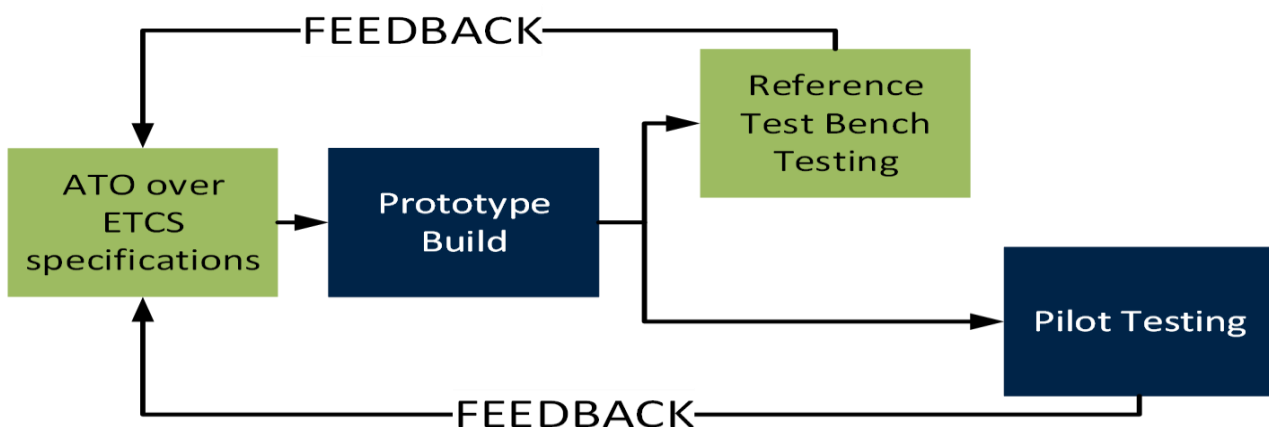


Figure 1: A feedback loop of ATO over ETCS specification and testing



### 3. SYSTEM ARCHITECTURE

#### 3.1 ATO over ETCS - System Overview

The system architecture used for this project followed the specification of ATO over ETCS described in the System Requirements Specification, Subset-125 (see Figure 2).

ATO over ETCS uses ETCS as an underlying safety system. The ability for automatic driving is provided through an ATO On-Board (ATO-OB) and an ATO Trackside (ATO-TS) unit. The communication between TCMS and the ATO-OB is executed over an interface according to Subset 139.

The ATO-TS receives information from a TMS in order to provide journey information to a train.

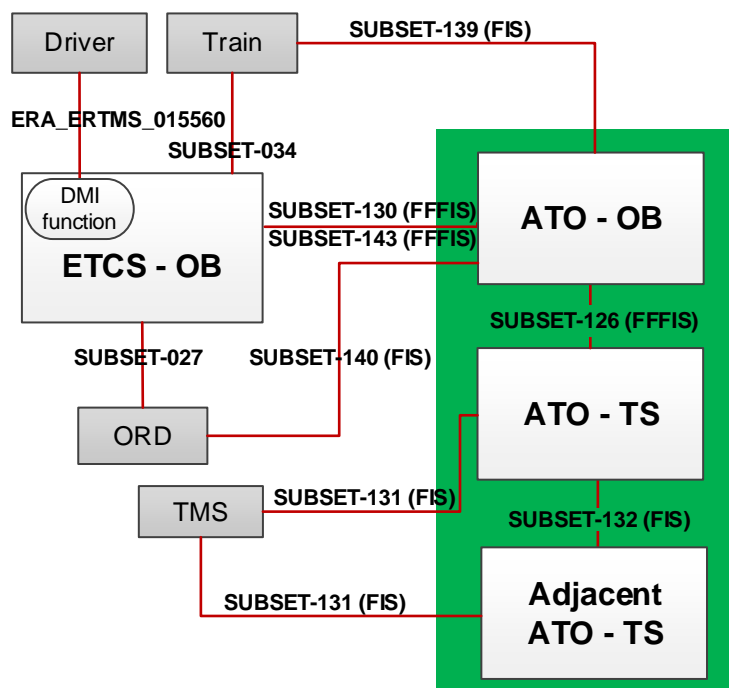


Figure 2: ATO over ETCS system overview

#### 3.2 ATO Cargo Demonstrator - System Overview

For the ATO Cargo Demonstrator a special solution of ETCS OBU – ATO OB converter interface has been developed because the existing ETCS system is only capable of Baseline 2.3.0d which means that ATO is not foreseen. The necessary project-specific alterations are described in the following chapters and can be seen in Figure 3.

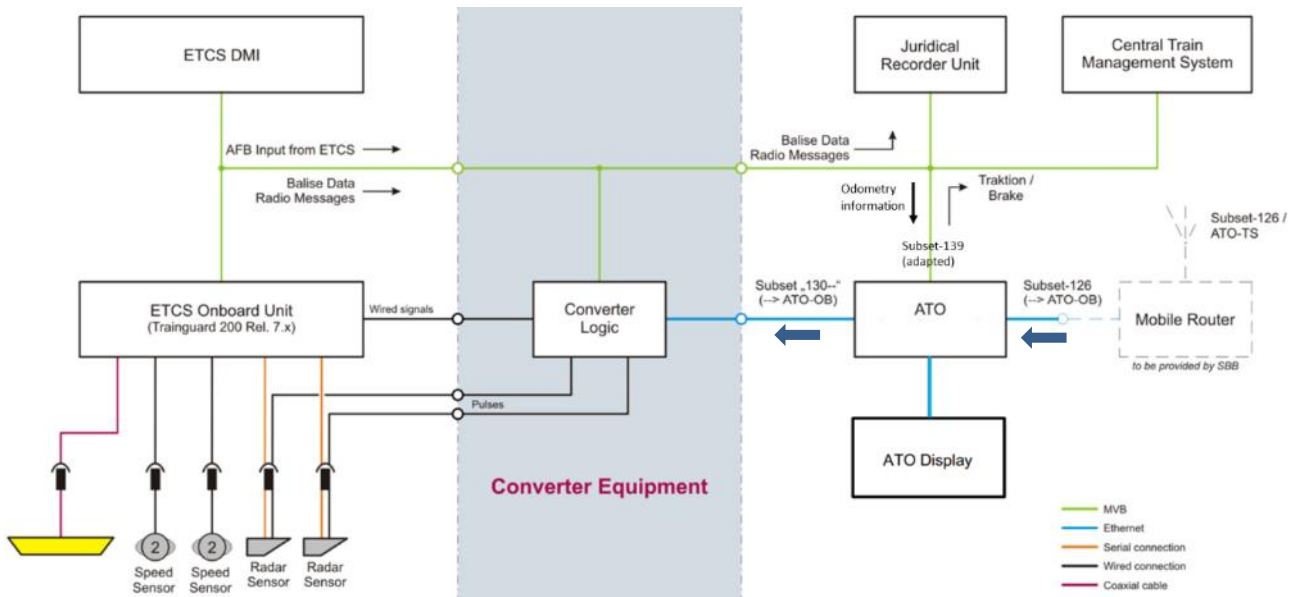


Figure 3: Overview of the system architecture of the ATO Cargo Demonstrator

### 3.2.1 Description of the vehicle

As a vehicle, a Bombardier TRAXX AC1 equipped with ETCS 2.3.0d and Switzerland country package was used. The vehicle used (serial number: 185 141) is property of DB Cargo CH.

The following adaptations were made to the vehicle:

1. The odometry of the European Vital Computer (EVC) was adapted to ensure that higher velocities up to 140 km/h can be safely handled and some necessary signals were tapped
2. Three ATO-OB units were integrated (Alstom, AŽD Praha, Hitachi Rail Italy)
3. The ATO Gateway also containing the fourth ATO-OB was integrated (Siemens)
4. The user interfaces for controlling the ATO system were integrated
5. The necessary cabling was integrated

### 3.2.2 European Vital Computer (EVC)

The original EVC of the ETCS system on the loco is a Siemens Trainguard 200 device. For the test runs, this EVC had to be modified, to make several signals available for the ATO-OBs. These signals are mainly:

1. Vehicle speed information
2. Balise-Attention-Signal

To allow handling of velocities up to the vehicle’s maximum speed of 140 km/h a modified odometry card was used.

The modification was documented in Siemens’ change report SyAendBer\_X2R-3 (see ref. [3], the document is confidential).



### 3.2.3 ATO Gateway

For the test runs the communication protocol between ETCS and ATO as defined in Subset 130 was used. This subset is based on Baseline (BL) 3 and needs a direct connection between ATO and ETCS. Since the available EVC only supports BL 2.3.0d it is not possible to directly connect an ATO-OB to the EVC. Therefore, an adapter called ATO Gateway was developed by Siemens Mobility.

The ATO gateway is connected to the EVC and has an Ethernet switch built-in which offers an Ethernet socket for connecting the ATO-OBs of the three other suppliers.

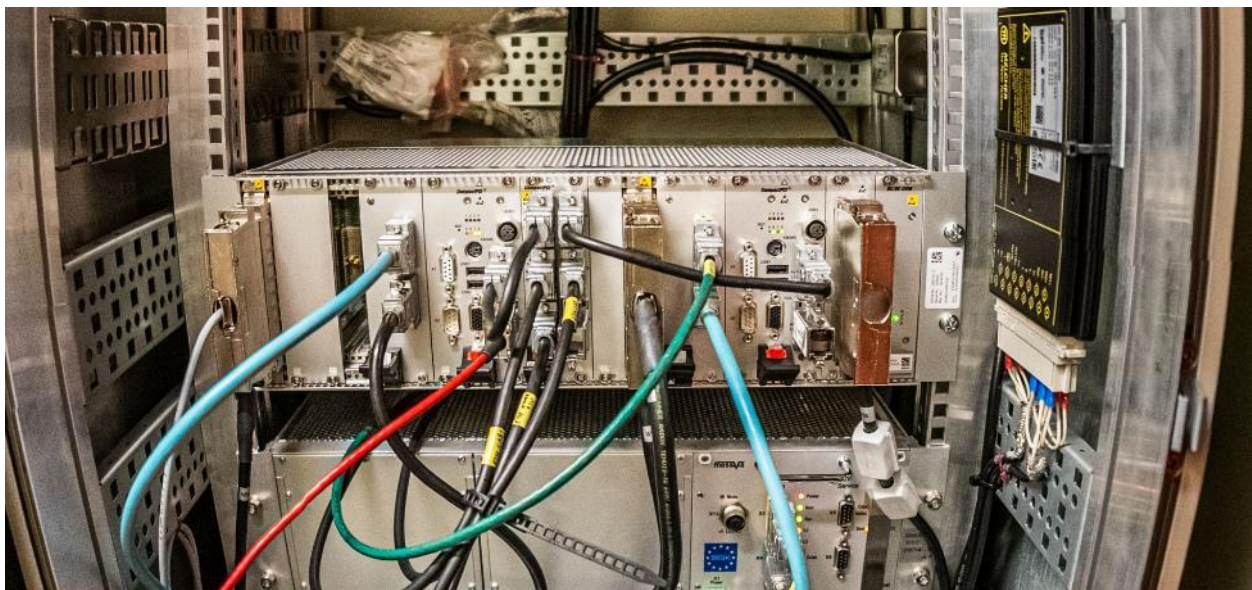


Figure 4: ATO Gateway provided by Siemens

### 3.2.4 ATO-On Boards (ATO-OBs)

Besides the ATO-OB from Siemens, which was directly integrated into the ATO Gateway, there were three ATO-OBs from the three different involved suppliers (Alstom, AŽD Praha, Hitachi). All of them contained connectors for MVB and Ethernet and could be fitted in a 19" rack. In Figure 5 the final state with all ATO-OBs integrated is shown. In the figure, the Hitachi ATO-OB is active and connected via MVB to the vehicle's TCMS and via Ethernet to the ATO gateway.

Also, the DB Cargo AG TechLOK Box used for Condition Based Maintenance purposes can be seen.

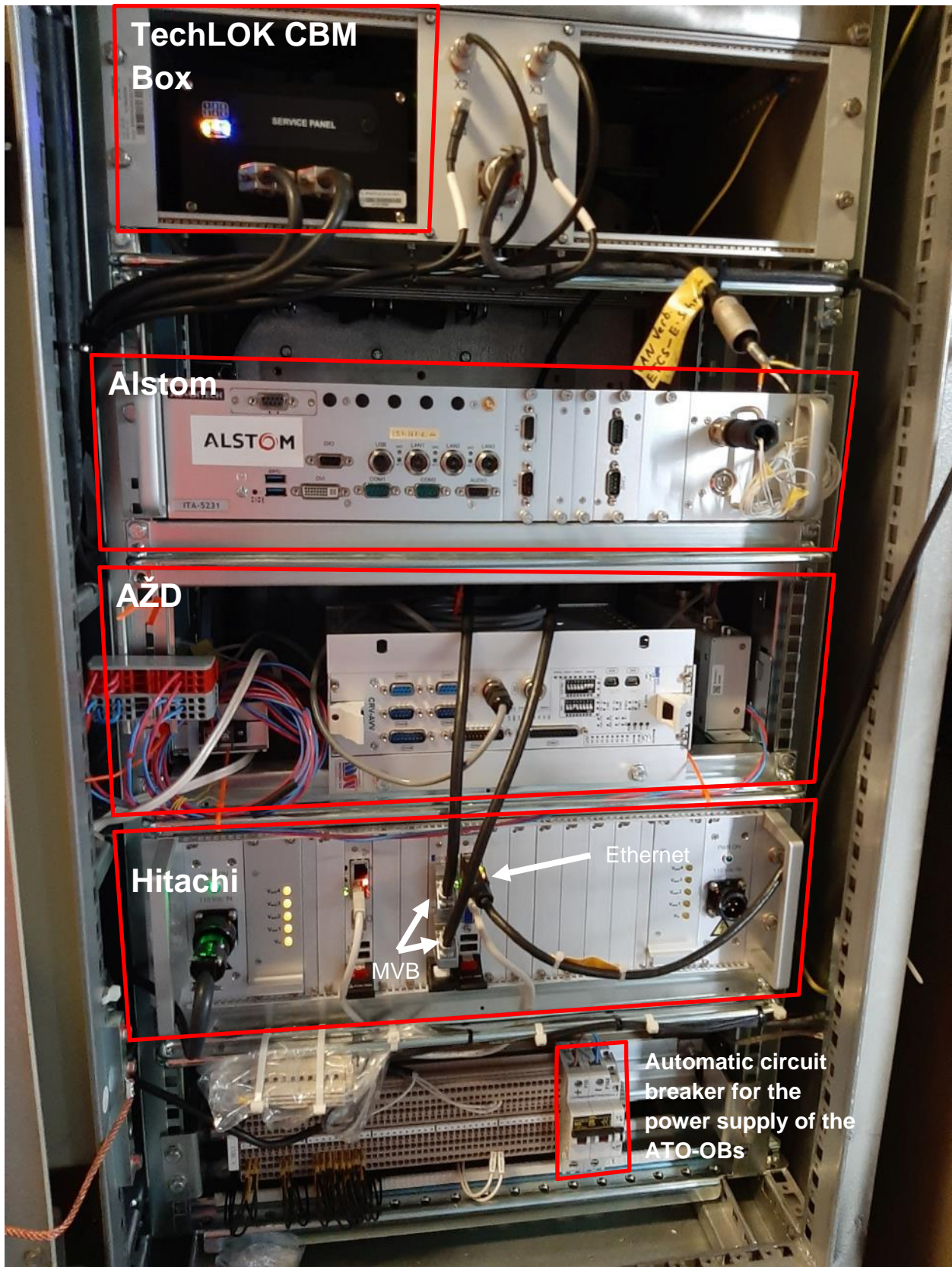


Figure 5: Electronic cubicle with ATO-OBs integrated

### 3.2.5 Router

A mobile router for the connection between ATO-OB and ATO-TS via public mobile network was provided by SBB.

### 3.2.6 User interfaces for Automatic Driving mode (AD mode)

In this section, the different user interfaces of the ATO system are described.

#### Button Box

The Button Box (Figure 6) was designed and manufactured by Siemens Mobility and gives the driver the possibility to control the most important functions of the ATO-System with four pushbuttons:

- ATO Start: Engaging AD mode
- Skip Request: Skip a planned stop at a stopping point
- Skip Revoke: Revoke before activated skip of a planned stop at a stopping point
- ATO Stop: Disengaging AD mode



Figure 6: Button Box



**ATO tablets**

Each supplier brought its own tablet to show the relevant information needed during ATO mode. In Figure 7 the tablet from AŽD Praha is shown as an example for the testing purpose.

There was no requirement in this project to design the content of the display according to any agreed specification. The full GoA2 solution incorporates the ATO icons and information into the ETCS display. This was not possible in this project as it would have required a change to the software of the BL 2.3.0d EVC. In future projects, it is intended to incorporate the standardized ATO relevant icons and information into the ETCS display of the respective vehicle.



**Figure 7: AŽD Praha supplier specific ATO tablet (DMI)**

**ATO On-Off Switch**

For safety reasons, a manual switch was integrated into the driver’s table to activate (I) or cut off (0) the power supply of ATO Gateway and ATO-OBs. The switch is shown in Figure 8.



Figure 8: Power supply switch for ATO system in the driver's table

### 3.3 Integration into the vehicle

The aforementioned adaptations of the vehicle and integration of additional devices were done in DB Cargo's Mannheim workshop.



## 4. PROJECT ORGANISATION

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### 4.1 Project partners and their role in the project

The partners of the ARCC project are (see Figure 9) DB Cargo AG (ARCC project lead)

Main tasks: Owner of the vehicles (locomotive and freight wagons), operational planning, locomotive driver

1. Bombardier (ARCC partner)  
Main tasks: TCMS software update, support with vehicle integration
2. Siemens Mobility (X2Rail 3 WP 10 coordinator)  
Main tasks: Coordination with the suppliers of the ATO On Board units (ATO-OBs) and development and implementation of the Subset 130 adapter / ATO Gateway
3. SBB Infra (Fr8Rail IV)  
Main tasks: General support with project planning and technical support, generation of Segment Profiles (SPs) and Journey Profiles (JPs), provisioning of ATO-TS and router.
4. BAV  
Main tasks: swiss national safety authority which checks vehicle dossier for test trial and gives permission.

Siemens acted as link and communication coordinator to the project X2Rail-3 WP10 with its partners:

1. Siemens Mobility (lead)
2. Alstom
3. AŽD Praha
4. Hitachi Rail STS

In this Work Package, each company developed and created one ATO-OB for the ARCC test runs.

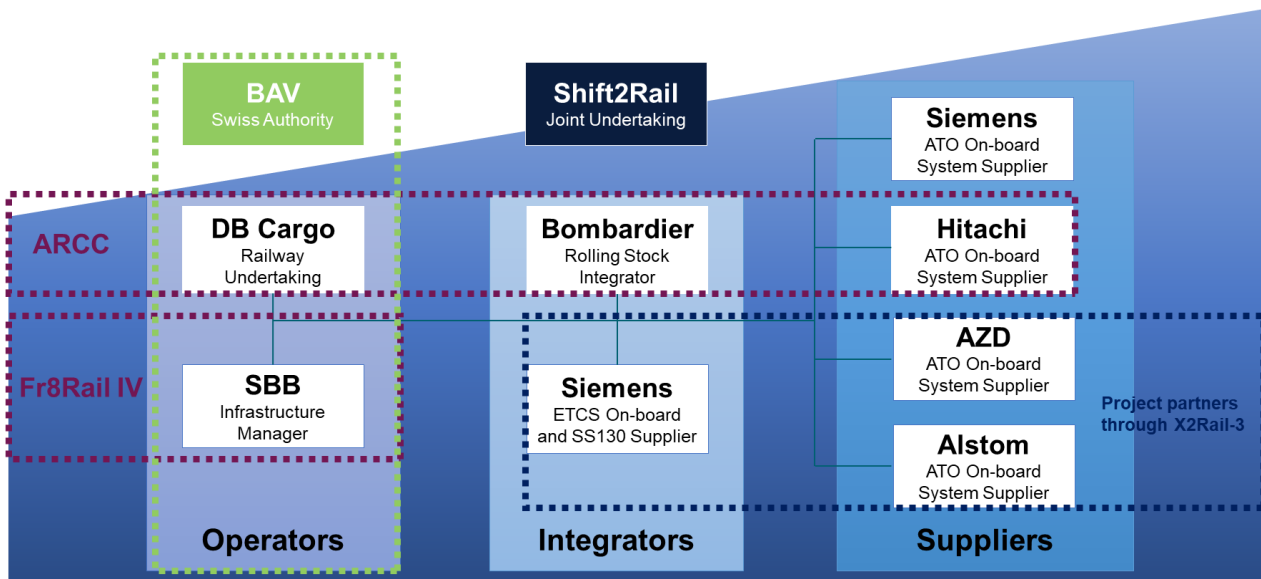


Figure 9: Overview of the project structure

## 4.2 Test environment

### 4.2.1 Train configuration

The train consisted of the loco and 14 ballasted wagons fully loaded with gravel (wagon type Eanos). The parameters of the test train were as follows:

- Mass of loco: 84 t
- The total mass of train 1274 t
- Train length: 240 m

The train configuration and length used in the test can be considered as the simplest one for automatic freight train control. E.g.: a mixed freight train with some tank wagons included would have been more challenging to control the dynamic behaviour of the train set, ....

### 4.2.2 Test track

At the beginning of the project, it was decided to use the track between Lausanne and Villeneuve as a test track. This track is equipped with ETCS BL2.3.0d and is used regularly by SBB for their ATO try-outs.

Due to construction works between Lausanne and Villeneuve the testing location had to be changed to the track between Sion and Sierre.

Figure 10 gives an overview of the most relevant operational locations of the track: Coming from Brig the L2 area starts right after the station of Salgesch at track kilometre 112.084 and ends shortly in front of the station of Châteauneuf-Conthey at track kilometre 87.929.

Besides the stations of Sion and Sierre there were two possible locations for timing points identified. Those are close to the station of St-Léonard (98.153 km) and the track junction of Pramont (102.307 km).



Tests have started and ended daily in Brig stabling yard where the trainset was parked during the test period. Since there is no ETCS trackside between Brig and the start of the ATO test track Sion – Siere the trainset started and ended in Level National Train Control and had a transition to ETCS Level 2 in between.

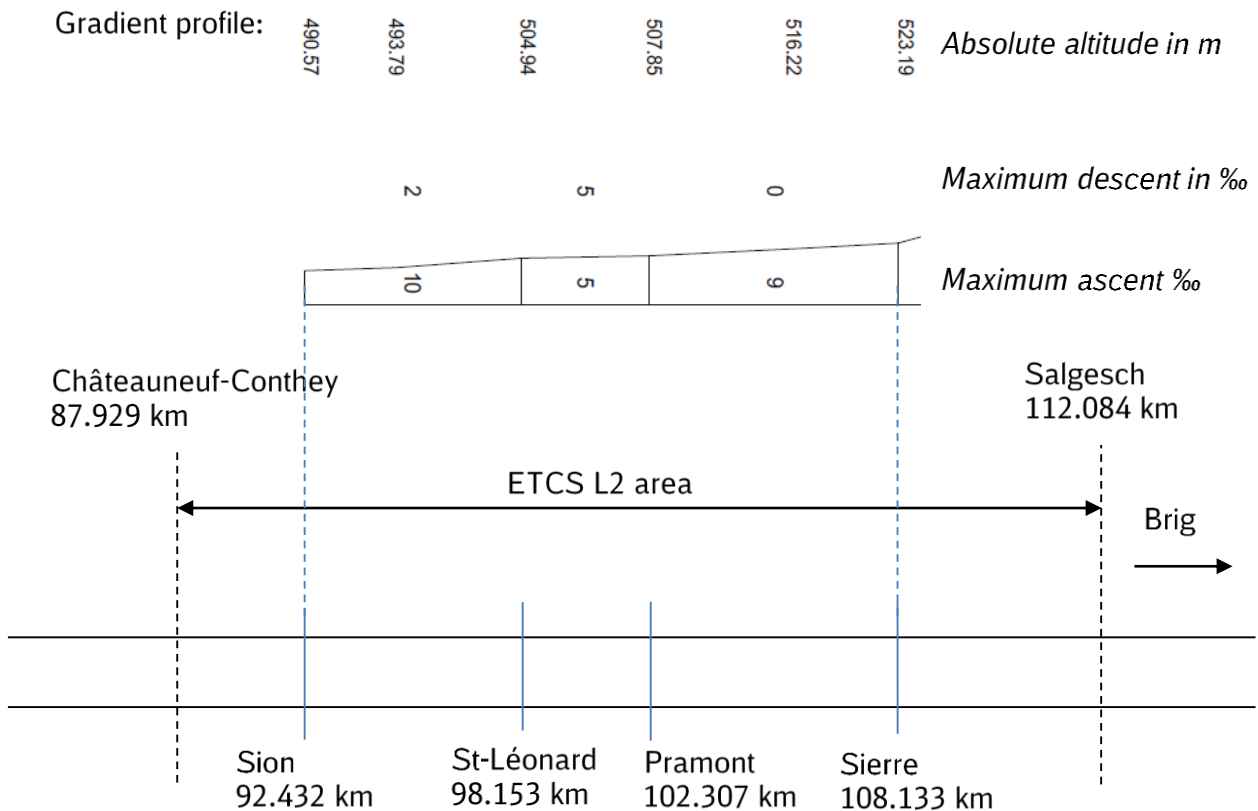


Figure 10: Track overview with the relevant operational locations and the gradient profile

Timing points were specified in both directions on both tracks before and after each of the locations, indicated in Figure 10.

#### 4.2.3 Data acquisition

For the purpose of the evaluation of the test runs, a set of data sources is available:

1. Manual notes during test runs and debriefing made by the test staff (project manager, test leader, test driver, Traffic Management test lead, ...)
2. Subset126: Data were logged with the Wireshark software on a PC that was connected to the router over a managed switch provided by SBB

Further data as e.g. data log has been requested from the X2Rail3 WP10 ATO suppliers to have additional sources for the analysis since DB Cargo has no access to the ATO OB systems to extract the recorded data from the TCMS during the test phase. However, it needs also to be investigated “who is the owner (Intellectual property rights) of such data”, since it will be logged by the ATO OB system but generated by the test drive from the responsible RU running on existing infrastructure.



### 4.3 Description of the test program

A set of test cases were defined with a special focus on freight train-specific challenges. A short description of the test cases is shown in the following table. The detailed information of the test cases can be found in ref. [2], Test Cases.

ID	Test
001	<p><b>Starting ATO Journey with a train moving</b></p> <p>In this test case, the train enters the L2 area with active ETCS and the ATO is started while the train is moving and takes over control.</p> <p>Main test objective: Demonstration of the correct procedure of start of the ATO operation on the move (Subset 125 Section 9.10 Transitions between States)</p>
002	<p><b>The train departs from a Stopping Point (next stopping point not reachable on time)</b> <b>Demonstration of the correct procedure of start of the ATO from standstill</b></p> <p>Main test objective: To test if the system tries to drive the train as fast as possible without violating the given speed limits and without applying a coasting strategy.</p>
003	<p><b>Missing Radio Connection at timing point, ATO has no Journey Profile to continue the journey</b></p> <p>The radio of the ATO-OB is disconnected manually in the locomotive</p> <p>Main test objective: To check the ATO's reaction when the radio connection is lost</p>
004	<p><b>The train stops accurately at a Stopping Point</b></p> <p>In this test case, the ATO shall stop the train at a predefined stopping point and show the respective symbol in the DMI</p> <p>Main test objective: Achieve an accurate stop and display this information according to SS125 8.2.2.1 a)</p>
005	<p><b>Train overshoots or undershoots a Stopping Point</b></p> <p>In this test case, the value for the stopping tolerance <math>Q\_Stop\_Location\_Tolerance(k,t)</math> shall be set to 0 (=10 cm).</p> <p>Main test objective: Force an overshoot or undershoot and test if the icon for undershooting and overshooting appears in the ATO DMI, according to SS125 8.2.2.1 b) / c)</p>
006	<p><b>The train stopped by signaling without planned stop, signaling clears to proceed when the train approaches the signal</b></p>



ID	Test
	<p>Depending on when the new MA is received and on the UIC air brake system characteristics the train may come to a stop. The indirect brake release delay time is observed by the ATO-OB after the signal “indirect brake not applied” is received by the ATO-OB from the TCMS.</p> <p>Main test objective:</p> <p>Test operation using the indirect brake release delay time</p> <p>SS125 Section 7.1.3.9</p> <p><b>Note:</b> According to the safety concept of some of the suppliers the ATO has to be manually engaged after a new MA is provided</p>
007	<p><b>The train stopped by signaling without planned stop, signaling clears to proceed shortly after train stops before reaching the signal</b></p> <p>When new MA is received, the train continues to drive automatically after holding and indirect brakes are released without any further command required from the driver.</p> <p>Main test objective:</p> <p>The ATO-OB shall stop the train at a distance in the rear of an EOA</p> <p>Test operation using the indirect brake release delay time</p> <p>SS125 Section 7.1.3.9</p> <p><b>Note:</b> According to the safety concept of some of the suppliers the ATO has to be manually engaged after a new MA is provided</p>
008	<p><b>The train stopped by signaling without planned stop, signaling clears to proceed 2 minutes or longer after train stops before reaching the signal</b></p> <p>When new MA is received, the train continues to drive automatically after holding and indirect brakes are released without any further command required from the driver.</p> <p>Main test objective:</p> <p>The ATO-OB shall stop the train at a distance in the rear of an EOA defined in the SP</p> <p>To test that the train starts immediately after the indirect brake release delay time has elapsed and a new MA is received</p> <p>SS125 Section 7.1.3.9</p>
009	<p><b>Filling stroke (Füllstoß/Querschnittswechsel)</b></p> <p>When the train is stationary the filling stroke command is applied by the driver</p>



ID	Test
	<p>Main test objective: To check that application of filling stroke control does not cause a reaction of the ATO-OB</p>
<p><b>010</b></p>	<p><b>Overcharger (Angleicher)</b></p> <p>When the train is stationary the overcharger command is applied by the driver</p> <p>Main test objective: To check that application of overcharger control does not cause a reaction of the ATO-OB</p>
<p><b>011</b></p>	<p><b>The train stopped by signaling with a planned stop approximately 300 m before EoA</b></p> <p>Stopping the train without interference between the ATO braking curve and ETCS braking curve is investigated in this test case.</p> <p>Main test objective: Achieve an accurate stop and display this information</p> <p>SS125 8.2.2.1 a)</p>
<p><b>012</b></p>	<p><b>The train stopped by signaling with a planned stop 105 m before reaching EoA</b></p> <p>Possible interference with the ATO braking curve and ETCS braking curve is tested.</p> <p>Main test objective: Achieve an accurate stop and display this information</p> <p>SS125 8.2.2.1 a)</p> <p>SS125 7.1.3 Operation with Supervised Speed Envelope Management</p>
<p><b>013</b></p>	<p><b>Moving brake lever</b></p> <p>The driver brakes with the driver UIC brake controller when the train is in AD mode</p> <p>Main test objective: While the train is automatically driven, the ATO-OB shall disengage if the driver activates manually the brake via the TBL</p>
<p><b>014</b></p>	<p><b>Disengaging ATO-OB by button box while ATO is commanding traction</b></p> <p>Show that after disengaging, the train only considers input from the Traction lever</p> <p>Main test objective:</p>



ID	Test
	<ul style="list-style-type: none"> <li>• Test SS 125 Section 8.1.1.4 ATO disengage</li> <li>• Traction is immediately withdrawn after disengaging</li> <li>• The train starts to coast</li> </ul>
<p><b>015</b></p>	<p><b>Disengaging ATO-OB by button box while ATO is braking</b></p> <p>Show that after disengaging, train only considers input from Brake lever after disengaging ATO</p> <p>Main test objective:</p> <p>Brakes are immediately released after disengaging</p> <p>The train starts to coast</p>
<p><b>016</b></p>	<p><b>Disengaging ATO-OB by trackside ATO inhibition zone</b></p> <p>During the handover process to manual driving (5 seconds) when entering the inhibition zone, the driver manually disengages the ATO. The ATO-OB goes to NA State and the ETCS-OB leaves AD Mode</p> <p>Main test objective:</p> <p>SS125 Section 6.4.2.6</p> <p>SS125 Section 9.10.3</p> <p>Test the functionality of ATO Inhibition Zone</p>
<p><b>017</b></p>	<p><b>Automatic Disengaging ATO-OB because of leaving ATO area</b></p> <p>Transition to manual driving with national CCS (5-second handover process)</p> <p>Main test objective:</p> <p>To test SS 125 Section 9.10.3 (Losing ATO Operational Conditions) at the end of a journey (leaving ETCS area)</p>
<p><b>018</b></p>	<p><b>Removing of MA (to be tested in First Test Cycle only)</b></p> <p>The MA is removed by the signaller.</p> <p>Main test objective:</p> <p>To test that the ATO-OB is not able to apply traction when the ETCS applies the emergency brake</p>
<p><b>019</b></p>	<p><b>Constant low speed to simulate wagon loading operation (10 km/h)</b></p>



ID	Test
	<p>A loading operation of a cargo train is simulated. It is investigated if the ATO can keep a constant low speed in a narrow range, even if the inclination of the track and therefore the resistance of the train changes</p> <p>Main test objective:</p> <p>SS 125 7.1.2.3. a) Speed Profile defined by 3) Additional Speed Restriction Speed level</p>
<p><b>020</b></p>	<p><b>Hill-start</b></p> <p>The ATO is engaged with the train standing in an inclination.</p> <p>Main test objective:</p> <p>To show that the train start is achieved without rolling backward</p> <p><b>Note:</b> The test case was rejected by the ATO suppliers</p>
<p><b>021</b></p>	<p><b>The train stops at a Stopping Point with a deactivated electrodynamic brake</b></p> <p>The electrodynamic brake of the loco is manually deactivated.</p> <p>Main test objective:</p> <p>ATO-OB can stop the train accurately with a deactivated electrodynamic brake</p> <p>SS 125 7.1.2.9 b) 1) II.</p> <p><b>Note:</b> The deactivation of the electrodynamic brake was not done on the loco,</p>
<p><b>022</b></p>	<p><b>Change of Time at Timing Points</b></p> <p>The time when the train shall arrive at the timing point is changed</p> <p>Main test objective:</p> <p>Test if the driving strategy of the ATO changes when the timing point information changes.</p> <p><b>Note:</b> This test case was executed often by changing the Journey Profile with the ATO Cockpit Tool.</p>
<p><b>023</b></p>	<p><b>Rerouting</b></p> <p>The route of the train is changed by a Journey Profile update</p> <p>Main test objective:</p>



ID	Test
	<p>Test SS 125 10.1.3.16 When a Journey Profile has already been sent to ATO-OB, the ATO-TS shall be able to update it if necessary, by sending a JP with the status “Update”.</p> <p>Test SS 125 10.1.3.17 When it receives a “JP Update” from the ATO-TS, the ATO-OB shall discard any previously received JP information from the first TP of the update.</p>
<p><b>024</b></p>	<p><b>Missing Radio Connection before Journey Profile received</b></p> <p>ATO-OB cannot enter AV state, JP Request is not sent due to a missing radio connection</p> <p>Main test objective:</p> <p>To test system reactions and check that ATO-OB cannot enter AV state</p>
<p><b>025</b></p>	<p><b>Braking Curve Violation by ATO</b></p> <p>Main test objective:</p> <p>Test if ETCS brakes in AD mode</p> <p><b>Note:</b></p> <p>This test case was disregarded because of possible obstruction of the regular operation on the test track. During the test runs the violation nevertheless occurred unintendedly.</p>

Some of the test cases have been deleted completely. Since the current state of the ATO OB specification and technical solutions could not cover all freight specific operational needs e.g. hill start. Furthermore, the subsets were also tested by SBB in previous passenger train tests from a functional point of view.

Due to the different levels of technical readiness between the different X2Rail3 WP 10 ATO suppliers, it was decided during the project, that each supplier could choose which functional test cases they wanted to execute. The results of these test cases were therefore documented individually by each X2Rail3 WP 10 ATO supplier. The test plan was simplified according to Figure 11 to focus on freight tests from ARCC view to allow individual subset testing for X2Rail3 WP10 partner.

The ARCC project decided to focus on freight-specific operational test cases since functional tests on subsets were already performed during SBB passenger tests and in the parallel X2Rail 1 Network Rail ATO passenger pilot tests. This means that the basic functionalities such as driving and braking as well as the interaction with the human factor and the dynamic behaviour (physical model) with an ATO-driven heavy and long freight train were mainly documented. E.g. Brake blending for freight, start, and acceleration stretching the train (coupler), braking in front of a switch, and red signal, ....

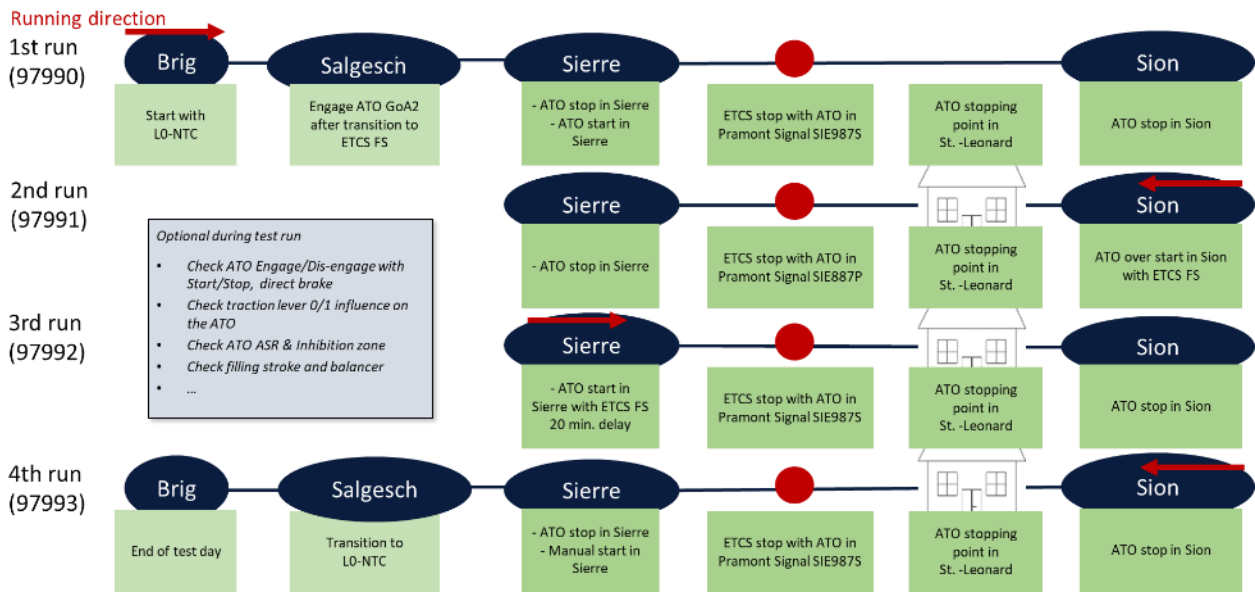


Figure 11: Test scenarios



## 5. RESULTS

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In this chapter, the achievements, and challenges, as well as necessary further actions for the next steps of the deployment of ATO (GoA2) as results of the tests, are described.

### 5.1 Achievements

- Plug & Play has been successfully proven for the
  - Vehicle ATO OB – TCMS communication interface to the TRAXX AC 1 test train,
  - ATO OB – ETCS OBU (SS 130)
  - ATO OB – ATO TS (SS 126)

after solving beginning implementation harmonization issues.

- All suppliers were able to control the generic communication to driving and braking functions of the vehicle over the defined interface. Some freight train control-specific functions could not be realized and tested.
- There were noticeable differences between the suppliers in the ability to control the loaded heavy long freight train automatically.

### 5.2 Discovered challenges

For the sake of understanding It is important to mention the following constraints during the test run period:

- I. DB Cargo Test driver has always to evaluate the situation and is allowed to stop or delay tests due to violation of the commercial traffic or operation schedule. Since DB Cargo as RU has the full responsibility to respect the safety and operation requirements with respect to swiss regulation and legal during the entire test phase.
- II. SBB commercial passenger traffic has always priority.
- III. Test train may be required to let pass the SBB passenger traffic and need to wait in the parking slot
- IV. SBB passenger traffic operation schedule is not allowed to be interrupted, violated, or influenced by the test train.

The following issues of controlling a heavy loaded and long freight train were discovered as challenges for the ATO system

- **110 test driver interventions** and **7 ETCS emergency brakes** were recorded during the test phase.
- In the first test cycles, the goal of the ATO-OB suppliers was to identify the characteristics of the locomotive and the loaded train. This shows that in the current status of development there exists only limited compatibility because there seems to be the necessity of calibration of the ATO system depending on the characteristics of the operated train. Therefore, each supplier started with the loco alone to parameterize the ATO on the loco alone and prove the control of the locomotive before switching to the full heavy loaded train convoy to mitigate operational or safety risks during the tests on the commercial test line. As soon as the DB



Cargo test driver accepted that the ATO system can control the loco and is ready to add the heavy long load, the tests were continued with the full train convoy.

- Engaging ATO on a slope (hill start):  
Start the train run after the stopping point with inclination was difficult for the ATO after engagement. The train rolled backward. One reason is, that it is a condition for engagement that the brake handle, as well as the brake system, must be in a released state (Subset-125 9.6.1.3 The ATO-OB shall engage only when the Traction Controller is in neutral or traction position. [8])
- Direct brake as holding brake:  
The direct brake is the brake that is used to hold the train. It was not always strong enough to hold the train.
- Brake release of indirect brake:  
The ATO system does not know about the release status of the brakes of the wagons of the train. Even if the main brake pressure at the loco is at its nominal value, it does not necessarily mean that all brakes are completely released. In the case that not all brakes were released, starting the run of the train could lead to flat spots at the wagons.
- The ATO accelerated in front of an EoA after the train already had been stopped. This means the train is accelerating again when the train stops too early in front of the EoA.

### 5.3 Analysis of the tested Subsets

This section focuses on the observed functional behaviour of the ATO according to Subset 125/126 and the interface between TCMS (Vehicle) and ATO-OB according to Subset 139.

#### 5.3.1 Dynamic control and environmental influence

##### 5.3.1.1 Generic dynamic control:

A major challenge for all suppliers was the speed control of the heavily loaded trainset. Each supplier modified the parameters of the speed control algorithm during the test runs. For test runs, this modification of parameters is acceptable or even intended. For a future deployment in regular operation, this kind of modification will not be possible. 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 in Figure 12. Spring  $k_2$  and damper  $b_2$  are attached to the wall and mass  $m_2$ . Mass  $m_2$  is also attached to mass  $m_1$  through spring  $k_1$  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  $m_1$ .

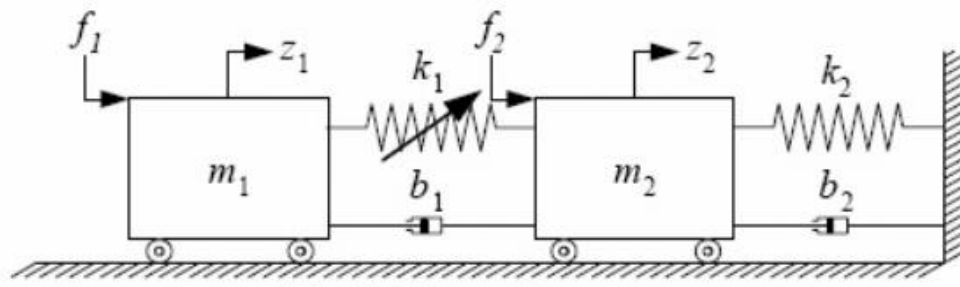


Figure 12: Freight train set dynamic control of a spring-mass-damper system

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.

**5.3.1.2 Hill-start:**

Starting in an inclination properly was not possible with any of the systems. This use case is challenging due to the complex interaction between train characteristics, brake status, and control of brake and traction. On request of the suppliers, this was not tested as a dedicated test case but occurred after starting at some stopping points.

**5.3.1.3 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.

**5.3.1.4 Stopping accuracy:**

It could be shown that stopping at defined stopping points could be done quite accurately in some cases.

The control quality and following determined stopping accuracy with the ATO is based on the reported position in the Segment Profile from the ATO-OBU itself when it reached the Stopping Point.

Following accuracy is determined as results of all tests:

- **ATO GoA 2 accuracy with loco alone: 26,3 m ± 49,07 ( $\mu \pm \sigma$ )**
- **ATO GoA 2 accuracy with full train set: 45,59 m ± 109,67 ( $\mu \pm \sigma$ )**

The distribution of the accuracy was quite widely spread.

For comparison purposes to today state of the art technology: with the legacy automatic driving and braking control function of the loco (AFB) can be achieved the following accuracy:



- **AFB accuracy with full train set:  $20\text{ m} \pm 5 (\mu \pm \sigma)$**

**5.3.1.5 Operational behaviour:**

Immediate start after new MA arrives: According to SUBSET-125, the train should continue its journey without any action from the driver. In the tested ATO-OBs this was realized differently. When the train was stopped by EoA, the driver had to press the “ATO Engage” button to start driving again after the MA was received.

This realized behaviour seems beneficial from a safety point of view because it avoids, that the train starts without the driver recognizing this.

**5.3.1.6 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.

**5.3.1.7 Traction control**

The traction request signal coming from the ATO-OB going into the vehicle TCMS is one of the most important variables to control the speed of the train. It can be shown that there are differences between the suppliers in controlling this variable.

Figure 13 shows a trip with the loco alone. It can be seen that the traction request variable is set to a value greater than zero only for short periods. This results in a sawtooth-like speed profile. Behaviour was differently implemented by the supplier.

Such behaviour of longitudinal vibrations can lead to a separation or derailment of the train.

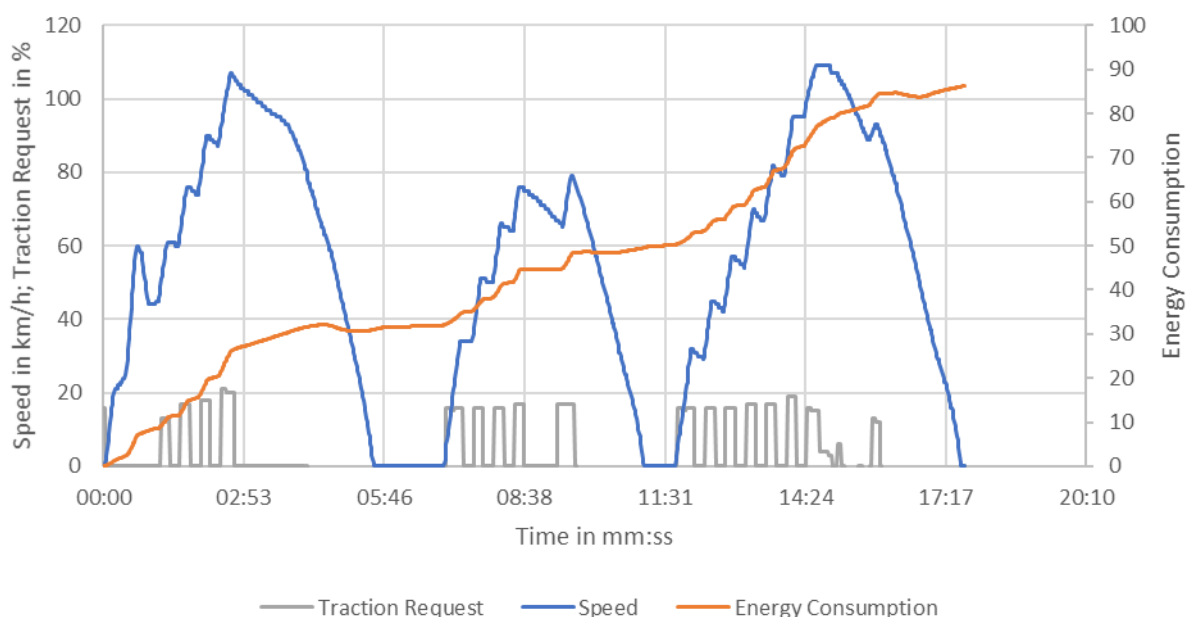




Figure 13: Example of suboptimal traction control behaviour resulting in a sawtooth-like speed profile, loco only

### 5.3.2 Interoperability

The proof of the interoperability of SS-126 requirements was mainly observed and documented together with SBB as the ATO-TS supplier (FR8Rail IV D 4.4). Fundamentally the interoperability has been demonstrated.

### 5.3.3 Interchangeability

#### 5.3.3.1 TCMS update and realization of the software interface SS-139

For this project, Bombardier Transportation changed the MVB configuration by adding ports to be able to exchange signals between vehicle TCMS and ATO-OB bidirectionally.

During the preparation of the test runs, it turned out that due to the design of the TCMS of the loco, not all functions foreseen for ATO are possible to implement. For example, one major deviation in the behaviour of the vehicle in AD mode compared to the specification in SS-125 was explored. SUBSET-125 [8] states:

*6.2.1.8 While it is engaged, the ATO-OB shall not take into account the traction commands coming from the driver. In consequence, if the driver commands traction manually via the TBL while the train is automatically driven, the ATO-OB shall remain engaged.*

However, the implementation by Bombardier was realized in a way that the traction command by the traction is taken into account also in AD mode. This means that the traction handle has to remain in position “0” when driving in AD mode to avoid an undefined state.

#### 5.3.3.2 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.

#### 5.3.3.3 Plug & Play standard interface:

To achieve full independence between hardware and software (as proposed by OCORA) a full specification of the Application Programming Interface (OSI Layer 1 - 7) is necessary. The current specification leaves room for interpretation to allow a vehicle-specific connection between ATO-OB and necessary vehicle functions for existing designs.



Therefore, for the tests, an adaption was used to create a communication interface between ATO-OB and TCMS (software change) and between the ATO-OB and the ETCS system (ATO Gateway). These communication solutions worked in general well for the project. But the functional interface had issues at the beginning of the test phase which was solved by troubleshooting between ATO OB and vehicle system supplier. However, not all functional interfaces from the ATO OB to the existing vehicle design could be realized.

For future projects, a functional vehicle adapter (as proposed by OCORA) could in general be a good solution for the retrofit of existing vehicles. The adapter solution needs to consider a lot of specific functionalities of different trains or locomotive types (e.g. driver desk application, brake/traction process time, ...). To achieve this goal, it is important to start a discussion about a general approach to create adapter solutions for existing vehicle designs

Subset-125 is based on the assumption that the vehicle provides a defined set of functionalities through the Subset-139 interface.

As this project has shown, even for modern existing locomotives the behaviour is often different from this assumed set of functions. The Functional Vehicle Adapter (FVA) intends to improve the engineering process of the ATO-OB/TCMS integration by:

- Providing a standardized but modular hardware and software interface that can be adapted to the specifics of the vehicle while retaining a fully generic FFFIS interface to the CCS systems.
- Providing a standardized way of parametrizing the routing and formatting of data exchanged between TCMS and ATO-OB, so that both the FVA and ATO-OB software remain generic.
- Providing a well-defined API for the addition of specific control functions and models, so that also vehicles with TCMS that were conceived for purely manual operations can efficiently be controlled by the ATO-OB.

Subset-139 provides many variables that can be used to control the behaviour of the TCMS in a very fine-grained way. This allows on one side for the development of different control strategies by the CCS suppliers. On the other hand, it creates the need to consider the different approaches both on the TCMS and the ATO-OB sides, which is not always possible for existing vehicles, as the trials have shown.

The FVA approach intends to reduce these dependencies so that advances and innovations on ATO technology become possible without being disrupted by vehicle integration issues.

For that discussion, it is necessary to bring the vehicle and CCS suppliers as well as the railways on the discussion to find a common solution

#### **5.3.4 Performance**

A major requirement for the application of ATO is the ability to run as close as possible to the safety-critical braking curve. The proposals to overcome the challenges of the current implementation are the following:

- Rules and frameworks for performance are missing. This may need iterative improvement by operational experience.



- ATO introduction with different performance levels (acceleration controlled by TCMS, control options for braking curve) for acceptance by the locomotive personnel needs to be taken into account.

### 5.3.5 Maturity (readiness for procurement)

For this project, a specification freeze version from 08/2018 has been used. Because of this, the Technical Readiness Level (TRL) of the specifications applied for this demonstrator was not intended to be ready for procurement.

This means that the application of the current specification (TSI 2022) for freight trains without further enhancement and field lessons learned/experience will lead to uncertain investment levels for Freight Railway Undertakings. The specification has to be continuously enhanced from e.g. pilot report feedback as already mentioned in chapter 2, figure 1, of that document.

In some cases, it was observed that an ATO-OBU detected an incorrect position and reported positional jumps during a repositioning using a Balise position. The phenomenon could not be clarified and need to be investigated further with the supplier. Since it was not systematically it doesn't seem to be a problem in the standard.

### 5.3.6 Further developments:

In further stages of the development of ATO, it could be useful to integrate a more sensitive slipping protection into the ATO control. If the driver recognizes slippery tracks, s/he normally accelerates with a reduced amount of traction force to avoid the intervention of the vehicle's slipping protection. The ATO could detect this situation through a special algorithm, as this is also the case for the legacy automatic driving and braking control function of the locomotive (AFB of TRAXX AC 1).

Next chapters 6,7 and 8 will give an more detailed overview on further developments.



## 6. CONCLUSIONS

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The test runs demonstrated ATO over ETCS, GoA2 on a freight train. Despite a lot of challenges during all project phases, the test could be carried out successfully in a quite diverse environment:

1. German vehicle
2. An international set of 4 different ATO system suppliers
3. Swiss railway infrastructure
4. Public mobile communication infrastructure

For the tests, the specification by UNISIG Subsets 125/126, 130, and 139 was used. The general communication between ATO-TS and ATO-OB as well as between ATO-OB and vehicle TCMS could successfully be achieved based on these Subsets. To have a full overview and clear requirements on the ATO and vehicle architecture and interfaces on ARCC ATO Design Architecture and Interfaces document has been created between vehicle and ATO supplier.

### 6.1 Vehicle dynamics

The driving algorithm of the software of the ATO-OB had to be adapted to the loco and the train. It is therefore questionable if full modularity and interoperability are possible. The goal would have to be able to deploy an ATO-OB without the necessity of adapting parameters regarding the dynamic behaviour of the train.

The initiative OCORA tries to improve this situation by the creation of an extended Subset 139. This Subset has additional parameters specified including input parameters for a vehicle model. The idea is to give the ATO-OB a better knowledge of the vehicle to improve the control of the dynamic characteristics.

### 6.2 ETCS interventions

During the test runs seven ETCS emergency brake interventions were observed.

For the ETCS interventions, it can be concluded that the ATO system was not always able to keep the vehicle speed within the permitted speed limits.

### 6.3 Human factor and system limits

Also, a high number of driver interventions was counted (110 times) and 7 ETCS emergency brakes. At least by the driver interventions the driver wanted to avoid the violation of the existing operation, safety rules and minimize operation breakdowns. The DB Cargo AG test drivers are very experienced, familiar with the geographical track environment and operational rules and have been professional trained by X2Rail3 WP10 and ARCC for the purpose to run the ATO tests.

E.g. interventions might have occurred because the driver wanted to reduce the maximum electrodynamic brake force which is regulated by national standards but not programmed in the ATO or vehicle software. The limitation of the electrodynamic brake force is a highly safety-relevant issue because the exceedance could result in a derailment. Therefore, it should be investigated how the maximum allowable electrodynamic brake force must be configured in the system.



For a GoA2 system the acceptance of the dynamic control, human factor, and the predictability of the behaviour of the automated functions are very important.

### 6.4 Recommendations to the ATO specification (TSI)

In this section recommendations from the test, runs are provided.

#### 6.4.1 The general recommendation to subsets 125, 126, and 139:

In general, the completeness and quality of the specification needs to be proven in a test environment prior to field testing. 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 successful integration and lasting stability of the system.

The current situation is not representing these statements, the main problems are shown in Figure 14. The following points could help to reach a generic description of Subset 125 and Subset 139:

- Development of a vendor-independent test (specification) model and environment to deliver a verification tool for the SS 139 interface specification
- Definition of rules for integration to different TCMS types e.g. of freight and passenger trains
- Creation of requirements for the adaption to different train integration requirements e.g. Vehicle Adapter → See proposal from OCORA on Functional Vehicle Adapter
- Close gaps and ambiguities within the interface specification → See ATO – TCMS interface description delivered by OCORA

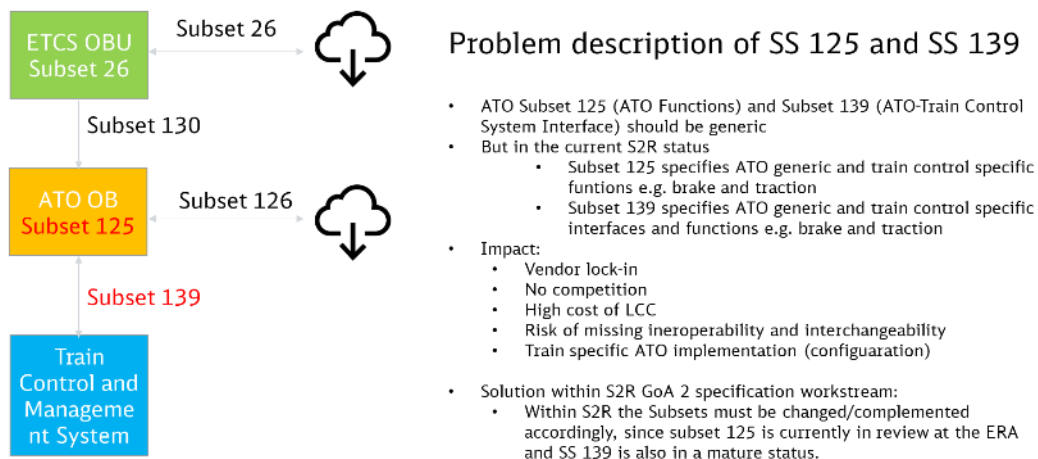
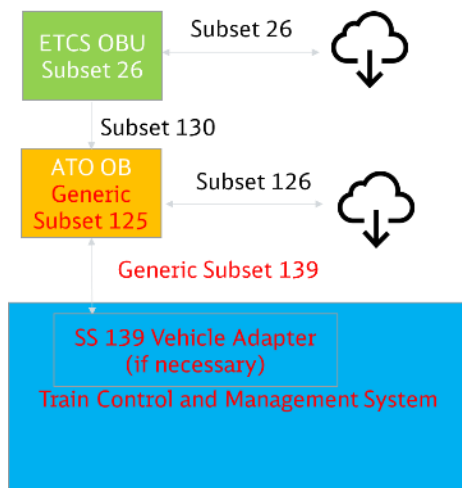


Figure 14: Current situation of UNISIG Subsets



Proposal for solution of SS 125 and SS 139 generic description

- Delete all train control system specific variable from SS 139
- Analyse impact of deleting all train control specific variable from SS 139 to SS 125 – align of SS 125 with SS 139 changes.
- Define in SS 125 high level requirements for train control system.
- Shift all functional specification within SS 139 to SS 125.
- Shift all train control specific functions and interface description to a separate document e.g. „train specific application“

Figure 15: Proposal of solution generic description of SS 125 and SS 139

6.4.2 Subset 125:

6.4.2.1 ATO disengages when the train is stopped by signaling

According to the safety concept of some of the suppliers, the ATO disengages when the train comes to stop even if the End of the Journey is not reached. The ATO then has to be manually engaged after the train stopped. This is different from the specification in Subset 125 but could be a reasonable solution especially for freight trains and could be considered in coming change requests.

6.4.2.2 Traction controller as a condition for operational state “Ready for engagement (RE)”

ATO goes to or stays in the operation state “Ready” if the driver brakes manually. This was a confusing situation for the drivers during the tests. If he presses the Engage button in this situation, ATO does not engage, which shows that the position of the Traction Controller is an engagement condition.

Therefore, the specification shall consider that “Ready for Engagement (RE)” is indicated to the driver only when it is possible to engage also with respect to the Traction Controller position. Therefore, it would be logical and clearer if the Traction Controller position is considered as a formal engagement condition. In this way, the driver would not be informed that the ATO-OB is “Ready for Engagement” when the Traction Controller is not in 0 position or the brake controller is in a braking position.

The following proposal of changes needs to be checked if there are any implications other than the intended ones. If so, another solution needs to be defined.

- a. SS 125 – 9.1.2.1 Add two additional conditions:
  - g) The TBL is not in the brake position.
  - h) While the train is stopped the TBL is not in traction position
- b. SS 125 - Figure 10:
 

The yellow arrow from EG to RE with the condition [8] should go to [AV] or the yellow arrow has to be removed and the condition expanded [6a].
- c. SS 125 -Table 5:
 

The transition condition (<8 -p5-) has to be moved from "EG->RE" to "EG->AV", i.e.



- add to condition (<6a -p4-). Alternatively, when it is added to [6a], (<8 -p5-) can be removed.
- d. SS 125 - Table 6: Remove "AND (the TBL is in neutral or traction position)" from condition ID 5, as it is now an engagement condition in [4].
  - e. SS 125 - 9.12.1.1 a) und b):  
The "and the TBL is in neutral or traction position;" conditions for a) and b) are now unnecessary as they are a condition to enter and stay in operation state RE. This shows that the new approach is more logical, as ad hoc supplemental conditions aren't needed anymore. The new conditions are:
    - a) The ATO-OB is in RE State, the train is moving;
  - f. b) The ATO-OB is in RE State, the train is stopped;
  - g. SS 125 - 9.6.1.3:  
This condition is not needed anymore as it is an engagement condition to enter the RE State.
  - h. SS 125 – 9.10.5.2 Change 2) into "2) The ATO-OB stops automatic driving. The ATO state changes to AV;"

#### 6.4.2.3 Low Adhesion Management:

If the ATO-OB is informed about the adhesion category from an external system, this information is sent to the ATO-TS. Project-specific it can be important that the adhesion category from the external system can also change the Operational Speed Profiles.

This is in line with Version 12 of the adhesion paper by Katherine Stowe [10].

#### 6.4.2.4 Missing Requirements

From the lessons learned from the ARCC Cargo ATO GoA 2 Demonstrator the following requirements are missing:

- i. Requirements for the handling of rolling stock-specific internal processing times and guidance
- j. Requirements for the handling of brake blending (pneumatic, electric, ....)
- k. Requirements of handling the proper style of driving with respect to operational rules derived from the infrastructure situation e.g. point machine, curve, gradient, ...
- l. Requirements of handling the proper style of driving with respect to environment situation e.g. weather condition, ...
- m. Requirements of handling the proper style of driving with respect to train characteristics like different loading e.g. length, class of wagon, coupler, kind of load, mass,...



## Findings in current in pending (discovered by SBB):

### 6.4.2.5 Problem with JP Update:

The current SS-125-010 rules:

10.1.3.17 (In SS125-0017, it's 10.1.1.21): When it receives a "JP Update" from the ATO-TS, the ATO-OB shall discard any previously received JP information from the first TP of the update.

12.3.1.2, Fig. 14 (IN SS125-0017, it's 12.3.1.2, Fig. 8): the ATO-TS sends to the ATO-OB a JP with the status "update" starting with the TP preceding the first TP impacted by the modification of the JP.

This is acceptable as long as there is no modification before the second TP of the JP. But if the very first TP is modified or suppressed, the TS must send the whole JP. The ATO-OB does not know that it also has to replace the very first TP or has to replace everything, especially if the first TP disappeared.

**Proposed solution from supplier:** This issue has been resolved in SS 125 V015 chapter 10.1.3.22 e) with the new status "Overwrite".

### 6.4.2.6 Problem with JP Request and Update

The current SS-125-010 & SS-126-016 rules:

In the case of a long Segment Profile with four timing points on it and a modification of the fourth: According to 10.1.3.17 (In SS125-0017, it's 10.1.1.21) and 12.3.1.2, Fig. 14 (in SS125-0017, it's 12.3.1.2, Fig. 8), the ATO-TS should send a JP Update beginning with the third. The ATO-OB shall replace everything from that one on. It is unclear if the information of that segment preceding this third timing point is sent. To avoid interpretation, it should be explicitly specified that also the SP has to be updated.

**Proposed solution from supplier:** With the new specification the Journey Profile Update refers to SP.

### 6.4.3 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. Therefore, we propose a different solution.

ATO knows the allowed ETCS speed through its Supervised Speed Envelope Management (SSEM, subset-125 [8], 7.1.3.1 The ATO-OB shall compute the maximum speed (SSEM) of the train can run avoiding ETCS intervention). ATO could use the SSEM to apply the known rules for allowed longitudinal forces from UIC 612-2 [11] or additional ones derived from national rules not covered by UIC 612-2.



## 6.5 Final conclusion (risk/chance)

### 6.5.1 Risk

From the RU procurement point of view, insufficient maturity of automation products can lead to high risks for projects, investment, and operations. This needs to be avoided for the sake of acceptance and migration of ATO technology through Europe.

Also, the human factor as acceptance of the ATO technology needs to be considered a high priority issue. Human-machine interface and operational topics must be fully respected for the further development of the ATO specification and products to avoid market failure and social impact.

### 6.5.2 Chance

The tests have proven that ATO delivers a significant potential for improvement of rail freight transportation in terms of efficiency and operation quality. DB Cargo as the RU and project lead is fully convinced that ATO technology can be the game-changer toward modal shift (from truck to freight rail) and CO2 reduction, particularly for freight application.



## 7. NEXT STEPS AND PROPOSAL OF FURTHER DEVELOPMENT OF ATO TO GOA 4

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### 7.1.1 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.

#### 7.1.1.1 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 ( $V_{soll}$  (german) –  $V_{shall}$ ) 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  $V_{soll}$  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.



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 18), 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  $V_{max}$ , 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.



Figure 16: AFB Vsoll adjuster of ICE 1

As with manual control, the driver always retains full responsibility for the safe performance of the train journey.



Figure 17: LZB Data Entry via Display

Since automatic driving with AFB and LZB on many routes with fully designed traction force and Vsoll actuators (then  $V_{soll}=V_{max}$  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](#))

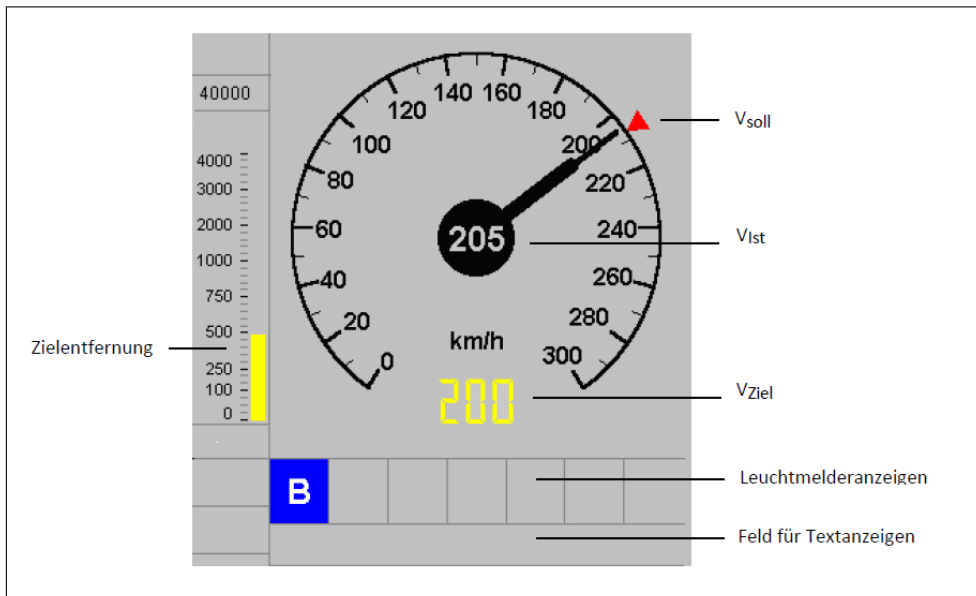


Figure 18: LZB command speed variable in a modern driver desk

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.

**7.1.1.2 Functional Vehicle Adapter as legacy vehicle design solution**

As reported in section 5.3.3.3. *“Therefore, for the tests, an adaption was used to create a communication interface between ATO-OB and TCMS (software change) and between the ATO-OB and the ETCS system (ATO Gateway).”*

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.

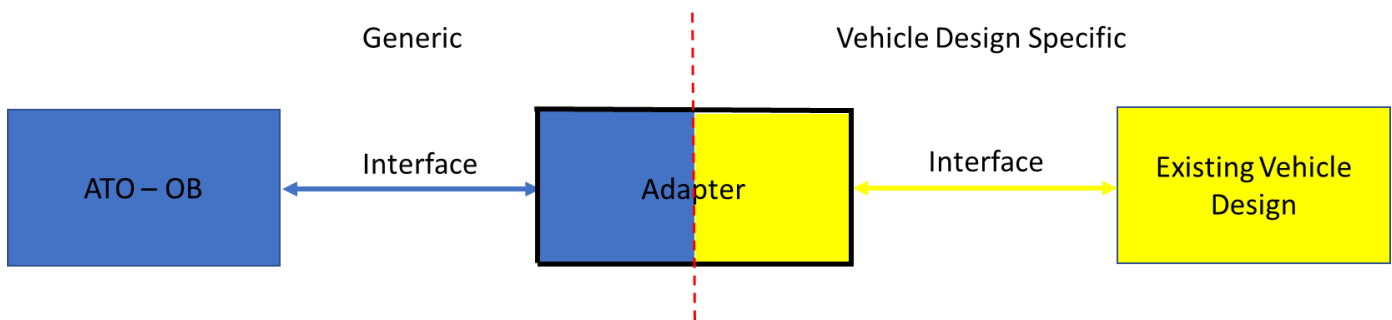


Figure 19: Adapter between generic ATO and Existing Vehicle Design

Also mentioned and described in 5.3.3.3. 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.

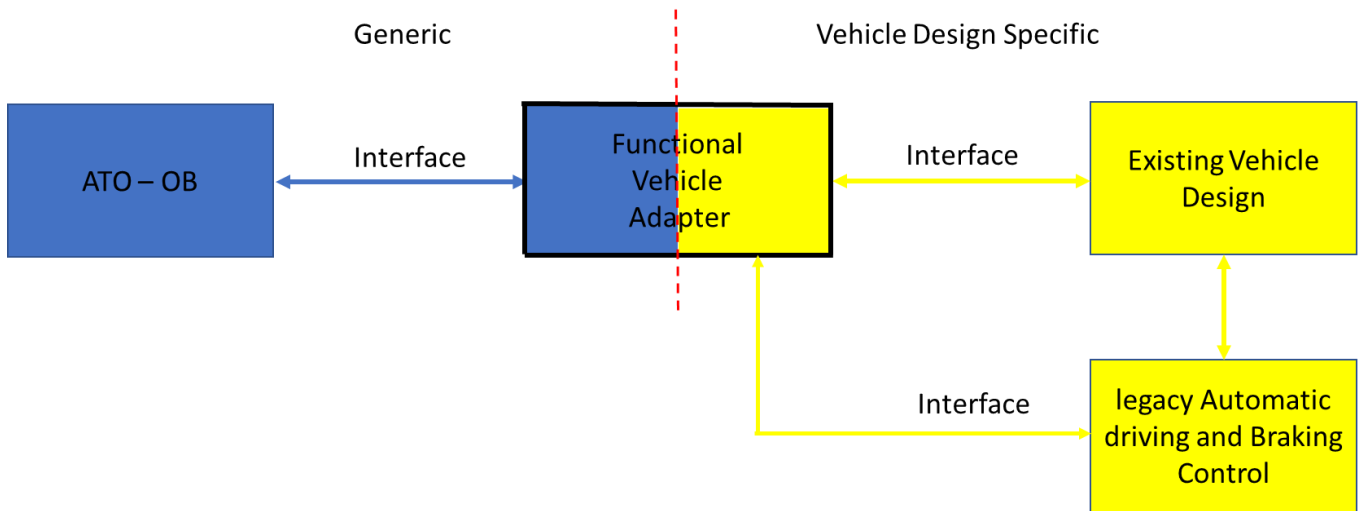


Figure 20: Use of FVA with Existing Vehicle Design and Legacy Automatic Driving and Braking Control

Further explanation of the application of the FVA is described in 5.3.3.3.

**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.

**7.1.1.3 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.)

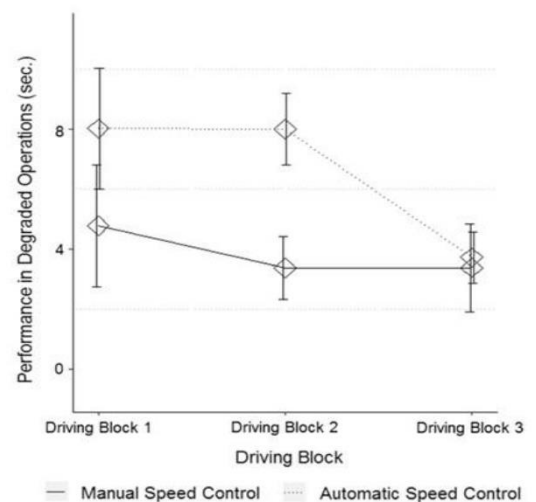


Figure 21: Average reaction times (M) and standard errors of the mean



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.)

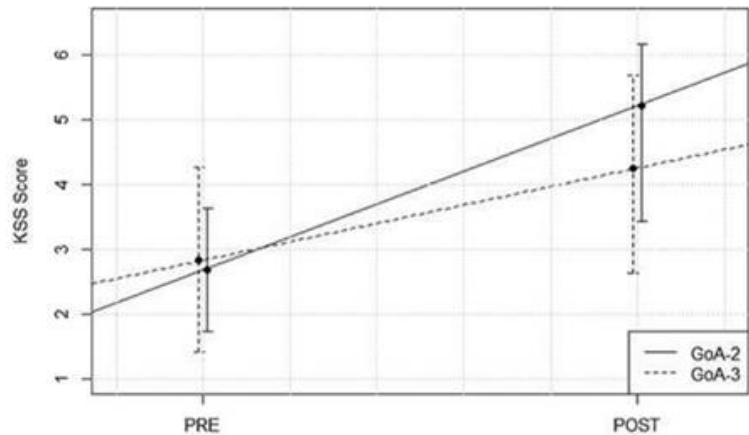


Figure 22: Effects of the Grades of Automation (GoA) on the Karolinska Sleepiness Scale scores over the course of the study.

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.

**7.1.1.4 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 .

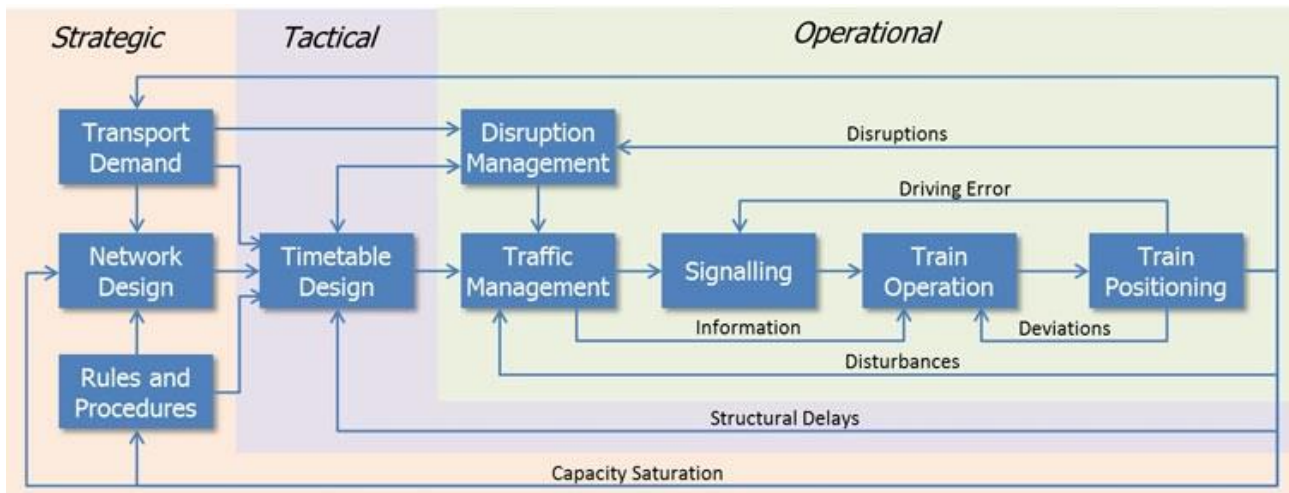


Figure 23: Railway Traffic System

(source: [Trends and developments in the automation of heavy rail operations \(globalrailwayreview.com\)](https://www.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.

**7.1.1.5 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 purposes 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.

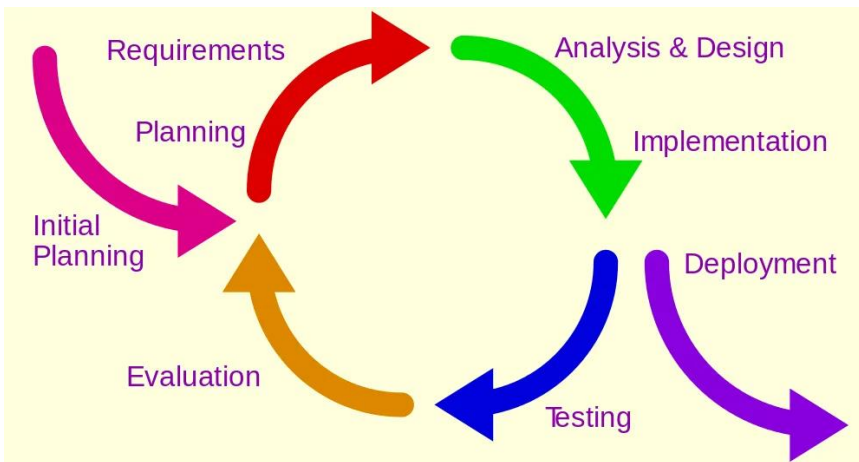
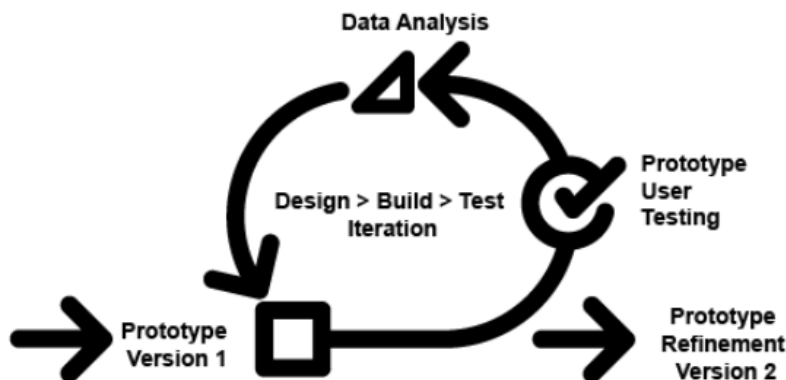


Figure 24: Cycle in a design or development process

(source: [Design iteration brings powerful results. So, do it again designer! | Interaction Design Foundation \(IxDF\) \(interaction-design.org\)](https://www.interaction-design.org/fundamentals/design-iteration-brings-powerful-results-so-do-it-again-designer/))

## ITERATIVE DESIGN CYCLE



Chris Becker © 2020

Figure 25: Iterative design with prototypes

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

### 7.1.1.6 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 initiatives e.g. S2R X2Rail4 GoA 4, TAURO, EUROPE’s Rail ... . The list will be attached to that document in the ANNEX A



## 8. LESSONS LEARNED

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The following points can be regarded as lessons learned from this project:

- 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 effectively and reliably 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 onboard equipment.
- After thoroughly scrutinizing the documentation by all partners in the project, a general design freeze is necessary to enable progress. Nevertheless, inconsistencies, quality issues, or missing elements will inevitably be found during the implementation phase. To mitigate the impact, strict documentation, and version management, and agreed-on procedures to manage abnormalities during the implementation phase are 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.
- The 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 into 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 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.



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



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[15] ATO-OB / ETCS-OB Interface Specification Appendix A - Communication Layers	0.0.2 07.09.2018



<p>[16] Subset-139 ATO over ERTMS ATO-OB / Vehicle Interface Specification FIS (Working Version 6)</p>	<p>0.0.10 W05 01.04.2019</p>
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## 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 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 inauguration		Data entry windows [after train composition] and Button "Train integrity"	Trigger for train inauguration 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 further criteria necessary 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 inauguration.	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	Washing		Symbol "Washing run"	Automatic trigger of washing run by ATO trackside function.	FprEN 16186-3	Table A.1



	information to the crew						
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	Coupling	TCMS	Symbol "Uncoupled"	Automatic update of train data to ATO trackside.	FprEN 16186-3	Table A.1



	information to the crew						
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 / Emergency 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 "Unintentionally applied brake"	Automatic alarm to ATO trackside function. Automatic back up for brake release if needed. Otherwise: Automatic Service brake.	FprEN 16186-3	Table A.1
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"	Automatic information to ATO trackside function. Automatic reset if possible.	FprEN 16186-3	Table A.1



				unintentionally off"			
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 commanded 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",	Automatic function commanded by ATO trackside	prEN 16186-2:2015 [E]	Table B.1



				"Neutral" and "Reverse"	function. According to: UIC 612-0		
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 Switches (MSS), Isolation Cocks, ...	Replaced by automatic switches. DT029-030		



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I hereby certify that the above statements are valid.

Baseliyos Jacob, DB Cargo AG

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First name Last name / Company

**Baseliyos Jacob** Digital unterschrieben von  
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*Blaz Jemensek / Slovenske zeleznice, d.o.o.*

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9th December 2021

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Jan Bergstrand, PLnpv,  
Trafikverket(TRV)

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E-Signature Jan Bergstrand



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Antonella Trombetta /Hitachi Rail STS

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20/12/2021

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Helene Desmoutier

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Date / Signature responsible person