OCORA

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Open CCS On-board Reference Architecture

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

Gamma Release

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1.01	Gamma release	BJ	2020-12-07

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References

Reader's note: please be aware that the numbers in square brackets, e.g. [1], as per the list of referenced documents below, is used throughout this document to indicate the references.

The following references are used in this document:

[1] OCORA-10-001-Gamma – Release Notes

1 Introduction

1.1 Document context and purpose

This document is published as part of the OCORA Gamma release, together with the documents listed in the release notes [1]. It is the first release of this document and it is still in a preliminary state.

The purpose of this document is to provide an overview of preliminary lessons learned and ensuing best practices to be used in the development of OCORA from the ongoing Shift2Rail IP 5 “Automated Rail Cargo Consortium Demonstrator Concept”. This document is in no way intended to replace any S2R IP5 ARCC project and design documents, that need to be delivered by e.g. the system or subsystem suppliers.

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

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

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

The goal of the ARCC GoA2 Demonstrator is to:

- understand and test the functional deployment of an ATO system within a full operational environment;
- provide empirical feedback with regard to ATO design to support upcoming S2R ATO development projects, e.g. X2Rail1 WP 4 (GoA4 Development) to improve design, engineering, test preparations and execution.

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

1.2 Why should I read this document and how to provide feedback?

This document is addressed to experts in the CCS, Rolling Stock and Freight Operation domain and to any other person, interested in the OCORA technical concepts for Freight ATO Tests. The reader will gain insights regarding the topics listed in chapter 1.1. and understanding of how Shift2Rail/OCORA intend to perform tests/demonstration to have first field results on the ATO specification.

3 ARCC GoA2 Demonstrator objectives

3.1 Objectives of ATO testing from the OCORA perspective

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

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

3.2 S2R and OCORA interaction

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

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

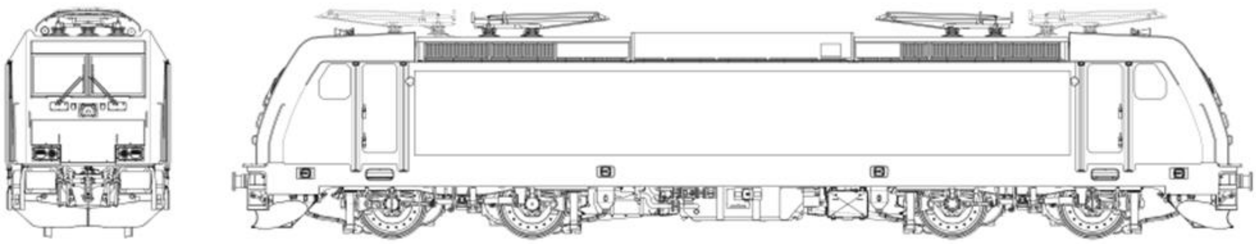
The ensuing, specific vehicle integration of the ARCC GoA2 Demonstrator – that required a few specific modifications that needed to be implemented in the TRAXX AC 1 system – is suitable for retrofitting on existing Multi Vehicle Bus systems, identified by the Shift2Rail X2Rail3 WP10 work stream.

4 ARCC GoA2 Demonstrator test configuration

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

4.1.1 Test Vehicle

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



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

Figure 1 - BR 185.1 CH TRAXX F 10 AC details

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

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

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

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

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

4.1.2 Test ATP System (Existing System)

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

- Trainguard®200 OBU;
- LZB 80/16 (No ETCS equipment);

- GSM-R SIM card;
- GSM-R data transmission.

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

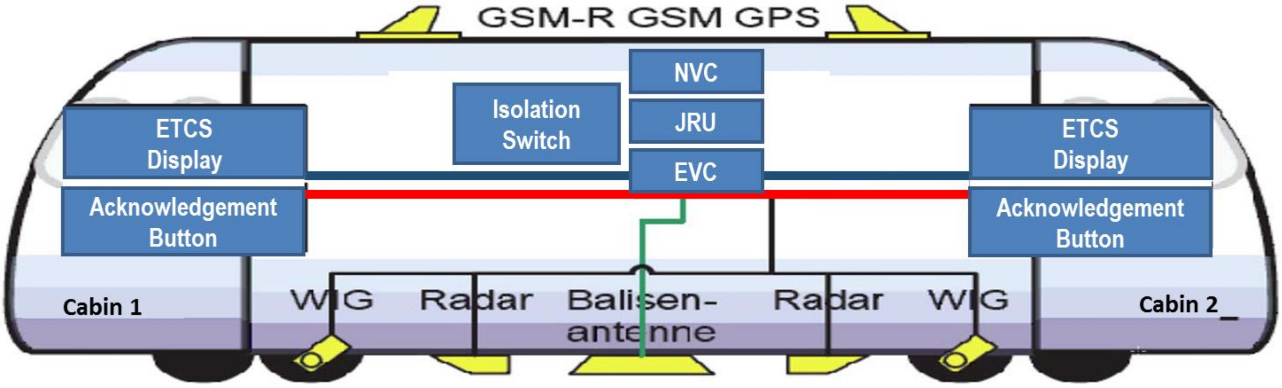


Figure 2 - TRAXX AC 1 BR 185.1 CH ETCS subsystem equipment

The ETCS subsystem equipment of the locomotive is illustrated in **Error! Reference source not found.**. The core of the ETCS vehicle equipment is the European Vital Computer (EVC). The non-vital computer (NVC) is used for communicating via GSM-R with the track infrastructure. The NVC includes the Communications Base System (CBS) software and has two GSM-R-Data-Mobiles. The NVC establishes a connection to a radio block centre (RBC), using the CBS software and GSM-R data modems via the GSM-R roof antennas, as far as this is required by the operated ETCS level. In addition to the time signal, the data recorder (JRU) retrieves and stores data that need to be registered (e.g. travel data) module according to SUBSET 027 requirements and which are conveyed via the MVB vehicle bus and a wired connections input.

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

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

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

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

The single state is responsible for the particular "ETCS Class B" specification and train protection technology. These components were only considered when there were effects or interactions due the European requirements of TSI CCS **Error! Reference source not found.**.

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

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

Figure 3 gives an overview of these interfaces.

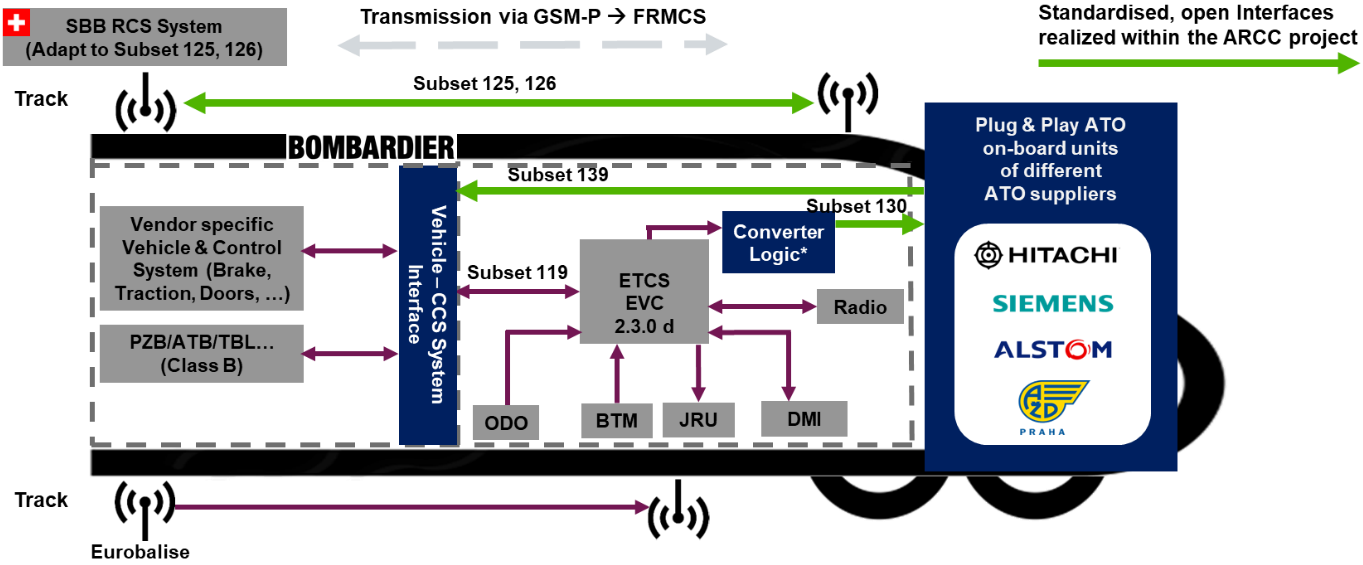


Figure 3 - ATO on-board Test Configuration overview

5 Test Cases

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

5.1 Freight Specific Test Cases

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

Stop testing includes:

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

5.2 General Test Cases

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

6 Lessons learned from the ARCC GoA2 Demonstrator project

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

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

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

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