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ERTMS/ATO OPERATIONAL PRINCIPLES

VERSIONS & MODIFICATIONS

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0.1	21/03/2012	Initial draft for review by EUG and UNISIG Members	Graham Scott
0.2	01/08/2012	First issue	Graham Scott
0.3	23/11/2012	Updated following review by EUG steering group	Graham Scott/Carine Marin
0.4	15/01/2013	Updated following review by EUG	Graham Scott/Carine Marin
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0.6	25/04/2013	Updated following EUG ATO Review Group Meeting 16/4/13	Carine Marin/Ken Chan/Mark Evans/Glyn Roberts
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1.4	17/03/2017	Update following substantial changes in Operational Requirements up to v1.9	Roman Treydel
1.5	07/07/2020	Update to reflect changes in specification review	Fabian Kirschbauer
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1.7	2022-02-18	Formatting and additional updates following name change AoE to ATO	Arvid Bäärnhielm
1.8	2022-03-23	Updated figure 1 following ATO-WP review.	Arvid Bäärnhielm
1.9	2023-03-07	Major update to include also GoA3 and GoA4.	S2R ATO WP GoA 3/4 Users
1.10	2023-06-23	Inclusion of Appendix A, containing the open points from the review of v1.8	S2R ATO WP Users
2-	2023-12-14	CCS TSI Application Guide version. The content is replicating version 1.8, which is the final version from S2R ATO WP GoA2 Workstream, aligning with the ATO specifications in the CCS TSI Appendix A.	Arvid Bäärnhielm

Contents

1 INTRODUCTION

The European Railways are currently in the process of implementing ETCS. The railways have identified an opportunity to achieve improved capacity, on-time performance and make energy efficiency improvements through developing and implementing Automatic Train Operation (ATO). ATO is the sub-system which performs some or all of the functions of automatic speed regulation, accurate stopping, door opening and closing, performance level regulation, and other functions assigned to a train driver or train attendant.

2 SCOPE

This document defines the ERTMS/ATO Operational Principles for operation in GoA1, GoA2, GoA3 and GoA4.

The ERTMS/ATO Operational Principles define an interoperable ATO that shall realise the benefits of ATO when applied to different railway infrastructures; urban, suburban, main line and high speed railways.

The ERTMS/ATO Operational Requirements shall cover requirements for different types of rolling stock; passenger trains, freight trains, maintenance trains and engineering vehicles.

The current version of this document is valid and commonly agreed for GoA1 and GoA2. The requirements for GoA3 and GoA4 are included for information but further development is in progress, especially for the automation of all driver functions as well as the definition of the system architecture.

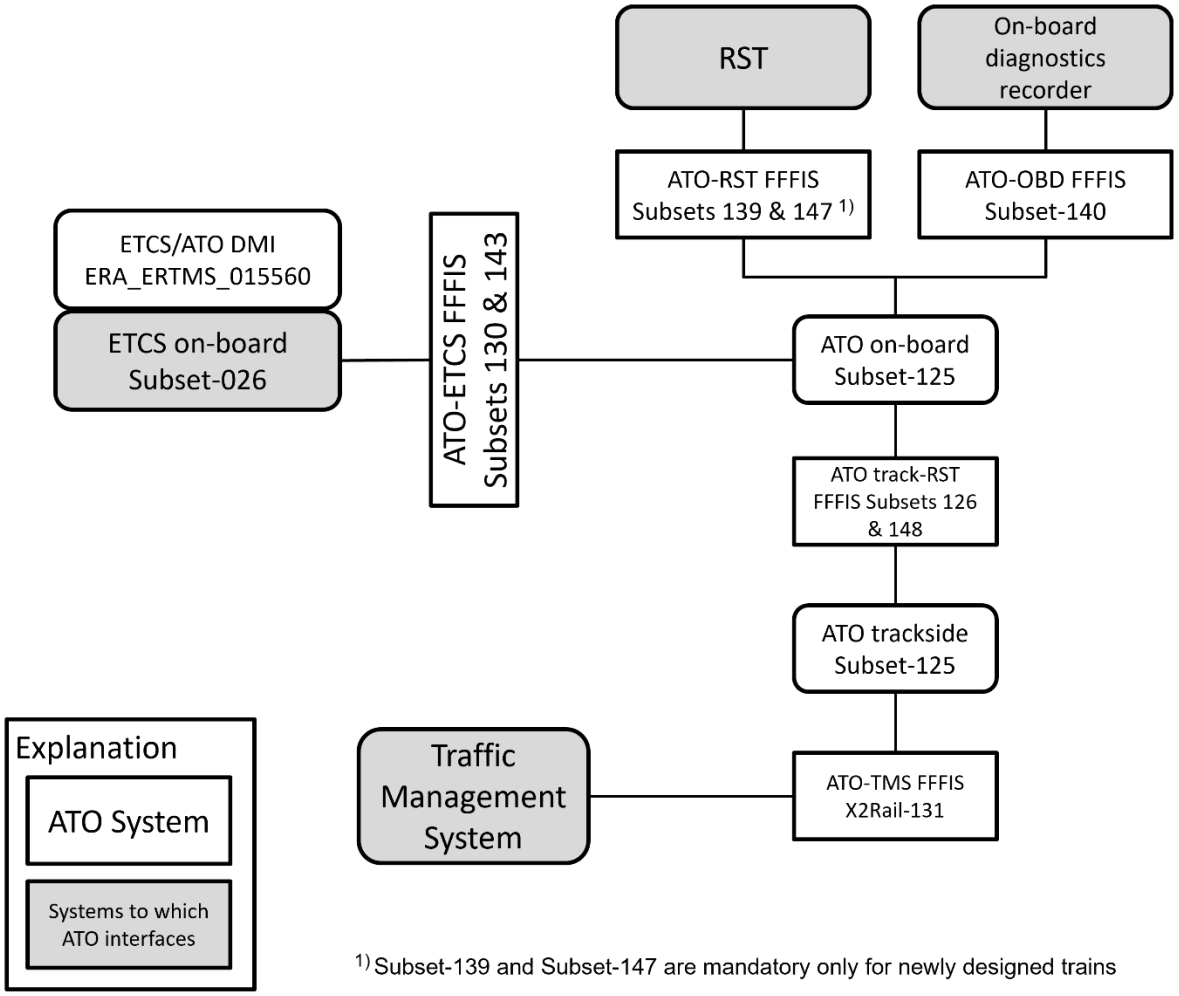
3 ERTMS/ATO SYSTEM OVERVIEW

The ERTMS/ATO system is based on two sub-systems: the ATP system (ETCS, see [RD1]) and the ATO system. Unlike ETCS the ATO system cannot operate in isolation; it can only drive the train automatically in areas where ETCS is guaranteeing the safe movement of the train. Both ETCS and ATO include on-board and trackside constituents. ETCS supervises the train ensuring that speed and movement limits are observed and the train proceeds only when it is allowed by the trackside to do so. The ATO on-board automatically drives trains, through control of traction and braking, including but not limited to accurate stopping at specified stopping positions using operational data provided by a traffic management system (TMS) and infrastructure data provided by trackside equipment.

The ATO trackside interfaces with the Traffic Management System which can automate normal signaller operations such as route setting and train regulation. ATO and TMS work together to maintain a train within a defined tolerance of the operational timetable whilst managing conflicts to ensure that overall train operation is optimised.

ATO is not a safety critical system and therefore any identified safety requirements as a result of the ATO operational requirements shall be assigned to other safety systems e.g. ETCS or Train Control Management Systems.

All the interoperable interfaces for the ATO system are shown in Figure 1.



1) Subset-139 and Subset-147 are mandatory only for newly designed trains

Figure 1: ERTMS/ATO System Architecture for GoA2

4 REFERENCES

The following documents have been used in the development of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including amendments) applies.

[RD1] Commission Regulation (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union

[RD2] ERTMS/ATO Glossary, EUG 13E154.

[RD3] EN 50126-1:1999: Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS).

5 TERMS, DEFINITIONS AND ABBREVIATIONS

The term, definitions and abbreviations are listed in a separate document titled “ERTMS/ATO Glossary” [RD2]

6 GRADES OF AUTOMATION

ATO covers a wide range of applications from manually assisted to fully automated operation of the railway dependent on the desired grade of automation (GoA) as chosen by the Railways.

The definition of GoA arises from apportioning responsibility for the given functions of railway operations between operational staff and the different railway systems. This is defined for the different GoAs in Table 1.

The level of GoA adopted by the Railways will influence the requirements of operation, operational facilities, rolling stock, and the type and number of staff required.

Different GoAs shall be used with the same train at different areas of the same line and by different trains on the same stretch of line.

It should be noted for operational purposes that if a member of operation staff starts to perform driving duties on a GoA3 or GoA4 train then the GoA is downgraded to GoA2 if automatic driving is still available and GoA1 if only manual driving is available.

Note 1: GoA 1 is only covered as a degraded fall-back grade of automation and does not form the basis of normal ATO operations.

Note 2: “Cruise Control” function is not within the scope and as such is not considered within the operational principles.

Ref. ID	PRINCIPLES OF RAILWAY OPERATION		GoA1	GoA2	GoA3	GoA4
			Non-automated train operation	**Semi-automated train operation**	**Driverless train operation**	**Unattended train operation**
			No ATO available	ATO available	ATO available	ATO available
			Train driver	Train driver	Train attendant	No staff on-board [1)]
ATO 1	**Performance and Energy Efficiency**	Optimise Performance and Energy Efficiency	Train driver	ATO	ATO	ATO
ATO 2	**Supervision and Regulation**	Manage Changes in Operational Conditions	TMS	ATO/TMS	ATO/TMS	ATO/TMS
ATO 3	**Yards, depot and stabling areas**	Operate ATO trains in yards depot and stabling areas	Train driver	Train driver and ATO	ATO	ATO
ATO 4.1	**Ensure safe movement of trains**	Ensure safe route	TMS, Interlocking	TMS, Interlocking	TMS, Interlocking	TMS, Interlocking
		Ensure safe separation of trains	Interlocking and ETCS	Interlocking and ETCS	Interlocking and ETCS	Interlocking and ETCS

Ref. ID	PRINCIPLES OF RAILWAY OPERATION		GoA1	GoA2	GoA3	GoA4
			Non-automated train operation	**Semi-automated train operation**	**Driverless train operation**	**Unattended train operation**
			No ATO available	ATO available	ATO available	ATO available
			Train driver	Train driver	Train attendant	No staff on-board [1)]
		Ensure safe speed	ETCS	ETCS	ETCS	ETCS
		Authorise train movement	ETCS	ETCS	ETCS	ETCS
ATO 4.2		Authorise change of the driving direction	ETCS	ETCS	ETCS	ETCS
ATO 4.3		Authorise couple and split a train	Train driver	Train driver	ETCS	ETCS
ATO 5.1	**Operate ATO trains**	Preparation and stabling	Train driver/ATO	Train driver/ATO	Train attendant/ATO	ATO/TMS
ATO 5.2		Data entry	Train driver/ATO	Train driver/ATO	Train attendant/ATO	ATO/TMS
ATO 5.3		Ensure starting conditions	Train driver/platform staff/ETCS	Train driver/platform staff/ATO	Train attendant/ATO	ATO
ATO 5.4		Operate an ATO train between two operational timing points	Train driver	ATO	ATO	ATO
ATO 5.5		Manage GoA and transitions	Train driver	Train driver/ATO	Train attendant / ATO	ATO
ATO 5.6		Change the driving direction	Train driver	Train driver/ATO	Train attendant/ATO	ATO
ATO 5.7		Couple and split an ATO train	Train driver	Train driver/ATO	ATO	ATO
ATO 5.8		Supervise the status of an ATO train	N/A	ATO	ATO	ATO
ATO 6	**Control Traction Power**	Manage traction power control	Train driver	ATO	ATO	ATO
ATO 7	**Supervise Railway**	Collisions with obstacles and persons on track	Train driver	Train driver	External system/ATO	ATO/external systems
ATO 8	**Supervise Loading and Unloading**	Control train, platform and emergency doors, interface to external systems	Train driver/platform staff	Train driver/platform staff/ATO/external systems	Train attendant/platform staff/ATO/ external systems	ATO/external systems

Ref. ID	PRINCIPLES OF RAILWAY OPERATION		GoA1	GoA2	GoA3	GoA4
			Non-automated train operation	**Semi-automated train operation**	**Driverless train operation**	**Unattended train operation**
			No ATO available	ATO available	ATO available	ATO available
			Train driver	Train driver	Train attendant	No staff on-board [1)]
ATO 5.8	**ATO status and Failures**	Supervise the status of ATO	ATO	ATO	ATO	ATO
ATO 9.1		Management of degraded operations	Train driver/ ATO/TMS	Train driver/ATO/TMS	Train attendant/ATO/TMS	ATO/TMS
ATO 9.2		Failures affecting all ATO trains operating within a particular area of control	Train driver/TMS	Train driver/ATO/TMS	Train attendant/ATO/TMS	ATO/TMS
ATO 10	**Manage further unsafe conditions**	Handle degraded and emergency situations	Train driver/ platform staff /external system	Train driver/ platform staff/ ATO/ external systems	Train attendant or platform staff/ ATO/ external systems	ATO/external system

1) No staff competent to operate the train

Table 1 – Grades of automation

7 GENERAL PRINCIPLES

7.1 GP1: Interoperability in a given grade of automation

In order to achieve interoperability within a given grade of automation, the on-board and infrastructure equipment shall take into account the goals summarised below:

- A train is equipped for operation in one or more GoA.
- A trackside is supporting operation of trains in the GoA the trackside is equipped for and any lower GoA.
- A train with an ATO system provided by supplier X shall operate on a track equipped with ATO infrastructure equipment supplied by Y;
- A train with an ATO system provided by supplier X shall be coupled with a train equipped with an ATO system provided by supplier Y (provided rolling stock can be coupled);
- ATO infrastructure equipment provided by supplier X and ATO infrastructure equipment provided by supplier Y or Z on adjacent portions of track shall be able to interface with a common TMS supplied by X, Y or Z;
- A train with an ATO system provided by X, Y or Z shall pass ATO and/or TMS boundaries X/Y, Y/Z and X/Z without any operational or technical disturbance;
- A train with an ATO system shall be able to pass between adjacent areas of traffic control and management without any operational or technical disturbance.

7.2 GP2: Interoperability between neighbouring ATO tracksides

ATO trains entering an ATO trackside shall be capable of operating at the highest available grade of automation common to the trackside and on-board ATO equipment of the trackside being entered. Seamless handover between adjacent ATO tracksides shall be supported.

7.3 GP3: Interoperability with different grades of automation

When the grades of automation are different between the infrastructure equipment and the on-board equipment, the ATO function shall be able to operate at the highest available common grade.

It shall be possible for a lower GoA to be selected by the on-board train operator or the trackside.

7.4 GP4: Interchangeability

ATO shall allow the replacement of any ATO constituent supplied by one industry provider by a constituent supplied by another industry provider but designed according to the same FFFIS and FIS specifications.

7.5 GP5: Adaptability

The ATO function shall be configurable by data change to enable line extension and modification of track layout and/or throughput increase and/or rolling stock fleet evolution.

7.6 GP6: Backward compatibility

ATO development shall ensure backward compatibility with any previous versions of ATO including all external systems at the interfaces.

8 AUTOMATIC TRAIN OPERATION PRINCIPLES

8.1 ATO 1: Performance and Energy Efficiency

8.1.1 ATO 1.1 - Defining performance parameters

The following performance parameters shall be specified for each application by the Railways.

- Reliability;
- Availability;
- Technical and operational fall back modes;
- Maintainability;
- Maximum speed;
- Headway;
- Journey time;
- Stopping accuracy;
- Required reaction times;
- Train characteristics;
- Operability.

The ATO system RAM performance shall comply with [RD3].

8.1.2 ATO 1.2 - Energy efficiency

ATO shall deliver the punctuality, capacity and headway requirements of the route whilst optimising energy efficiency.

8.2 ATO 2: Supervision and regulation

8.2.1 ATO 2.1 - Supervise train operations

During ATO operation, it shall be possible to:

- Supervise train location by monitoring trains automatically using train identification and status (including delay information) to recognise deviations from normal operation as soon as possible;

8.2.2 ATO 2.2 - Manage the train service

During ATO operation, it shall be possible to:

- Input the journey profile from the planning system;
- Start the journey profile;
- Dynamically modify the journey profile in real time to take account of changes in operating conditions including:
    - disruption management;
    - re-routing;
    - re-timing.
- Adapt the train's journey profile to meet any update of the operational timetable;
- Regulate trains to avoid bunching of trains and to reduce delays to trains in the case of disturbances;
- Dispatch ATO trains to harmonise the starting of ATO trains, corresponding to results of train regulation and ensuring connecting services;
- Operate both ATO and non-ATO trains simultaneously.

8.3 ATO 3: Yards, depots and stabling areas

8.3.1 ATO 3.1 - Operate a train in yards, depots and stabling areas

ATO trains shall be able to operate in yards, depots and stabling areas under ATO control.

8.3.2 ATO 3.2 - Manage transfer between yards, depots and stabling areas and the mainline

The movement of ATO trains to or from yards, depots and stabling areas and the mainline shall be supported by ATO.

8.4 ATO 4: Ensure safe movement of ATO trains

National systems, rules, processes and ETCS shall ensure the safe route, safe separation of trains, safe speed and authorisation of train movement. ATO shall only be operational if all safety pre-conditions are continuously met.

8.5 ATO 5: Operate ATO trains

The ATO system shall start, stop, coast, and control the speed of the train such that acceleration, deceleration, and jerk rates are within passenger comfort limits or freight/maintenance train design limits and the train operating speed is below the speed limit imposed by the safety system.

8.5.1 ATO 5.1 - Preparation and stabling

ATO shall support:

- Preparation and awakening of ATO, including a self-check, at any location prior to setting the train in operation;
- Starting in the appropriate GoA with or without manual intervention after awakening;
- De-energising the ATO on-board by on-board or trackside command.

8.5.2 ATO 5.2 - Data entry

Data required for ATO shall be entered only once and then distributed to all relevant train and infrastructure systems as required to support the grade of automation.

8.5.3 ATO 5.3 - Ensure starting conditions

Departure of ATO trains shall only be authorised if all necessary operational and safety pre-conditions are fulfilled.

8.5.4 ATO 5.4 - Operate a train between two operational timing points

ATO trains shall calculate the most energy efficient speed profile to comply with journey profile requirements and the ETCS Most Restrictive Speed Profile.

8.5.5 ATO 5.5 - Manage GoA transitions

ATO trains shall support transitions between different grades of automation.

8.5.6 ATO 5.6 - Change the driving direction

In GoA3 and 4 ATO shall be able to change direction either automatically or under the direction of the ATO trackside.

8.5.7 ATO 5.7 - Joining and splitting a train

It shall be possible to join and split ATO trains either automatically or under the direction of the ATO trackside or the on-board train operator depending on the GoA.

8.5.8 ATO 5.8 - Advisory Information

ATO shall display to the train driver or attendant the information relevant for the current journey. In GoA1, ATO shall provide speed and coasting advise to the driver.

8.6 ATO 6: Control traction power

During ATO operation, traction power control shall be managed either by the train driver or automatically on given sections or on all sections dependant on the GoA. Including:

- Efficient power consumption;
- Transitions between different sources of traction power in the operational area;
- Loss of traction power.

8.7 ATO 7: Supervise Railway

Supervision of the operation in GoA1 and GoA2 is part of the responsibility of the train driver. However, in GoA3 and GoA4, the ATO function shall:

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- Supervise border between platform tracks and other tracks;
- Supervise obstacle detection devices.

8.8 ATO 8: Supervise Loading and Unloading

The ATO system shall support supervision of passengers on platforms and shall provide an interface to communication and surveillance systems. For ATO passenger trains, opening and closing of doors is commanded by ATO but authorised by an external safety system. This principle applies to train doors and where used, platform doors and emergency doors.
For freight operations, the ATO system shall support stopping an ATO operated train at a precise location for loading/unloading and shall interface with external systems for loading and unloading whilst the train is moving.

8.9 ATO 9: ATO Status and Failures

8.9.1 ATO 9.1 - Supervise the status of the ATO

The status of ATO related to diagnostics and failures during operation shall be available to the on-board train operator and the trackside.

8.9.2 ATO 9.2 - Management of degraded operations

Each grade of automation shall incorporate degraded modes of operation to minimize the operational impacts of equipment failures and to permit train movements to continue safely (i.e., maximize system availability).

The downtime or unavailability of an operationally critical function should be minimized through the use of local and remote diagnostic capabilities and appropriate operating and maintenance procedures [i.e., minimize mean time to repair (MTTR)].

ATO shall be designed to support degraded modes of operation in the event of failures, with ETCS continuing to provide ATP with minimum reliance on adherence to operating procedures.

For all grades of automation, a failure management plan, based on failure analysis and operating processes or procedures, shall identify train operating modes that will take advantage of the degraded modes of operation and recovery capabilities of ATO. The goal of the plan shall be to eliminate hazards to passengers and staff while continuing to provide passenger and freight services.

8.10 ATO 10: Manage further unsafe conditions

The status of the train related to safety of passengers, freight or assets during operation shall be supervised.

Failures or incidents shall be managed to optimise performance during degraded mode and emergency situation and return operations to normal as quickly as possible. ATO shall aid recovery from journey profile deviations and optimise the time to return to scheduled operation.