Automated Train Operation
Innotrans 2018
ATO over ETCS
Shaping connected mobility.
Voices on automatic train operation

“As soon as 2020, around 40 percent of train journeys could be running automatically. We also expect 20 to 30 percent of long-distance travel to be partially automated by then.”

Dr. Jochen Eickholt, CEO of Siemens Mobility Division, 2016

“The extension of ETCS is the basis for autonomous driving on railways and prepares the next technology push in railway traffic.”

„Zukunft Bahn“ quality program, German Railways, 2015

“Automated driving is, in the medium and long term, one of the major innovation levers to improve the competitiveness of rail freight transport.”

Technology and innovation strategy @ DB Cargo, 2017

“ATO is an important component of SmartRail 4.0 and contributes to the aims of safety and increased capacity.”

SmartRail 4.0 – an innovation program of the Swiss railway industry, 2018
Contents
ATO over ETCS

01 ATO as part of digitization
02 Challenges for mainline rail services
03 Benefits of ATO system
04 Concept and architecture
05 ATO over ETCS
06 Introduction strategies
07 Outlook
08 References
ATO as part of digitization
Diverse automation functions are already in use on railways today:

- **Electronic interlockings** control and protect routes
- **Automatic train control systems** ensure that trains run safely
- **Intelligent operations control systems** set routes and provide support in exceptional operating situations

**Digitization = optimization** of operational sequences and continuous automation towards fully automatic rail operations
Introduction of highly automatic operation in mainline rail services
Towards fully automatic train operation

<table>
<thead>
<tr>
<th>Manual operation</th>
<th>Highly automatic operation</th>
<th>Fully automatic operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervision by driver</td>
<td>Limited driver action</td>
<td>No supervision by driver</td>
</tr>
<tr>
<td><strong>GoA 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual train operation with driver</td>
<td></td>
<td></td>
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<tr>
<td>Supervision and control train operation (SCO)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provision of driving recommendations for energy-optimized train runs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver drives completely manually</td>
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<td></td>
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<tr>
<td>Obstruction detection by driver</td>
<td>Automatic train operation after driver interaction</td>
<td></td>
</tr>
<tr>
<td>Manual train dispatching by driver or train attendant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train monitoring and intervention in emergency situations by driver or train attendant</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GoA 2</strong></td>
<td>Automatic train operation</td>
<td>Unattended train operation (UTO)</td>
</tr>
<tr>
<td>Automatic train operation with driver</td>
<td></td>
<td></td>
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<tr>
<td>Semi-automatic train operation (STO)</td>
<td></td>
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<tr>
<td>Automatic train operation after driver interaction</td>
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<tr>
<td><strong>GoA 3</strong></td>
<td>Automatic train operation without driver</td>
<td></td>
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<tr>
<td>Driverless train operation (DTO)</td>
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<tr>
<td></td>
<td>Automatic train operation</td>
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<td></td>
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<tr>
<td><strong>GoA 4</strong></td>
<td>Automatic train operation without staff</td>
<td></td>
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<tr>
<td>Unattended train operation (UTO)</td>
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<tr>
<td></td>
<td>Central monitoring or automation functions for handling of train disturbances and emergency situations</td>
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Challenges for mainline rail services
Major constraints in introduction of automated driving in mainline rail services

- Single operator for infrastructure and vehicles
- Purely passenger transport
- Identical vehicles with similar characteristics
- Simple infrastructure closed and access-protected
- Integrated system as closed solution of a single vendor

- Various operators for infrastructure and vehicles
- Mixed traffic comprising high speed, regional and freight transport
- Multiple vehicles with different characteristics
- Highly complex infrastructure open and publicly accessible
- Network-wide interoperability with a wide range of signaling solutions of multiple vendors
Benefits of ATO system
Enhanced infrastructure and transport capacity by decreasing headways

Improved timetable stability and punctuality by means of consistent driving behavior

Energy savings by means of an optimized driving strategy

Reduced mechanical wear and tear and less noise by means of homogeneous driving with less braking

Increased passenger comfort by means of smoother, homogeneous driving

Increased flexibility for demand-oriented train services (for GoA 3/4)

Substantial increase in performance already with introduction of highly automated train operation
Concept and architecture
Connection to operations control systems is key to optimum train control with a high benefit

**Infrastructure database**
- Static infrastructure data with detailed track information (topology, geometry)

**Trackside ATO (ATO-TS)**
- Generation of journey profiles and segment profiles from timetable and infrastructure data
- Handling of communication links to trains

**Operations control system**
- Dynamic timetable data with detailed information about train movements
- Train tracking / forecasting
- Conflict detection / resolution

**On-board ATO (ATO-OB)**
- Calculation of the optimum speed profile
- Train control by access to the traction and brake control system

**Automatic train protection system (ATP)**
- Safe monitoring of train movements
ATO over ETCS
ETCS and ATO are perfect partners for safe automatic train operation

**ATO over ETCS – the next technology push for ETCS**

- **ETCS** is the standardized European train control system and is also gaining acceptance as an international standard
- **ETCS** completely monitors the permitted speed and the end of the movement authority
- **ETCS** also guarantees safety for automatic train operation with ATO
- **Specification** of interoperable ATO as an overlay over ETCS (ATO over ETCS) as part of the Shift2Rail project
- **Network-wide optimization** of train movements by ATO with an online connection to the trackside traffic management system
Shift2Rail reference architecture “ATO over ETCS” (GoA 2) for interoperable automatic train operation with ETCS

- Generation of journey profiles and segment profiles from timetable and infrastructure data
- Handling of communication links to trains

- Calculation of the optimum speed profile
- Train control by access to the traction and brake control system

Traffic management system
- Dynamic timetable data with detailed information about train movements
- Train tracking / forecasting
- Conflict detection / resolution

- Safe monitoring of train movements

Traction and brake control
- Calculation of the optimum speed profile
- Train control by access to the traction and brake control system
- Generation of journey profiles and segment profiles from timetable and infrastructure data
- Handling of communication links to trains
ATO shortens headways by homogeneous driving and later braking and thus increases line capacity

Potential for optimization through ATO

ATO – Automatic Train Operation
ETCS – European Train Control System
ATO shortens headways by later braking

ATO and ETCS Baseline 3 braking curves

ATO also allows for shorter headways for high-speed applications

- **ATO brakes later** than humanly possible without causing brake application by ETCS
- Some driver indications and warnings are suppressed to avoid irritation when ATO is active
Benefits of ATO

ATO reduces headways
• Eliminating variability in driving techniques
• Driving more accurately
• Driving closer to safe ETCS braking curves

ATO stops more accurately (±0.25 m possible)
• Suitable for wheelchair ramps and platform screen doors
• Opening doors when safely released by ETCS
• Shortening stopping times

ATO improves performance
• Shortening timetable recovery times following delays
• Reducing energy costs and mechanical wear
• Decreasing carbon footprint

ATO drives consistently
Favorable conditions for introduction of ATO systems in mainline rail services

The numbers of passengers are increasing continuously.

The introduction of ATO systems can help to increase network capacity without new tracks.

ATO is specified as “ATO over ETCS” in the “Shift2Rail” project.

This provides the necessary conditions for interoperable ATO. Investments can be invested gradually and remain protected.

With Thameslink, Siemens Mobility has realized the first commercial ATO application in mainline rail services with ETCS.

This means that we have excellent experience in highly automatic train operations according to GoA 2 under real-life operating conditions for mainline applications.

Existing fleets are modernized.

New vehicles can already be equipped with an ATO system. The installation and, in particular, certification costs required for later installations can be considerably reduced.
Introduction of automatic operation in mainline rail services in areas with a particularly high benefit

Rapid transit and regional rail services

- Typically operating in larger but still restricted rail networks, often with concentrated high-density inner-city links
- Combining certain mainline aspects with mass transit characteristics (fixed headways, short stopping times)

Freight rail services

- Locomotives operate frequently along the same corridors and lines in a more or less fixed rotation
- Experience gained in the optimization of automatic control of heavy, loco-hauled trains

Optimized traffic flow for maximum possible throughput with high timetable stability

Reduction in energy consumption and mechanical wear and tear
# Steps in implementation towards highly automatic train operation according to GoA 2

## Technical measures

<table>
<thead>
<tr>
<th>Enhancement of traffic management system</th>
<th>Impact on ATO system</th>
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<tbody>
<tr>
<td>• Utilization of the timetable as a key element for the execution of operations</td>
<td>• Availability of necessary timetable data based on current operations</td>
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<tr>
<td>• Upgrading with intelligent dispatching functions (forecasting, conflict detection and conflict resolution)</td>
<td>• Optimum train control even in unplanned exceptional operating situations</td>
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## Introduction of trackside ATO (ATO-TS)

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<tr>
<td>• Acquisition of static infrastructure data with detailed track information</td>
<td>• Availability of static infrastructure data on ATO-TS to generate segment profiles</td>
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<tr>
<td>• Provision of a connection to the existing traffic management system (via X2Rail-131, if necessary with specific adapters)</td>
<td>• Availability of up-to-the-minute timetable data on ATO-TS to generate journey profiles</td>
</tr>
<tr>
<td>• Usage of the interface to on-board ATO (ATO-OB) according to Subset-126</td>
<td>• Provision of journey profiles and segment profiles to on-board ATO (ATO-OB)</td>
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## Introduction of on-board ATO (ATO-OB)

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<tr>
<td>• Equipment of vehicles with ATO-OB (and ETCS-OB) according to “ATO over ETCS”</td>
<td>• Calculation of optimum speed profiles and control of the vehicle’s traction and braking system</td>
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</tbody>
</table>
Integration of all vehicles into automation strategy for network-wide optimization of rail services

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<thead>
<tr>
<th>Connected Driver Advisory System (C-DAS)</th>
<th>Connected Automated Train Operation (GoA 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Continuous connection to the operations control system to provide up-to-the-minute timetable data</td>
<td>• Control of the vehicle’s traction and braking system based on the optimum speed profile</td>
</tr>
<tr>
<td>• Calculation of the optimum speed profile based on the current track and timetable data on the ATO on-board unit</td>
<td>• Train runs automatically in adherence to the permitted speeds and safely monitored by ETCS</td>
</tr>
<tr>
<td>• Display of driving recommendations on the driver HMI based on the optimum speed profile</td>
<td>• Opportunity for entry into later automatic train operation</td>
</tr>
<tr>
<td>• Driver drives the train manually under consideration of the driving recommendations</td>
<td>• Highly automatic train operation with maximum possible operational benefit for network-wide optimization</td>
</tr>
<tr>
<td>• Opportunity for entry into later automatic train operation</td>
<td>• Basis for fully automatic train operation in line with GoA 3/4</td>
</tr>
<tr>
<td>• Integration of non-automatable vehicles into a network-wide automation strategy</td>
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Mobility Management – Mainline Rail Automation
Towards fully automatic train operation in line with GoA 3/4 via organizational and technical expansions

MindSphere for extended data analysis...

- Adjustment of normative and legal conditions
- Definition of operational fallback scenarios in case of disturbance
- Adjustment of operating rules
- Technical support in case of vehicle disturbances and emergency situations
- Automatic obstacle detection and platform protection (obstruction detection)
- Utilization of state-of-the-art communications (e.g. 5G)

MindSphere...

- Various operators for infrastructure and vehicles
- Mixed traffic comprising high speed, regional and freight transport
- Multiple vehicles with different characteristics
- Highly complex infrastructure open and publicly accessible
- Network-wide interoperability with a wide range of signaling solutions of multiple vendors

MindSphere

Automatic obstacle detection and platform protection (obstruction detection)

Technical support in case of vehicle disturbances and emergency situations

MindSphere for extended data analysis...

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References
Siemens is pioneer and world market leader for highly and fully automatic train operations

Siemens has already equipped more than 300 route km for metro systems with technology for driverless train operations worldwide and is therefore market leader in this field.

ATO for freight transport (2016)
Demonstrator for automated driving in rail freight transport

Shift2Rail „ATO over ETCS“ (X2Rail-1)
Specification and development of interoperable ATO (09/2016 - 08/2019)

ATO demonstrator for SBB (2018)
ATO over ETCS L2 with ETCS Baseline 2.3.0d

„Digital S-Bahn Hamburg“ (2021)
Reference project for „Digitale Schiene Deutschland“

Autonomous tram (2018)
Demonstrator for automatic obstacle detection in real-life operation

Thameslink (2018)
First commercial ATO application in mainline rail services with ETCS
Thameslink
First commercial ATO application in mainline rail services with ETCS

World’s first commercial ATO application in mainline rail services in combination with ETCS

- Delivery of rolling stock, ETCS and ATO
- Increased capacity on existing infrastructure (24 trains per hour, track and direction on the north-south inner-city link of London)
- Capacity objectives only achievable with ATO
- ATO over ETCS in the core area (communication via Packet 44) with ETCS Level 2 Baseline 3
- Start of passenger services with ATO in May 2018
“Digital S-Bahn Hamburg”
Reference project for „Digitale Schiene Deutschland“

First-time implementation of highly and fully automatic train operation in regional and mainline rail services in Germany

- Joint project with City of Hamburg and DB AG
- Equipment of a 23 km section with ETCS Level 2
- Equipment of four trains and the trackside operation control with ATO over ETCS
- Unattended, fully automated train operation between depot and platform
- Putting into operation by the “Intelligent Transport Systems (ITS)” world congress in October 2021
Shift2Rail „ATO over ETCS“ (X2Rail-1)
Specification and development of interoperable ATO

Public-private joint undertaking from industry, rail operators, research institutions and the EU Commission to promote innovations in the rail sector

- ATO is part of the IP2 innovation program „Advanced Traffic Management and Control System“ to achieve interoperable automatic train operation in combination with ETCS
- Siemens Mobility is project coordinator for X2Rail-1 with „ATO over ETCS“ (AoE) (09/2016 - 08/2019)
- Objective of X2Rail-1 / AoE: delivery of specifications and technical demonstrators for GoA 2, feasibility analysis and operational concepts for GoA 3/4
ATO demonstrator for Swiss Federal Railways
ATO over ETCS L2 with ETCS Baseline 2.3.0d

- Joint project with SBB
- Integration of ATO into an existing vehicle with usage of the existing ETCS on-board equipment
- Implementation of the ATO interface to ETCS-OBU with ETCS baseline 2.3.0d
- Data exchange between ATO-OB and ATO-TS in accordance with the standardized interface as per Shift2Rail Subset-126
- Highly automatic driving with optimum speed profile and precise stopping based on the timetable on the rapid transit line between Lausanne and Villeneuve with ETCS Level 2
- First test runs with ATO in August 2018
ATO for freight transport
Demonstrator for automated driving in rail freight transport

World’s first demonstration project for automated driving in rail freight transport

- Joint project with DB Cargo in 2016
- Integration of ATO and additional sensor technology into an existing locomotive
- Automated driving at maximum speed as well as driving through a speed restriction section, automated braking and starting according to track specifications
- Automated sensor-supported approaching to car cuts for coupling
- Sensor-controlled obstacle detection
- Remote control via tablet
Autonomous tram
Demonstrator for automatic obstacle detection in real-life operation

*World’s first demonstration project for autonomous tram in real-life road traffic*

- Joint project with Verkehrsbetriebe Potsdam GmbH (ViP)
- Rapid correct reaction to many challenges (pedestrians, crossing vehicles and priority situations)
- Lidar, radar and camera sensors as digital “eyes” to read the traffic environment
- Complex algorithms as “brain” to interpret, evaluate and predict driving situations
We turn your vision into reality.