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# Automated Train Operation



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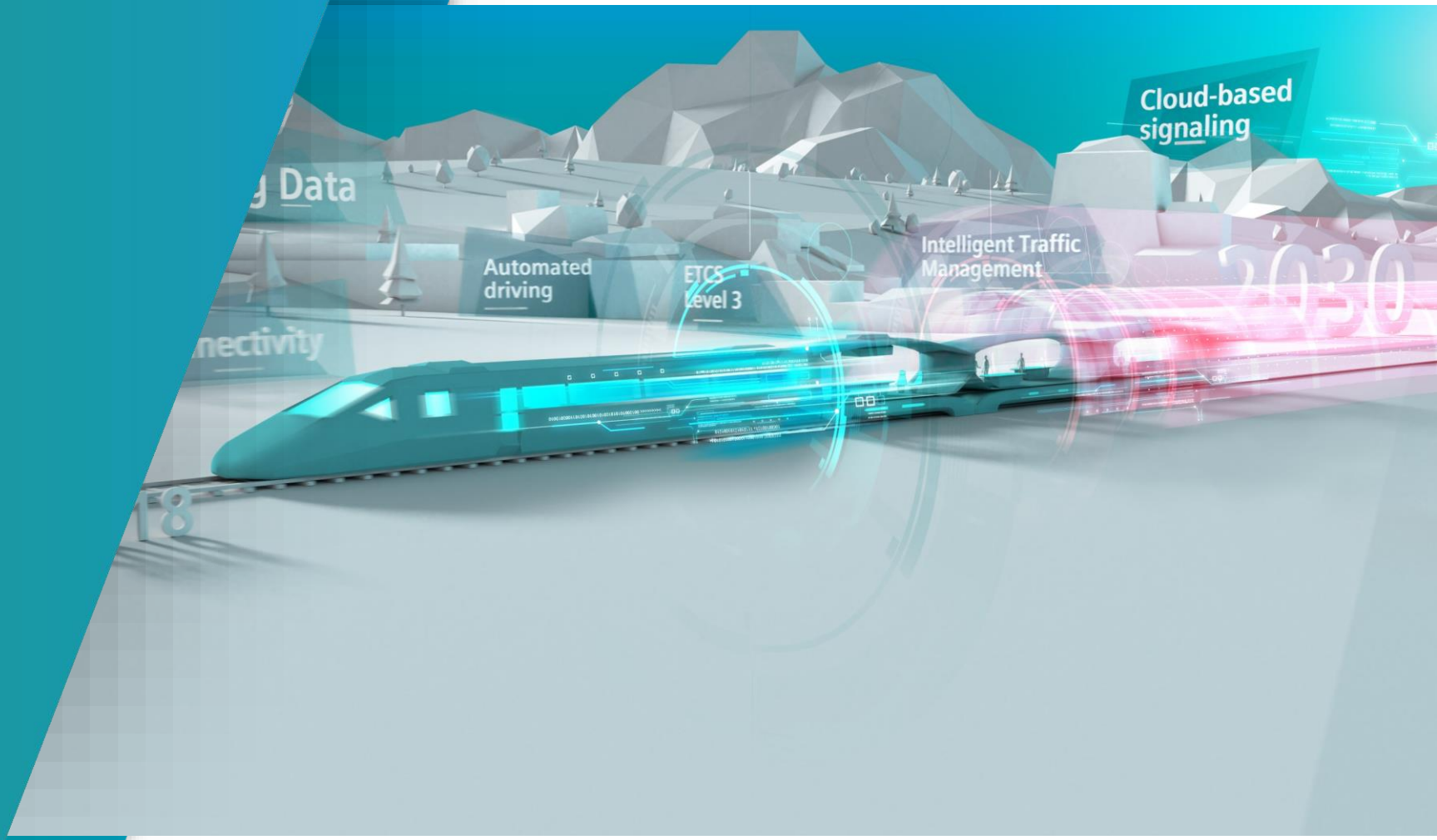
# Innotrans 2018
# ATO over ETCS

Shaping connected mobility.



# Voices on automatic train operation

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*“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

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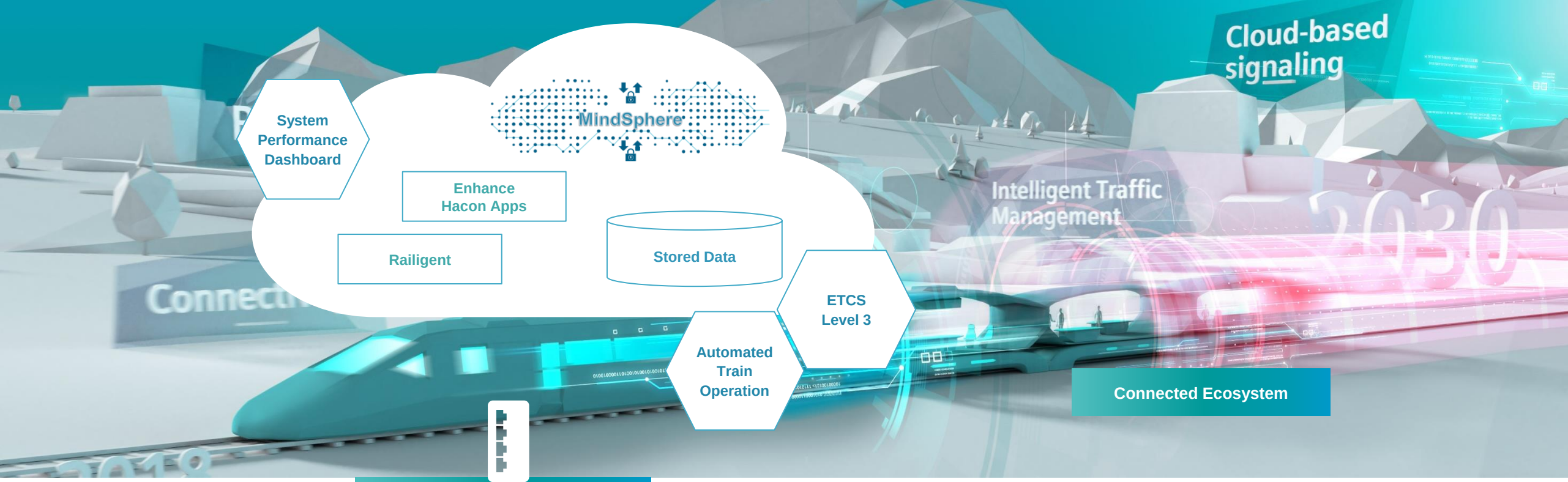
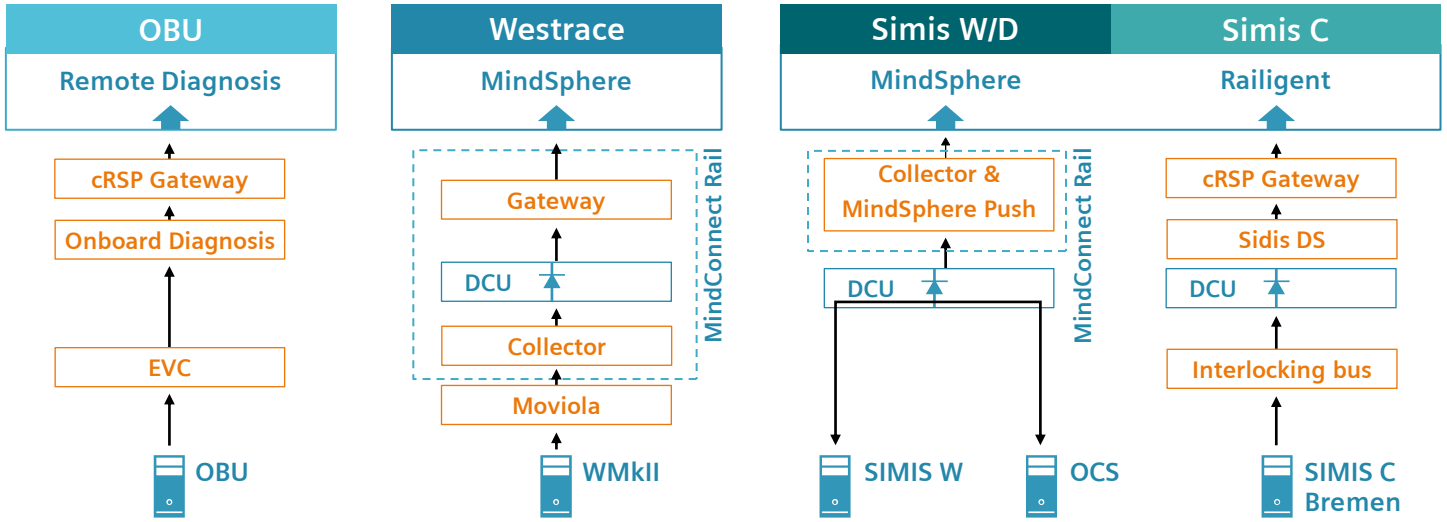
# ATO as part of digitization


Cloud-based signaling
MindSphere
System Performance Dashboard
Enhance Hacon Apps
Railigent
Stored Data
ETCS Level 3
Automated Train Operation
Intelligent Traffic Management
2030
Connected Ecosystem
Connected Technology


OBU
Remote Diagnosis
cRSP Gateway
Onboard Diagnosis
EVC
OBU
Westrace
MindSphere
Gateway
DCU
Collector
Moviola
WMkII
MindConnect Rail
Simis W/D
MindSphere
Collector & MindSphere Push
DCU
SIMIS W
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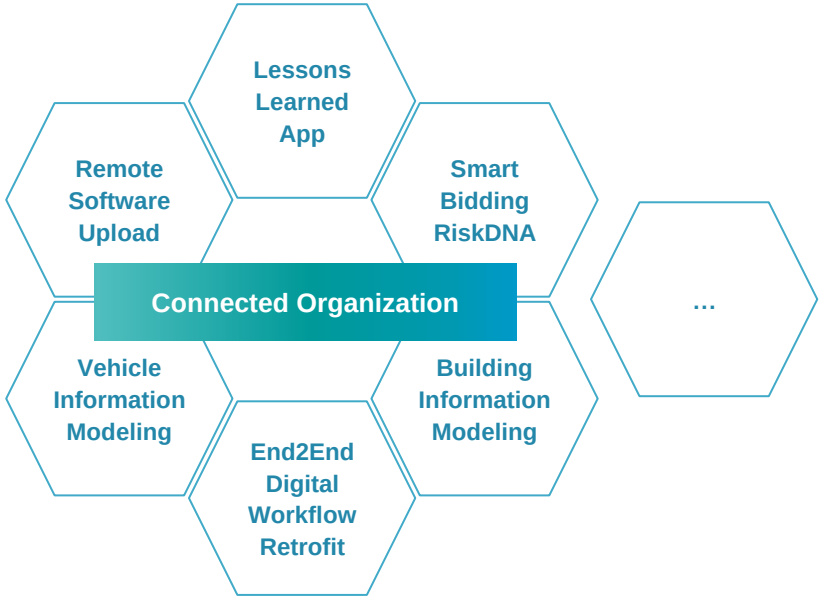
MindConnect Rail
Simis C
Railigent
cRSP Gateway
Sidis DS
DCU
Interlocking bus
SIMIS C Bremen


Lessons Learned App
Remote Software Upload
Smart Bidding RiskDNA
Connected Organization
...
Vehicle Information Modeling
Building Information Modeling
End2End Digital Workflow Retrofit

# Next step towards full automation

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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

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**Manual operation**
Supervision by driver

**Highly automatic operation**
Limited driver action

**Fully automatic operation**
No supervision by driver

| GoA 1 | GoA 2 | GoA 3 | GoA 4 |
|---|---|---|---|
| Manual train operation with driver<br>Supervision and control train operation (SCO) | Automatic train operation with driver<br>Semi-automatic train operation (STO) | Automatic train operation without driver<br>Driverless train operation (DTO) | Automatic train operation without staff<br>Unattended train operation (UTO) |
| Provision of driving recommendations for energy-optimized train runs | | | |
| Driver drives completely manually | Automatic train operation after driver interaction | Automatic train operation | |
| Obstruction detection by driver | | Automatic obstruction detection (obstacle detection, platform protection) | |
| Manual train dispatching by driver or train attendant | | | Central or automatic train dispatching |
| Train monitoring and intervention in emergency situations by driver or train attendant | | | Central monitoring or automation functions for handling of train disturbances and emergency situations |

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# Challenges for mainline rail services

# Major constraints in introduction of automated driving in mainline rail services

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## MASS TRANSIT

**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

## MAINLINE

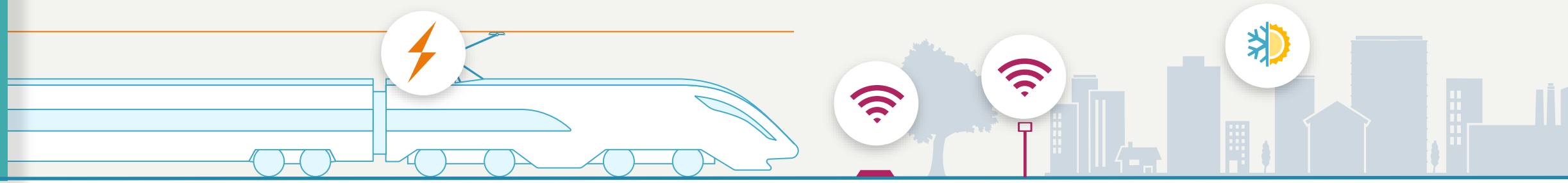
**Various operators**
for infrastructure and vehicles

**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



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# Benefits of ATO system

# Substantial increase in performance already with introduction of highly automated train operation

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- **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)

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# Concept and architecture

# Connection to operations control systems is key to optimum train control with a high benefit

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TRACKSIDE

**Infrastructure database**

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

Infra-strcture data

**Trackside ATO (ATO-TS)**

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

Timetable data

**Operations control system**

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

ON-BOARD

Traction and brake control

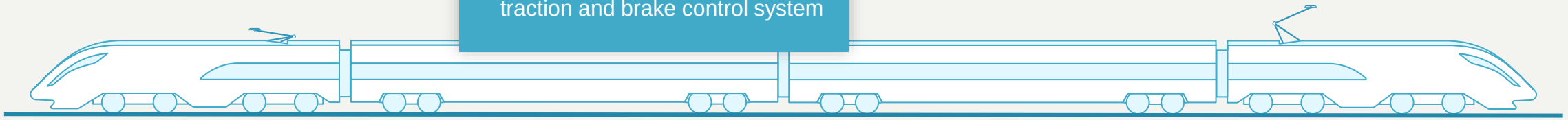
**On-board ATO (ATO-OB)**

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

Monitored speed levels

**Automatic train protection system (ATP)**

- Safe monitoring of train movements



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# ATO over ETCS

# ETCS and ATO are perfect partners for safe automatic train operation

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## *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

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TRACKSIDE

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

**Traffic management system**

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

ON-BOARD

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

- Safe monitoring of train movements

# ATO shortens headways by homogeneous driving and later braking and thus increases line capacity

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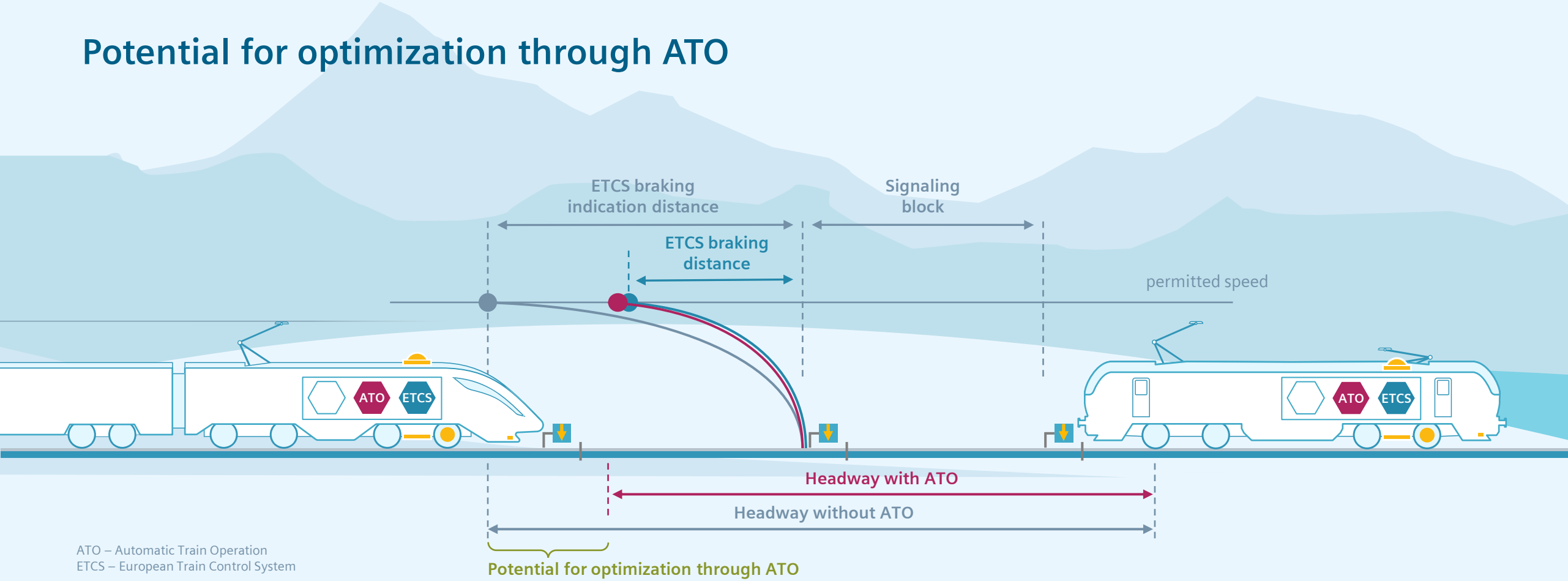
## Potential for optimization through ATO




ATO – Automatic Train Operation
ETCS – European Train Control System

# ATO shortens headways by later braking
# ATO and ETCS Baseline 3 braking curves

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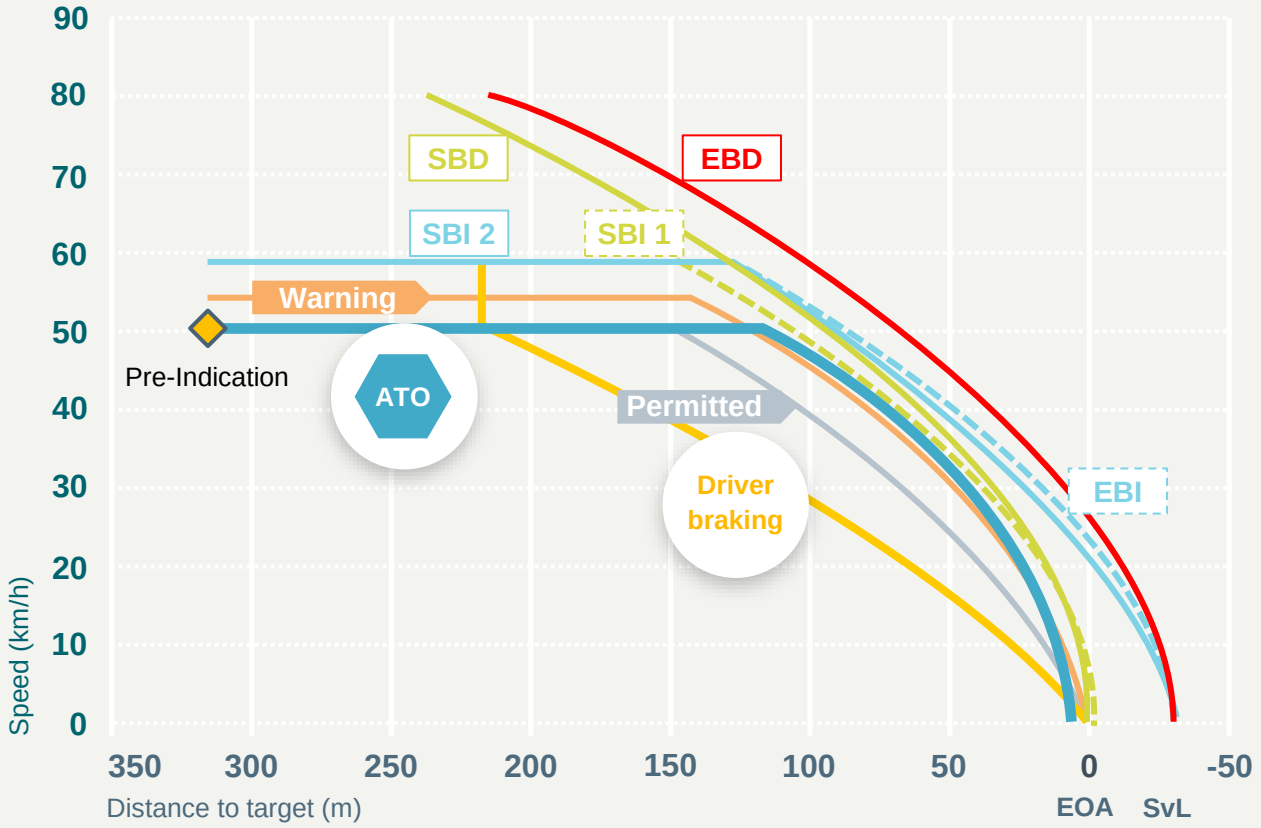



**ATO also allows for shorter headways for high-speed applications**


Normal ETCS indications

ETCS pre-indication
Driver should get ready to brake

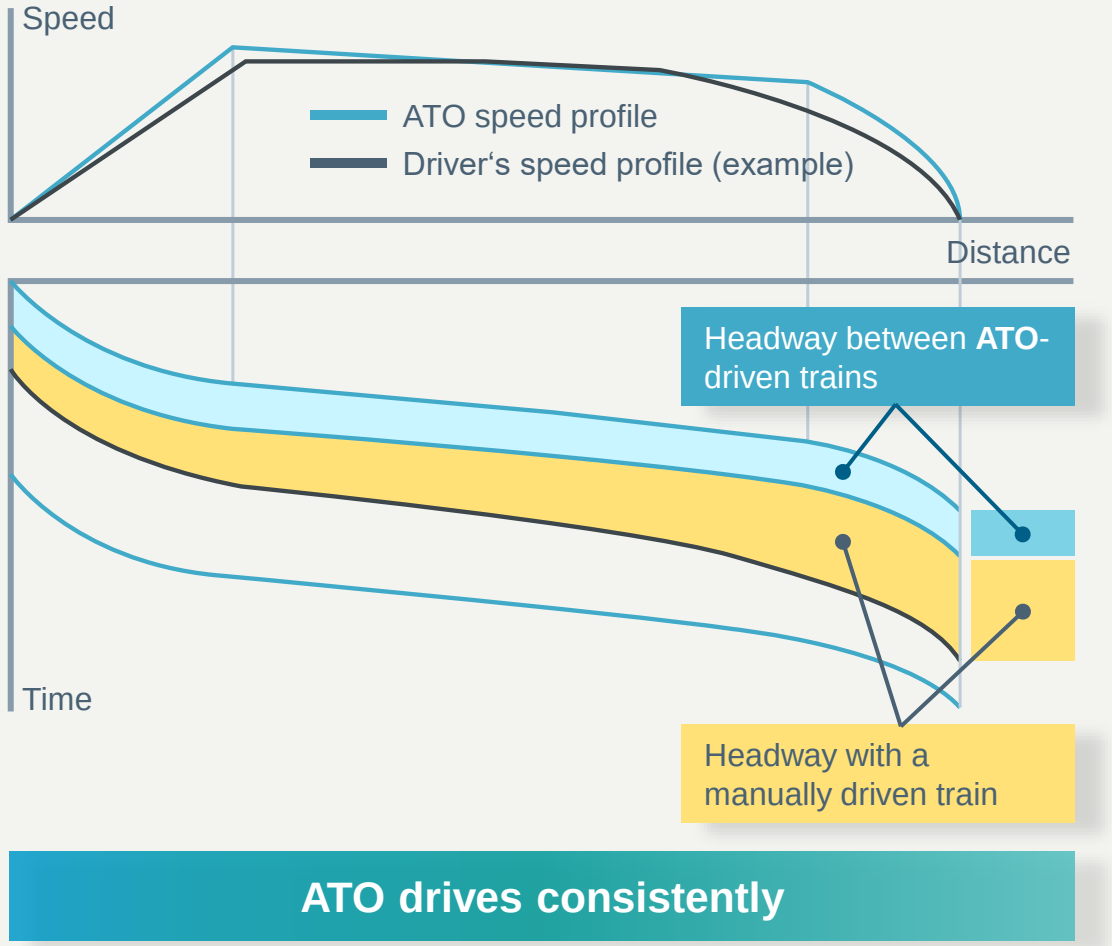
ETCS indication
Driver should start braking

ETCS warning
Driver must brake

ETCS brake application

- **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

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# Introduction strategies

# Favorable conditions for introduction of ATO systems in mainline rail services

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**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

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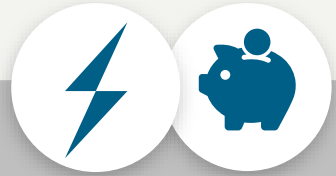
## Rapid transit and regional rail services

- 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)

**Optimized traffic flow for maximum possible throughput with high timetable stability**

## 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



**Reduction in energy consumption and mechanical wear and tear**

# Steps in implementation towards highly automatic train operation according to GoA 2

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| Technical measures | Impact on ATO system |
|---|---|
| **Enhancement of traffic management system** | |
| • Utilization of the timetable as a key element for the execution of operations | • Availability of necessary timetable data based on current operations |
| • Upgrading with intelligent dispatching functions (forecasting, conflict detection and conflict resolution) | • Optimum train control even in unplanned exceptional operating situations |
| **Introduction of trackside ATO (ATO-TS)** | |
| • Acquisition of static infrastructure data with detailed track information | • Availability of static infrastructure data on ATO-TS to generate segment profiles |
| • Provision of a connection to the existing traffic management system (via X2Rail-131, if necessary with specific adapters) | • Availability of up-to-the-minute timetable data on ATO-TS to generate journey profiles |
| • Usage of the interface to on-board ATO (ATO-OB) according to Subset-126 | • Provision of journey profiles and segment profiles to on-board ATO (ATO-OB) |
| **Introduction of on-board ATO (ATO-OB)** | |
| • Equipment of vehicles with ATO-OB (and ETCS-OB) according to “ATO over ETCS” | • Calculation of optimum speed profiles and control of the vehicle’s traction and braking system |

# Integration of all vehicles into automation strategy for network-wide optimization of rail services

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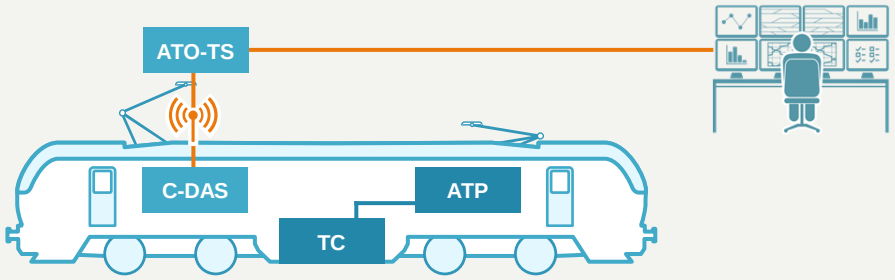
## Connected Driver Advisory System (C-DAS)

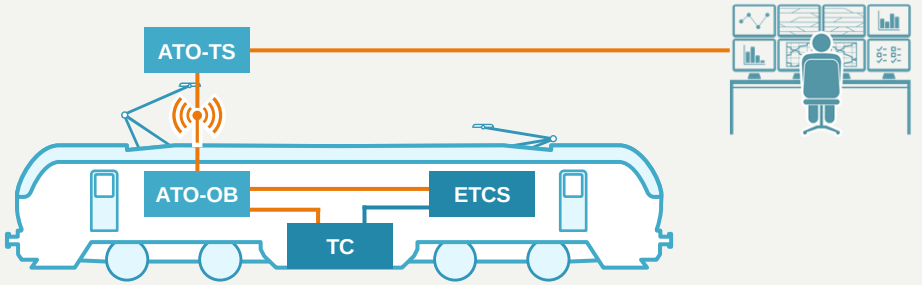
- Continuous connection to the operations control system to provide up-to-the-minute timetable data
- Calculation of the optimum speed profile based on the current track and timetable data on the ATO on-board unit
- Display of driving recommendations on the driver HMI based on the optimum speed profile
- Driver drives the train manually under consideration of the driving recommendations




- Opportunity for entry into later automatic train operation
- Integration of non-automatable vehicles into a network-wide automation strategy

## Connected Automated Train Operation (GoA 2)

- Control of the vehicle's traction and braking system based on the optimum speed profile
- Train runs automatically in adherence to the permitted speeds and safely monitored by ETCS




- Highly automatic train operation with maximum possible operational benefit for network-wide optimization
- Basis for fully automatic train operation in line with GoA 3/4

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# Outlook

# Towards fully automatic train operation in line with GoA 3/4 via organizational and technical expansions

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MindSphere for extended data analysis…

MindSphere

…and to provide additional services

- 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)

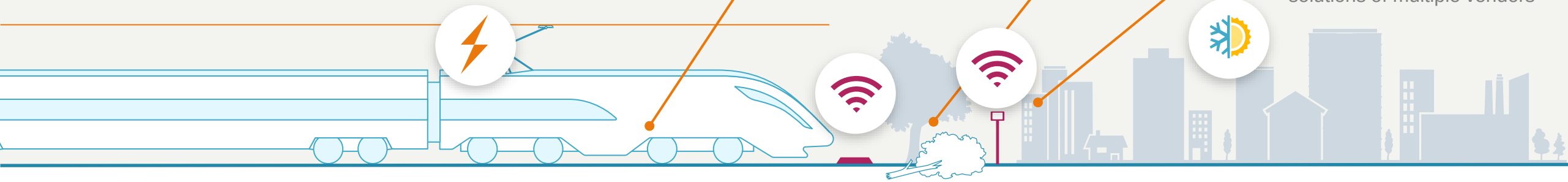
**Various operators**
for infrastructure and vehicles

**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



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# References

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

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***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.***

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

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

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

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

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

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

# Thameslink

## First commercial ATO application in mainline rail services with ETCS

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***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“

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***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

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***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

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- 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

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***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

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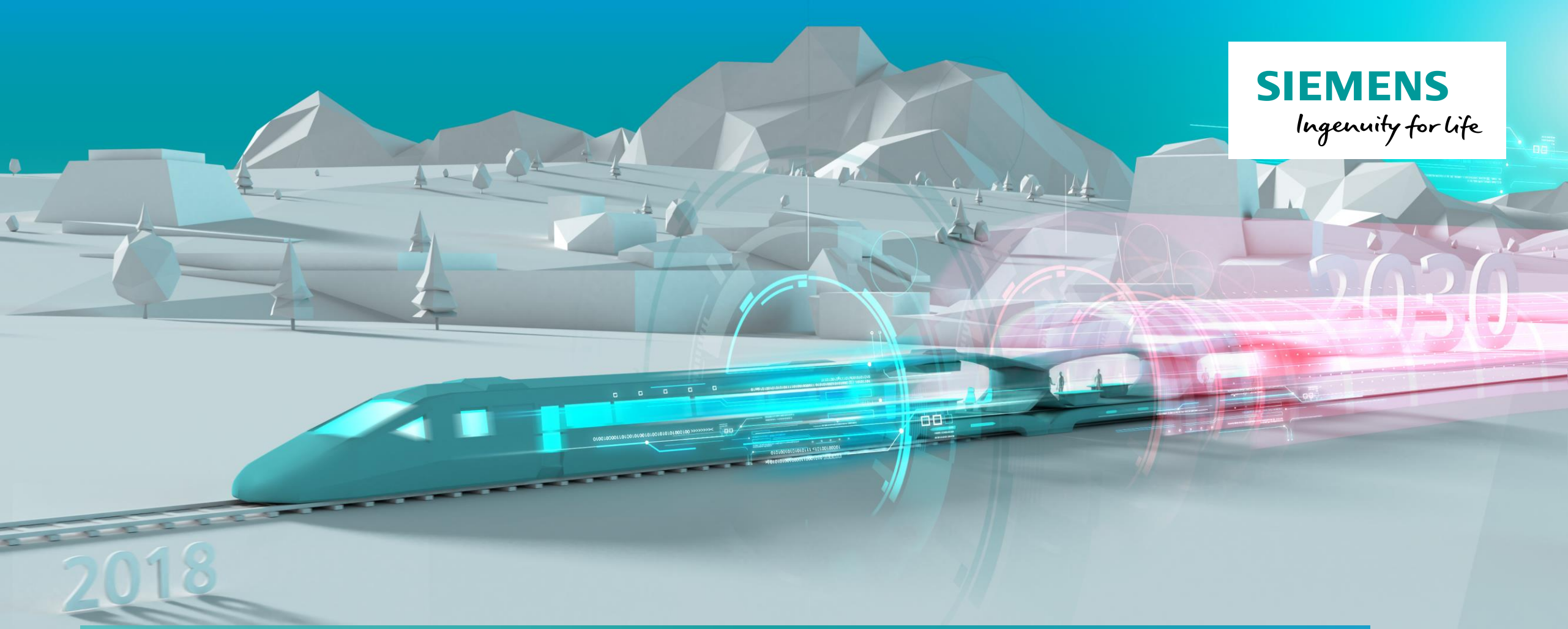
***World's first demonstration project for autonomous tram in real-life road traffic***

- 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

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