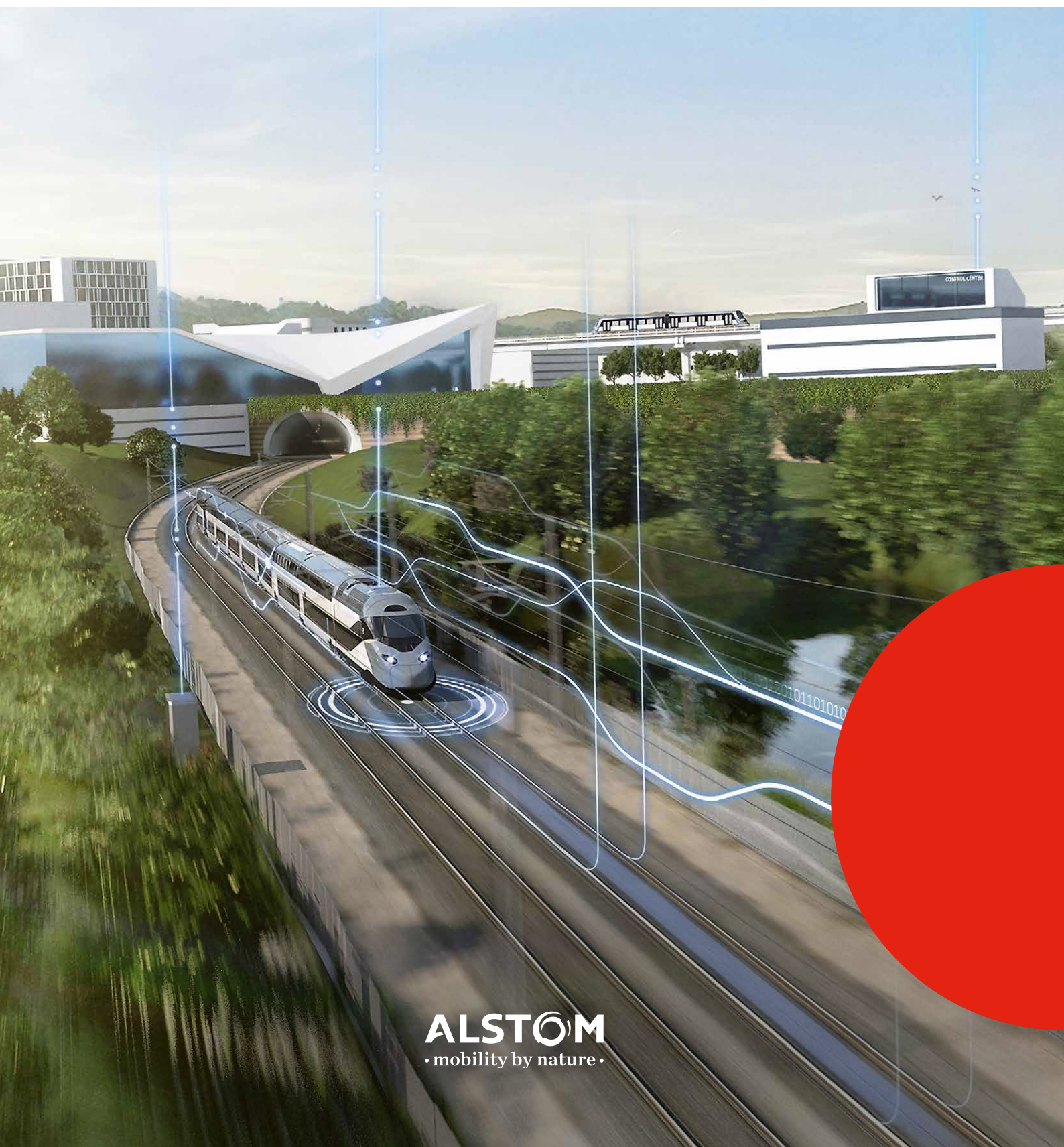


# ONBOARD GOES DIGITAL

Retrofitting trains for  
tomorrow's digital rail



**ALSTOM**  
• mobility by nature •

# Digitale Schiene Deutschland: digitisation on track with Alstom ETCS

The European Train Control System (ETCS) facilitates rail traffic across borders. Digital rail network technology ensures true interoperability and paves the way to automatic train operation. ETCS eliminates the need for trackside signals, increases speed, and reduces maintenance costs – all while maintaining the highest level of safety.

Traffic volumes are continuously growing, and rail transport is becoming increasingly international. To meet these challenges safely, Germany's outdated signalling technology is undergoing modernisation. Tracks and vehicles are being retrofitted step by step.



The German network will be upgraded to ETCS Level 2 without signals by 2035.

Digital interlocking and trackside ETCS will replace the current national systems. Germany alone will see the conversion of 35,000 km of track, distributed over 157 network districts.

In the long term, there will be no duplication of trackside equipment with old and new systems. During the migration period, however, all trains will therefore need several control systems on board: the national PZB or LZB systems and the European ETCS as signalling technology for digital rail operations and European traffic.

#### Line network

- As of 2021: 406 km ETCS Level 1 LS or Level 2
- Planned by 2035: 33,300 km ETCS Level 2



Initially, vehicles will be equipped with the ETCS European signalling system.

In order to benefit from the advantages of Digitale Schiene Deutschland (DSD) on the upgraded lines, a large part of the approx. 15,000 existing vehicles must be equipped with ETCS within the next 10 years.

The new ETCS systems will be installed on the vehicles in addition to the existing national systems. This will ensure smooth operation when the line is converted.

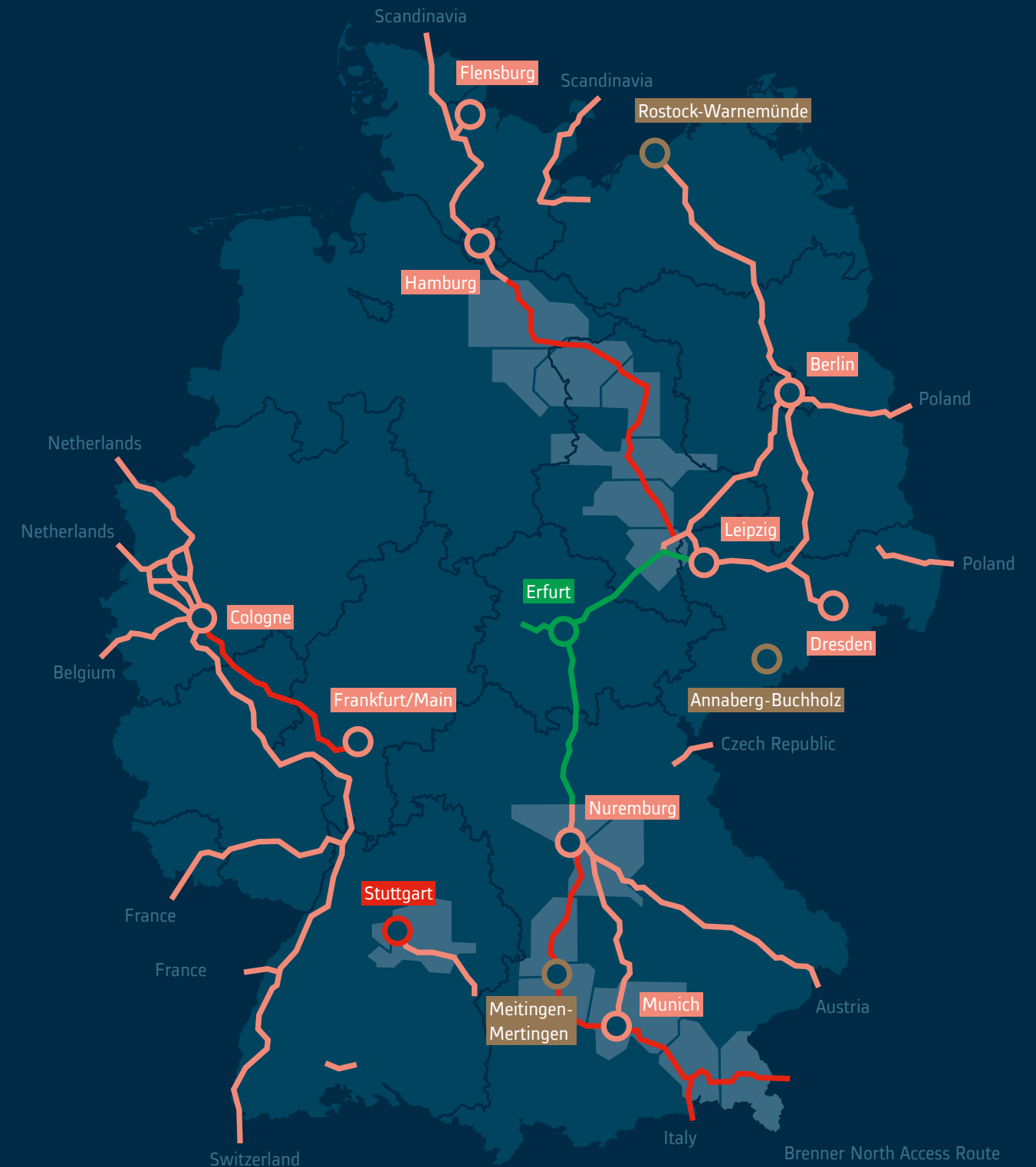
#### Vehicles

- As of end of 2021: 2,000 vehicles ETCS Baseline 2 or Baseline 3
- Planned by 2035: 13,000 vehicles ETCS Baseline 3

27

Alstom has delivered innovative, high-performance solutions and been closely involved in the development of the latest European standards for over 27 years.

## LINE PLANNING



- Planned extensions (by 2025)
  - Existing ETCS lines
  - Planned ETCS lines (by 2030)
  - Network districts to be equipped
  - Planned digital signal boxes
- Source: Digital Rail Germany



# With the ETCS onboard system, digital rail innovations are automatically included

With ETCS onboard, high-performance components are integrated in the vehicles. Alstom's proven ETCS control computer, the European Vital Computer (EVC), is where all connections to odometry, radio, and the interface in the driver's cab come together. Alstom's current EVC version meets all the requirements of Digitale Schiene Deutschland (DSD), and is ready for Automatic Train Operation (ATO) and future technologies such as FRMCS.

With ETCS Level 2, trains can operate at speeds of up to 350 km/h without fixed signals. In addition, interoperable traffic and ATO are possible. ETCS is the basis of future innovation in the field of train control.

## Integration of ETCS and Train Control Management System (TCMS).

The Train Control Management System (TCMS) controls all functional processes in the train. It interacts with the ETCS computer and visualises the current operating states of the door control, air conditioning, drive control, brake control, and other systems on the driver displays.

As different manufacturers' TCMS systems differ in terms of hardware and communication signals, ETCS integration must be adapted to each manufacturer's system. To this end, every change to the TCMS software is validated and documented by specialist experts.

If changes to the TCMS are necessary, Alstom implements them according to the specifications of EN 506577.

## Benefits of ETCS

- Higher frequency, greater capacity, improved safety
- No locomotive or traction unit changes at borders
- Reduced service time and cost

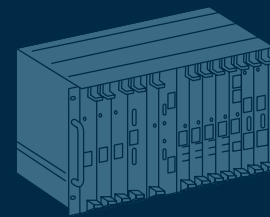
## ETCS functions

- ETCS monitors both the position and the speed of the train and thus ensures compliance with speed and distance limits
- If necessary, it triggers the brakes to prevent the train from exceeding the permissible speed and distance limits
- ETCS is scalable through levels 1, 2, and 3 to meet the needs of different routes, usage profiles and railway administrations
- Thanks to the different ETCS levels, the scope of functions can be individually adapted to the operator's needs
- Even during the long migration period, the Alstom ETCS solution ensures safe rail traffic thanks to its proven integration of the legacy systems LZB and PZB as a Class B system

# #1

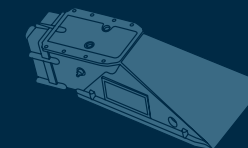
Alstom is number one – both for ETCS retrofits in the DACH region and for ETCS onboard equipment with over 19,000 units worldwide.

## EVC (European Vital Computer)



- Central ETCS onboard computer, advanced 3rd generation
- Communicates with the vehicle control system
- Processes trackside data
- Diagnostics, maintenance, and ATO as integrated components

## Radar



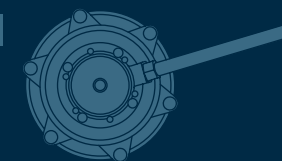
- Speed detection via the Doppler effect

## Radio antennas (GSM-R/GNSS/GPRS/FRMCS)



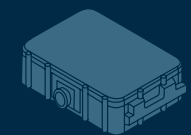
- ETCS data radio
- GNSS reception (precise combination of GPS reception and other positioning systems)
- Receives trackside data
- Transmits vehicle position to the Radio Block Centre (RBC)

## Wheel sensor



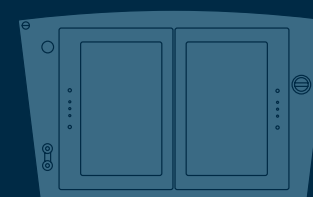
- Determination of distance and speed via rotation and wheel diameter

## Eurobalise antenna



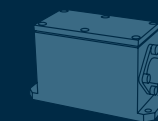
- Exchange of telegrams with trackside balises
- Transmits information to the EVC for processing

## DMI (Driver Machine Interface)



- Input and control panel in the driver's cab
- Redundant 2x8-inch equipment
- Display with all important information for drivers
- Operator input (train data)

## Acceleration sensor

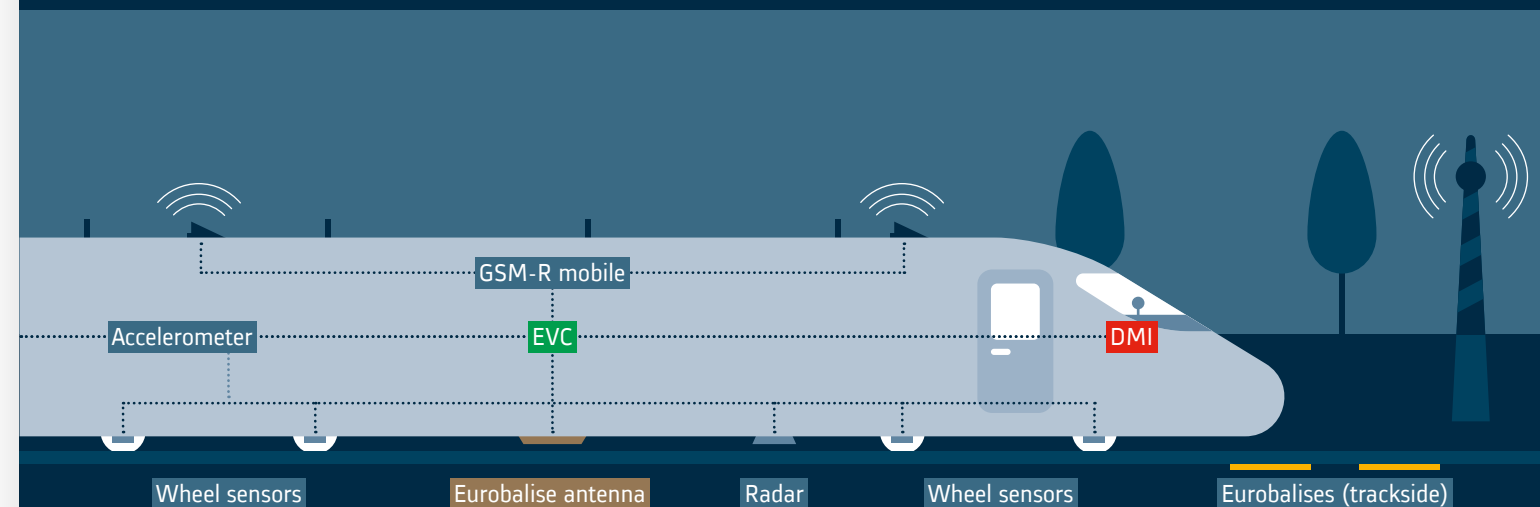


- Detects movement of the vehicle even when skidding and sliding

## Optical sensors



- Speed is determined on the basis of an optical system including a photo receiver



# Today, many trains are already running reliably with modern ETCS solutions from Alstom

ETCS vehicle retrofits from Alstom have proven their worth. They are scalable and can be adapted to all routes and vehicles – up to freight and high-speed traffic. Each solution is delivered by a local engineering team. To meet the full range of customer requirements and all national and cross-border deployment plans, our development sites and our first-of-class factory are fundamentally involved.

## DIGITAL NODE STUTTGART 333 VEHICLES



Two customers, two vehicle manufacturers, four series, 333 vehicles. Rollout of DSD vehicle installation including ETCS and ATO.

- 52 Talent 3 vehicles
- 155 BR 430 vehicles
- 66 Flirt 3 & XL vehicles
- 60 BR 423 vehicles
- Two customers (S-Bahn Stuttgart and SFBW)
- Cutting-edge technology thanks to the latest ETCS onboard unit (EVC-3) from Alstom
- World's first Automatic Train Operation (ATO) at GoA-2 level in commercial operation, based on ETCS and fully integrated in the ETCS hardware
- Innovation in Germany: Train Integrity Monitoring System (TIMS) and FRMCS pre-fitting in preparation for ETCS Level 3.

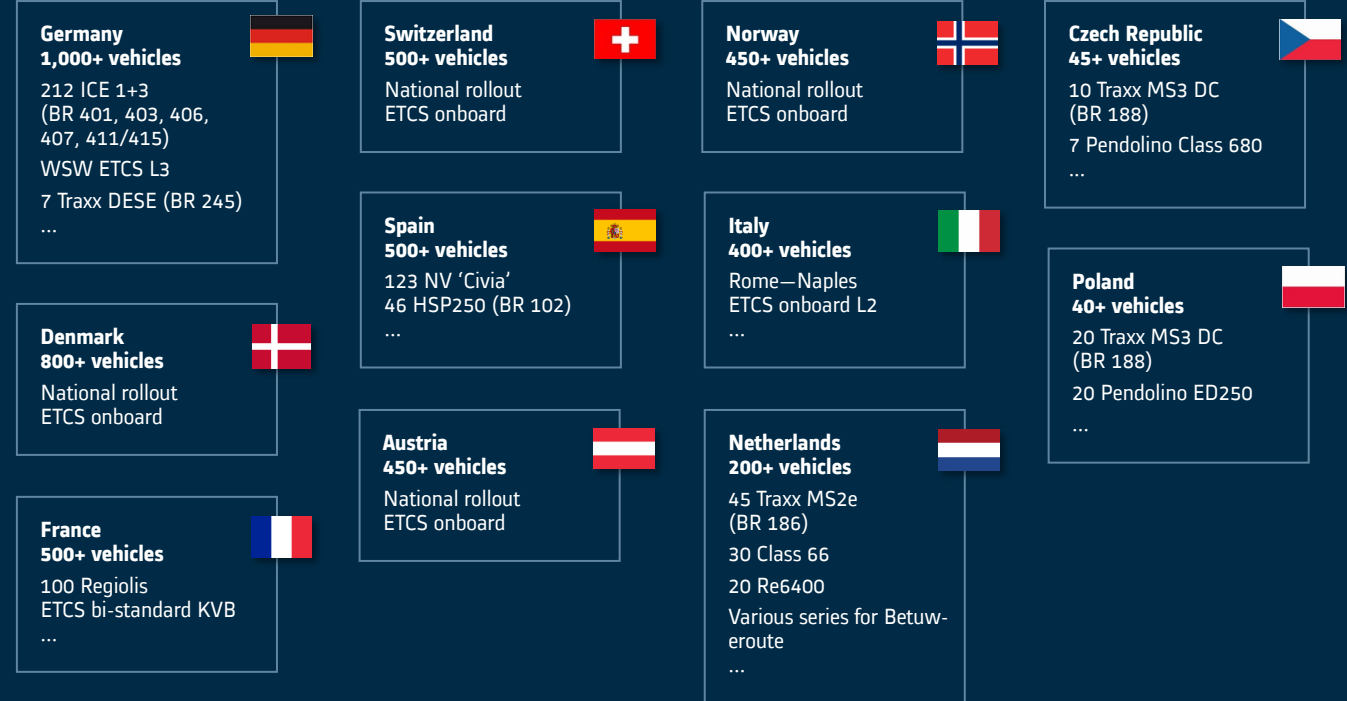
**Results**  
The Digital node Stuttgart is a lighthouse project for the introduction of digital rail in Germany.

The system was designed for high-performance operation, both trackside and onboard.

For this purpose, ATO is being used for the first time in regular operation in Germany. At the same time, the vehicles are also being modernised inside and out for passengers (redesign).



## ALSTOM IS THE MARKET LEADER FOR ETCS ONBOARD SOLUTIONS





## ÖBB ROLLOUT 450 VEHICLES



In Austria, Alstom has fine-tuned the speed and reliability of its ETCS rollout: 5 vehicles per week were converted in Linz and Vienna.

- From 2011 to 2014, 450 vehicles from six series were equipped with ETCS units
- Contract signed on 03/12/2009
- Start of operation in December 2012 with approx. 250 vehicles
- Vehicle conversion in cooperation with ÖBB Technische Services
- Conversion in 5 days per unit
- WBT (web-based training) tool as a basis for locomotive driver training
- Development of ETCS expertise for maintenance at ÖBB Technische Services

### Results

- On-time commissioning of the vehicles for the start of operation on the new lines
- On-time re-approval in 9 countries, coordinated with vehicle retrofitting
- Stable operation for 10 years
- Punctuality of vehicles in operation significantly improved (compared to PZB) due to elimination of operating errors
- All reliability figures agreed for ETCS availability have been exceeded

## DB LONG DISTANCE: 212 ICE TRAINS



Integration in existing vehicle technology, validation, and approval. Sharing of specifications via design reviews.

- 212 trains with 424 installed ETCS onboard units
- Conversion of almost all series in the ICE fleet: 401, 403, 406, 407, 411/415
- Implementation of European approval requirements for cross-border operation to Belgium, Austria, France, and the Netherlands
- Signing of contracts for the 5 series 2008-2019
- Start of operations 2009-2018

### Results

- Rapid conversion times of one vehicle per week
- Extensive training of DB drivers and DB maintenance staff in the use of the new ETCS train control technology on lines such as Berlin-Munich
- Reduced journey times: e.g. Berlin-Munich in less than four hours



## ICE TRAINS: CONVERTED ON TIME



# At the forefront of digital signalling technology in Germany, Austria, and Switzerland

Alstom is a global player with a long tradition in the DACH region. Our products get people and goods moving – in cities, on regional or long-distance transport. Our position as market leader for ETCS onboard equipment is supported by a strong network of sites located very near our customers.

Our Digital & Integrated Systems division covers all solutions for onboard and trackside signalling, as well as a comprehensive portfolio of services.

The reorganisation of the Alstom Group in Germany following the successful integration of Bombardier has made us the largest supplier of railway systems in the DACH region. We are present in every region and would be happy to advise you on tailor-made solutions for your projects.

**Berlin**

- DACH headquarters
- 150 employees
- Digital train control (ETCS & ATO)
- Customer support and sales

**Hennigsdorf**

- 2,100 employees
- First-of-class factory for EMUs

**Braunschweig**

- 100 employees
- Engineering and project support for digital Interlocking
- Control and signalling technology

**Kassel**

- 700 employees
- First-of-class factory for locomotives

**Mannheim**

- 900 employees
- Development site for TCMS and Class B systems

**Zürich and Neuhausen**

- 400 employees
- Innovation centre for train automation and green mobility
- Drive and signalling technology

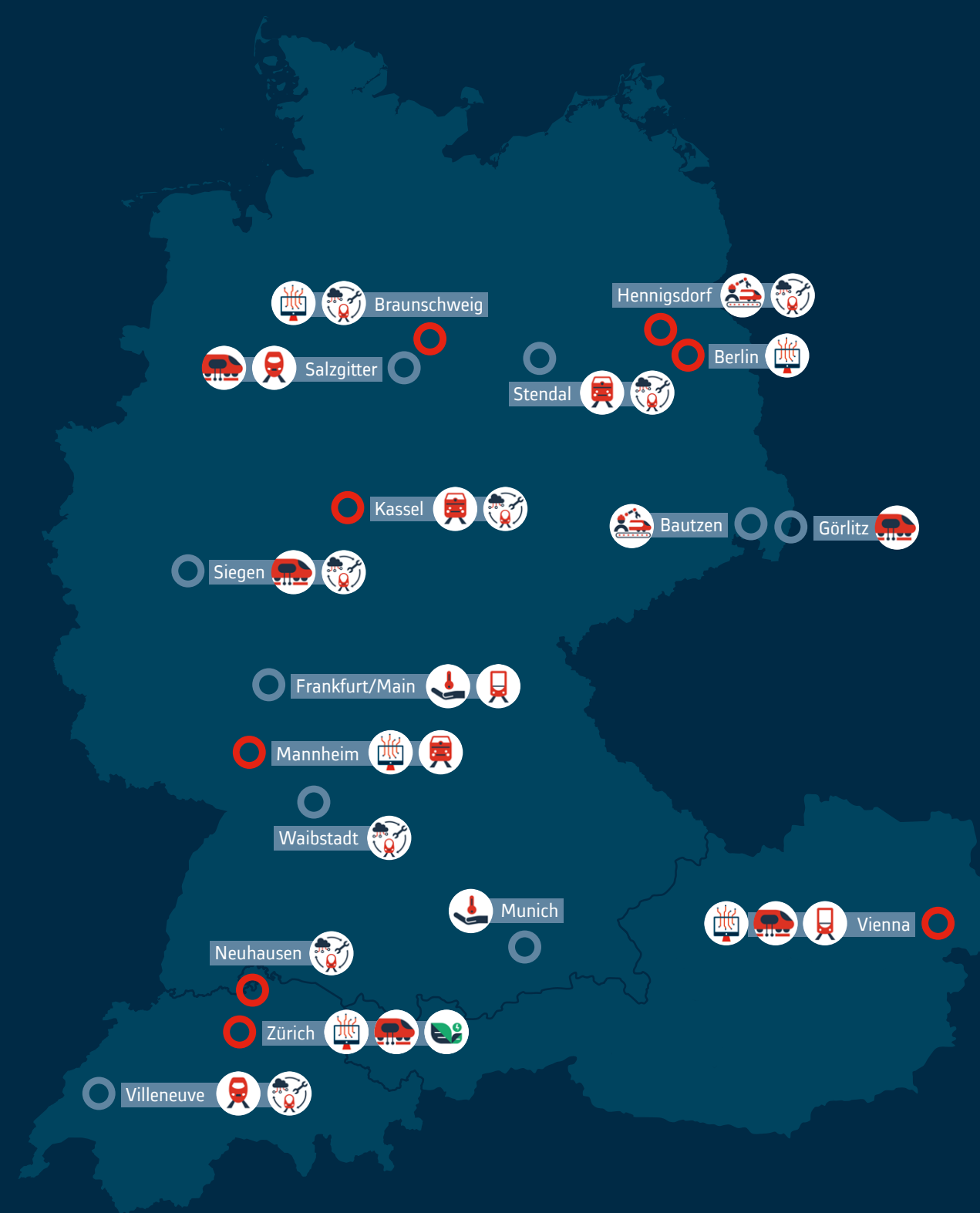
**Vienna**

- 700 employees
- Project support for signalling technology



7,480

In Europe, 7,480 specialists work in Alstom's Digital & Integrated Systems division, with over 13,000 worldwide.



Alstom develops and supplies digital mobility solutions that utilise the latest technology

- Service
- Signalling technology
- Components
- Mainline
- LRV
- Locomotives
- Works
- Systems
- Hydrogen



# When retrofitting for ETCS, quality and flexibility are our best arguments

When it comes to retrofitting vehicles, you benefit from our unique expertise. Alstom plans and schedules the conversion exactly according to your requirements. From the engineering of prototypes in the first-of-class process to fleet conversion, you're on the safe side thanks to our flexibility and experience in all phases of the ETCS retrofit.

Operators need an interoperable ETCS solution that offers performance and reliability for a wide range of different network operation requirements.

A world leader in ETCS rollout, Alstom is successfully implementing the latest Baseline 3 Release 2, driving the development of new versions, and engaging with Europe's Rail on future releases.

Alstom's ETCS solutions offer optimal efficiency and a high level of safety.

Our onboard ETCS solution, with more than 19,000 onboard units in over 200 vehicle types worldwide, has been proven in operation with the new Baseline 3 standard and is ready for installation and integration on all types of new trains. Alstom is the world leader in ETCS retrofitting.

All vehicle types, project sizes, and application profiles (national, international, local) can be served with this solution from Alstom.

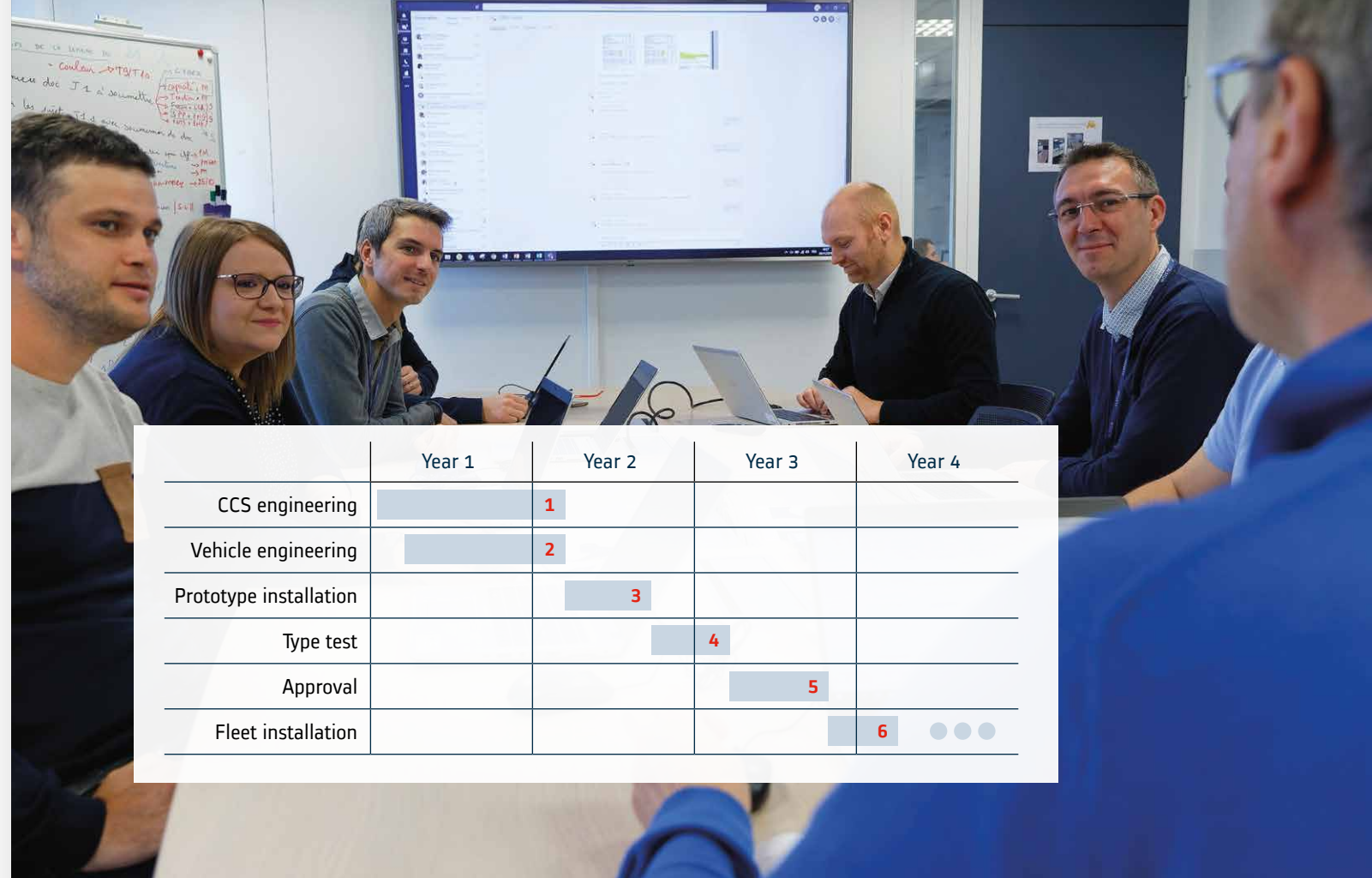
Through its standardised interface, Alstom's on-board ETCS solution is compatible with a wide range of national train control systems. The ETCS onboard offers several specific transmission modules (STMs) for compatibility with national systems.

Our expertise in ETCS solutions extends far beyond Europe, with the first implementation of ETCS in Australia and the deployment of over 600 trains in Norway, Mexico, Morocco, Algeria, China, India, and Turkey.

### First-of-class factory

Obtaining approval for the fleet to be retrofitted plays a key role in any retrofit project. Alstom is the only ETCS manufacturer with a bundled first-of-class approach to efficiently perform the retrofit.

Depending on the vehicle type, Alstom bundles all expertise in mechanical integration, safety, engineering, and testing at specific sites.



	Year 1	Year 2	Year 3	Year 4
CCS engineering		1		
Vehicle engineering		2		
Prototype installation		3		
Type test			4	
Approval			5	
Fleet installation				6

## 1 FIRST-OF-CLASS SYSTEM ENGINEERING

Determination of the components required for control, command, and signalling (CCS) to achieve the customer solution.

- Development of the system solution, taking into account European and national specifications as well as contractually relevant customer requirements
- Configuration of the ETCS system and the national train control systems based on the project requirements
- Procurement of the required system components for tests and the first-of-class vehicle
- Testing of the vehicle-specific ETCS onboard units
- Preparation of the documentation for verification

## 2 FIRST-OF-CLASS MECHANICAL ENGINEERING

Planning of the technical and space requirements for installation of the components in the first customer vehicle while maintaining all existing vehicle functions.

- Evaluation and as-built documentation of the vehicles as a basis for engineering
- Planning of the mechanical and electrical conversions and installations on the vehicle
- Preparation of the conversion documentation (circuit diagrams, wiring lists, drawings, BOMs, conversion instructions, etc.)
- Preparation of documentation for verification of vehicle modifications (e.g. statics and strength, fire and smoke, electromagnetic compatibility, calculation of vehicle construction gauge)
- Calculation of weight and energy consumption performance

## 3 INSTALLATION AND COMMISSIONING

Installation, testing, and commissioning of the required ETCS equipment in the first-of-class vehicle. The customer is free to choose the location and team for the vehicle retrofit – including the appropriate Alstom industrial site.

- Maximum installation quality thanks to Alstom's experience as a vehicle manufacturer and in the execution of retrofits
- Our specialists carry out the installation themselves or assist your service personnel during installation
- Quality assurance during installation enables the installation areas concerned to be as good as new
- Preparation of installation documentation and updating of as-built documentation
- Even the first-of-class vehicle is covered by the warranty

# 120

There are currently 120 ETCS projects under Alstom management.

# Freedom of choice when it comes to infrastructure and the installation team

Have space in your workshop? Would you like to work with an external service partner? Our experts will support you at every stage of the project. Whether it's for a first-of-class vehicle or serial installation, you choose the location and team, we ensure a smooth process. Of course, we also take care of the complete vehicle conversion – all-inclusive.

## 4 FIRST-OF-CLASS TESTING

Functional testing of the installed components with ETCS tests and static tests, as well as dynamic tests at low speed.

- On the first-of-class vehicle, in-service tests validate whether the installed systems comply with the installation specifications and are correctly connected to the train interfaces
- GSM-R integration tests validate the interaction between the GSM-R radio equipment and the GSM-R target network
- Odometry performance tests validate the performance of the ETCS systems in regular and degraded situations
- Electromagnetic tests validate the reception of the ETCS balise telegrams by the Eurobalise antennas
- General functional tests validate in a real environment whether all customer requirements are correctly implemented
- All tests are extensively documented

## 5 FIRST-OF-CLASS APPROVAL

Vehicle approval for ETCS and the previous signalling technology through the precise documentation of all modifications to the vehicle.

- Accompanying all the phases specified above, verifications, tests, expert opinions, approvals, etc. are prepared in accordance with the 4th Railway Package and national regulations in order to obtain vehicle type approval
- During certification, the focus is on the modified subsystems of the vehicle with the aim of demonstrating no retroactive effect on the existing system

## 6 FLEET INSTALLATION AND APPROVAL

Commissioning of the first-of-class vehicle and start of the modification of further vehicles at the customer's site or at an Alstom plant.

- Fleet vehicles are equipped in conformity with the first-of-class prototype
- Ideally, several fleet vehicles are equipped at the same time to minimise downtimes
- European legislation allows up to four weeks for obtaining 'Conformity to Type'. Thanks to high-quality dossiers, Alstom usually achieves this much faster.
- Fleet installation can be carried out by Alstom specialists or by the customer's trained service personnel
- The conversions can be carried out at Alstom or at a customer site



### All-inclusive at the Alstom site

- Full use of Alstom infrastructure
- Service provided by Alstom employees and workshop, for example in Braunschweig or Hennigsdorf
- Provision of tools and installation materials

### At the customer's site

- The customer's infrastructure and workshop space is used
- If requested: service by Alstom employees

### At third party sites

- Site commissioned by the customer or Alstom
- Service by external employees

## IMPLEMENTATION EXAMPLES

### BR 403 in Nuremberg

- Prototype: at the customer's site with employees of the customer
- Fleet installation: at the customer's site with employees of the customer

### BR 401 in Hamburg

- Prototype: at the customer's site with Alstom employees
- Fleet installation: at the customer's site with Alstom employees

### BR 407 in Salzgitter

- Prototype: at the Alstom site with Alstom employees
- Fleet installation: at the Alstom site with Alstom employees



# Automatic train operation has begun. Get on board – with Alstom!

Automatic train operation (ATO) is a key driver in the railway industry. On the Digital Node Stuttgart project, Alstom is introducing GoA-2 ATO the first time on the S-Bahn and regional train fleet. For many years, we have been the world market leader in driverless and driver assistance technologies for metro systems. With research projects in Germany and France, we are also at the forefront of the development of highly automated systems (GoA-3 and GoA-4) in mainline railways.

As a founding member of Europe's Rail, Alstom is leading the way in highly automated train operations. Alstom's ATO solution is integrated in the ETCS hardware and requires no additional components.

ETCS ensures interoperability, guarantees safety and sustainability, while ATO ensures maximum performance through higher capacity and network optimisation. By eliminating bottlenecks and supporting environmentally friendly transport today, the perfect combination of ETCS and ATO is set to enable a significant increase in rail capacity.

# 30%

Automatic train operation increases rail capacity by up to 30% – depending on the mode of operation.

The next steps are already under way to develop our technology in open environments for trams, locomotives, and high-speed trains, bringing new benefits to operators, infrastructure managers, and passengers:

#### More capacity

- Increase in the frequency of trains and/or better catching up in the event of delays
- No more buffers for driver reaction times, best possible driving style at all times
- Stability and less dispersion in the timetable

#### Greater flexibility

- Flexible operation (real-time adjustment/smoothing of train headways)
- Cross-route train running management

#### Lower operating costs





- Reduction of energy consumption by 15% in long-distance transport and up to 45% in local transport
- Less wear and tear on trains and tracks

#### Improved passenger comfort

- Improved service quality due to higher punctuality and adherence to journey times
- Accurate stops on platforms
- Smooth braking curves at off-peak times

#### Degrees of automation

Train automation is based on different levels of automation – from GoA-0 (without automated train control) to GoA-4 (unaccompanied operation). Each level increases operators' control over their fleet while improving efficiency and performance.

Degree of automation Mode of operation	Start train	Moving and stopping	Closing doors	Operation during interruptions
 <b>GoA-1</b> Automatic train control with driver			<b>Driver</b>	
 <b>GoA-2</b> Automatic train control + automatic operation with driver				
 <b>GoA-3</b> Automatic operation, usually without driver				<b>Accompanied</b>
 <b>GoA-4</b> Unaccompanied train operation	<b>Automatic</b>			

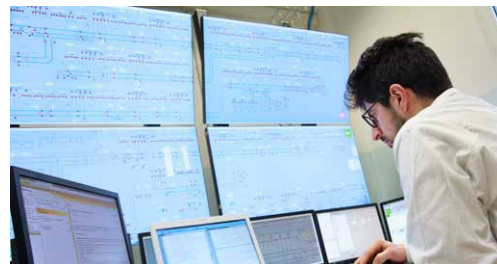




# Service and aftersales are the icing on the cake of our ETCS solutions

With tailor-made packages, we provide support exactly where you need it after a successful conversion. Whether it's predictive maintenance, training, real-time monitoring, spare parts supply, software updates, remote diagnosis, or any number of other things, our experts are available around the clock. This way, problems are detected before they occur.

## FROM REACTIVE TO PROACTIVE SUPPORT



### Product launch plan

- Responsive plan for all project stages to ensure a trouble-free launch of the ETCS
- Knowledge transfer for the independent qualification of the operator
- Step-by-step support up to regular operation

### Stages

- Design of training courses, operating concept and supply packages
- Spare parts deliveries, warranty support
- Support tailored to customer needs over the entire life cycle

### Training

- Preventive and corrective maintenance
- Regular training
- Extension to other series
- At your site, via e-learning, or at our locations

### Expertise in our service team

- Minimising the impact of failures
- Identification and analysis of technical problems
- Complex troubleshooting
- Remote or on site

### Remote fleet monitoring

- Remote diagnostics and maintenance solutions to monitor asset condition and performance
- Continuous improvement, based on experience feedback worldwide

### Software upgrades

- Retrofit with ATO or ETCS
- Adaptation of the hardware to the latest TSI versions (e.g. ETCS Data Only Radio)
- ETCS software maintenance



**Intuitive interface**  
ERP and maintenance information system



**Scalable solution**  
Expansion of the existing system and process capacity



**Real-time monitoring**  
Dashboards with current messages and events on performance



## Health Hub

**Availability**  
Continuous optimisation over the product's entire life cycle



**Permanent access – everywhere**  
Via app or web interface, online or offline, at the site or in the Cloud



**All in one system**  
Data processing for all areas involved (rolling stock, infrastructure, signalling technology)





**Contact for ETCS and ATO retrofits:**  
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