



# Systemtechnik Activity Report 2021/2022





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**DB Systemtechnik**

## Robustness and functional performance for the railway system



Deutsche Bahn is currently also in the focus of society because of the 9-euro ticket. However, many new travelers not only bring full trains, but also push the means of production in the railway sector to their limits and beyond. Today, challenges often arise at the many interfaces in the railway system.

As a railway engineering and testing service provider who has mastered vehicle, infrastructure and, above all, interface issues, DB Systemtechnik supports everyone involved in the railway sector with its know-how.

We are constantly expanding our product portfolio and consistently expanding digital solutions to promote the introduction of ETCS in Germany in particular.

This year's activity report once again gives an overview of the wide range of activities performed by DB Systemtechnik and an insight into some of the projects on which our experts are successfully working for our customers worldwide.

A handwritten signature in black ink that reads "Hans Peter Lang". The signature is written in a cursive, flowing style.

**Your Hans Peter Lang**  
Managing director  
CTO Deutsche Bahn AG

# ECM Certification DB Systemtechnik GmbH

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*„ECM certification lays the foundation for consistent and safe maintenance, which ensures safe rail operations and compliant interoperability in Europe.“*

*Erik Siegemund, ECM-Team, DB Systemtechnik*

## As of November 2021, DB Systemtechnik GmbH is ECM 1 and 2 certified in accordance with EU Regulation 2019/779.

Directive 2008/110/EC of the European Parliament and Council requires owners and keepers of rail vehicles to assign an entity in charge of maintenance (ECM) to each vehicle. The ECM is responsible for ensuring that the vehicle is in a safe operational condition and is registered as such in the European Vehicle Register.

As of 16 June 2022, all rail vehicles in the European rail sector are also subject to a certification requirement in accordance with EU Regulation 2019/779. Every ECM must provide evidence of a functioning and certified maintenance management system as of this date. The following basic principles must be arranged to increase safety and quality and to ensure that the requirements for technical interoperability are met:

- Clearly defined responsibility for maintenance
- Control of all relevant maintenance processes through a process-based maintenance management system
- Consistent and detailed requirements at the organisation
- Proof of suitability through certification

The expert team from DB Systemtechnik GmbH guides all existing and future ECMs along the path to certification and advises which steps in the certification process are important and which legal issues need to be considered.

We went through the process of becoming ECM 1 and 2 certified ourselves, earning certification in November 2021, so that we can offer our customers even better advice and assistance. This means that we are now also able to assume full ECM 1 (maintenance management) and ECM 2 (maintenance development function) responsibility for our customers.

**We are able to draw on DB Systemtechnik's extensive expertise in all aspects of vehicle and component technology and offer customers full service from a single source.**

This service is intended primarily for smaller rail companies, eliminating the need for them to set up their own maintenance management system and acquire the necessary engineering expertise themselves.

We can also take on the full ECM function by working together with partners for the fleet maintenance management function (ECM 3) and maintenance delivery function (ECM 4).



**DB Systemtechnik**  
**The reference projects**  
**2021/2022**



Photo: DB Systemtechnik/Marcel Jäckle



The (stationary) demonstrator vehicle DIRK in which the measurements in the LUQAS project were carried out.

## Investigations into air quality in rail vehicles (LUQAS)

The "Air Quality in Rail Vehicles" (LUQAS) project is a cooperative venture initiated and operated by DB AG and the German Aerospace Centre (DLR). Against the background of the current COVID-19 pandemic, the project investigated the dispersion paths of aerosol particles in the passenger area of rail vehicles. According to the scientific knowledge available up to that time, the virus was mainly transmitted via the smallest particles of fluid, which were absorbed via the mucous membranes, e.g. of the nose or mouth and possibly the eye. Proactive investigations, therefore, were to determine how aerosol particles are dispersed in the passenger area under the operational boundary conditions, what specific role the air conditioning system plays in this, and what impact, for example, the usual measures such as distance and mandatory masks have.

Extensive preliminary theoretical work was carried out in the project (e.g. definition of fleet-relevant investigation scenarios, investigation of the transferability of the results to other classes). Based on the preliminary theoretical work, an experimental and simulation specification was created as a basis

for extensive flow and dispersion measurements as well as corresponding numerical flow simulations (CFD) **in the stationary demonstrator vehicle DIRK (ICE 2 open saloon coach) and in the MEiKE environmental chamber.**

DLR was supported in the performance of the dispersion measurements. The results obtained from the project were evaluated and analysed accordingly. As a follow-up to the LUQAS project, supplementary measurements were taken, evaluated and analysed in the DIRK and in an S-Bahn vehicle in cooperation with the DLR.

The air quality studies carried out allowed the influence of the air conditioning system and various relevant parameters on the dispersion of aerosols in the passenger area of rail vehicles to be evaluated.

## Investigation of coupling processes with digital automatic couplings for freight wagons

The DAC4EU consortium led by DB AG is testing the use of the digital automatic coupling (DAC) type 4 on selected freight wagons as part of the research project "DAC Demonstrator Pilot Project for Demonstration, Testing and Approval of the Digital Automatic Coupling (DAC) for Rail Freight Transport", which is commissioned and funded by the German Federal Ministry for Digital and Transport (BMDV). The DAC should enable freight wagons, as well as their power, data and compressed-air lines, to be coupled together automatically without the need for heavy physical work.

Several coupling types (Scharfenberg, latch type, SA-3, Schwab) from different manufacturers were tested under various comparable environmental conditions.

**Reproducible and comparable ambient conditions of -25 °C to +45 °C were therefore created at DB Systemtechnik's Minden facility for climate-related functional testing of railway vehicles (MEiKE), causing the couplings to be iced up and covered with snow.**

Subsequently, it was possible to evaluate the coupling and uncoupling process with regard to unrestricted operability through cooperation with other DB Systemtechnik specialist departments.

The test results provide information about the functionality of the couplings under extreme environmental conditions. In addition, the test results provide an objective basis for comparison of the different couplings.



Figure 1: Freight wagon with DAC in the MEiKE environmental chamber during the functional tests under winter conditions.



Figure 2: DAC subjected to icing during the functional test under winter conditions.

Photos left side: Oliver Oldach  
Photo right side: Philipp Müller

## Obsolescence management for climate-control PLC

Type 620/622 multiple units of DB Regio in the Cologne diesel network are equipped with a Mitsubishi FX1s climate-control PLC (programmable logic controller). This includes software to control the preheating behaviour of the railcar. There was no longer a supply of spare parts for this system. A failure would mean that comfortable conditions could not be maintained in the passenger compartment and driver's cab. A replacement solution had to be found within the scope of continuous maintenance.

**DB Systemtechnik was therefore commissioned to deal with the obsolescence management.**

A favourable solution can be found in the successor product from Mitsubishi. The FX3s has just as many connections and almost identical dimensions, making it very easy to replace the hardware. However, this means that there is a need to create new software for this successor model. DB Systemtechnik therefore wrote new control software that had to be fully documented, evaluated and integrated.



The writing of a control software within DB Systemtechnik also requires the assessment of the influence on the climate system and its validation within tests.

The customer was able to benefit in two ways: The biggest advantage is that spare parts are now available again for the climate-control system in the train. In addition, it was possible to improve a function within the software which makes the climate system in the train more robust against small signalling failures. In this project,



## Projects at the wheel-rail test rigs in Kirchmöser

For about 10 years, the removal of series squats in Deutsche Bahn's rail network has been one of the cost drivers of track maintenance. Series squats are cracks (caused by rolling contact fatigue) under the rail running surface occurring over distances up to several kilometres. Due to their location and direction of propagation, they are often detected at a late stage, so that their removal by grinding or milling is associated with high costs due to the considerable depth of the faults. In some cases, the only thing left to do is to replace the rails.

**DB Netz AG commissioned DB Systemtechnik in 2019 to investigate the mechanisms of squat formation in order to lay the foundations for a sustainable maintenance strategy to control series squats.**

To this end, targeted tests on squat formation were already being carried out from 2020 onwards on the newly created wheel-on-rail simulation test rig B in Kirchmöser. This test rig makes it possible to simulate not only vertical and lateral forces but also longitudinal forces in the wheel-rail contact surface. It is precisely these longitudinal forces that arise in modern rail vehicles, especially when applying driving and braking forces to the wheels, that are seen as a possible cause for the development of series squats.



Within the scope of the rig tests, incipient squat cracks were initially generated reproducibly under defined loading conditions. In addition, rails ground according to different methods were analysed for their tendency to crack. As a result, it was determined that faulty grinding of the rails could be ruled out as the cause of squats.

The project also investigated the influence of the level of traction forces as well as environmental influences ("wet rail") on the development of squat cracks. As a result, no coherent picture has yet emerged. Nevertheless, the rig tests facilitate an analysis of individual factors influencing squat growth under controlled conditions, which cannot be achieved by investigations in the track.

The influence of "white etching layers" (WEL), already known from damage investigations, was confirmed as the decisive cause for the formation of squats.

These are individually occurring, strictly localised structural transformations in the contact surface of wheel and rail, which are caused by traction influences and can be intensified by the above mentioned "wet rails".

In 2022, therefore, a model for the computational prediction of the occurrence of "white layers" during the driving and braking of rail vehicles will be launched as part of a follow-up project together with VIF Graz and other partners. DB Systemtechnik's wheel-rail test rigs will also play an important role here. The model builds on the findings of previous rig tests.

## Optimisation of the test frequency of sound signalling devices at DB Regio

Residents living near stabling sidings know all about it when the sound signalling equipment (signal horn) of a train is tested early in the morning. Especially in conurbations such as Frankfurt, this almost always results in noise pollution. This test step is a fixed part of the upgrading process of the traction units and serves the purpose of safety or a general functional check. If the sound signalling device does not function or is untested, there is an obligation to reduce.

**In order to meet the challenge of maintaining the safety and functionality of the sound signalling system on the one hand and reducing the resulting noise nuisance for residents to a minimum on the other, DB Systemtechnik together with DB Regio came up with a solution.**

For this purpose, the experts first approached the problem with a statistical data analysis of a wide range of sound signal equipment data and investigated possible corrective action, e.g. by possibly reducing the quantity of faulty sound signal equipment identified during the upgrade process.

The data analysis was then extended in the next step to selected vehicle fleets and classes of DB Regio as well as covering a longer medium-term period.

This made it possible to describe the quality and quantity of the data, the number of failures for individual classes as well as regions, a derivation of the statistical statement by means of sample size and test frequency, as well as an evaluation of the size of the statistical error.

Based on these results, DB Regio is currently working on a possible adaptation of the traction unit upgrade process to spread the frequency of tests over a longer period of time.





## Accident remediation of a GRP front cab with the aid of a 3D scan

The accident remediation of rail vehicles requires expertise, selected technologies and, above all, speed so that the operator can rely upon the return of an operational vehicle as soon as possible.

**DB Systemtechnik has now demonstrated that this is also possible in the case of vehicle damage where the manufacturer's documentation is not available, using the example of a damaged glass fibre reinforced plastic (GRP) front cab.**

We find out more from Patrick Raabe, Head of Vehicle Design at DB Systemtechnik in Leipzig.

### ***Mr Raabe, why was the refurbishment of the glass fibre reinforced plastic front cab so special?***

For some classes, we do not have sufficiently detailed drawing documents that are necessary to create a renovation solution using the associated verification. And so we had no way of carrying out mechanical engineering on the basis of a 3D model and a finite element method (FEM) calculation for this accident damaged vehicle either. In these cases, the only option up to now has been to replace the entire GRP front cab with a new part, which always involves very high costs and a long procurement period.

### ***And how did you then solve the problem of the "missing vehicle documentation" and what does "reverse engineering" actually mean?***

Perhaps we should deal with reverse engineering first: this refers to the reversal of the product development process – i.e. the return of design and simulation models from physically existing components. And regarding the missing vehicle documentation: in this case, a 3D scan and ultrasound material analyses were our "tools" for obtaining a model with which it once again became clear: repair is better than replacement

### ***What happened during the 3D scan and what material analyses were carried out?***

I'd like to give a very rough outline of the work that we carried out in close cooperation with our partner, DB Fahrzeuginstandhaltung in Krefeld.

After preparatory activities such as cleaning and aligning the GRP front cab, its outer and inner contours were recorded using a 3D scanner. The CAD model was then derived and reworked so that it met all our design and simulation requirements.

However, such a scan does not yet provide any conclusions about "the inside" of the component, so we extracted all the necessary material properties and the layer structure of the GRP laminate with the help of material samples and examinations. Subsequently, the material data obtained in this way was merged with the 3D model to obtain a comprehensive simulation model.



### ***And that enabled you to answer the question "Is repairing better than replacing?"***

Yes, it did.

With the model obtained, we could in turn evaluate the corresponding load cases using the FEM and the effects of the actual damage. The result is clear: the damage can be restored with our proven methods and repairing is better than replacing, as it is much faster and cheaper.

### ***Sounds simple!***

Yes, but still exciting, because this is the first time we have used the process to this extent. This procedure is worthwhile, because the repair costs in such cases are considerably lower for the vehicle keeper than replacing the entire front cab in the event of damage.

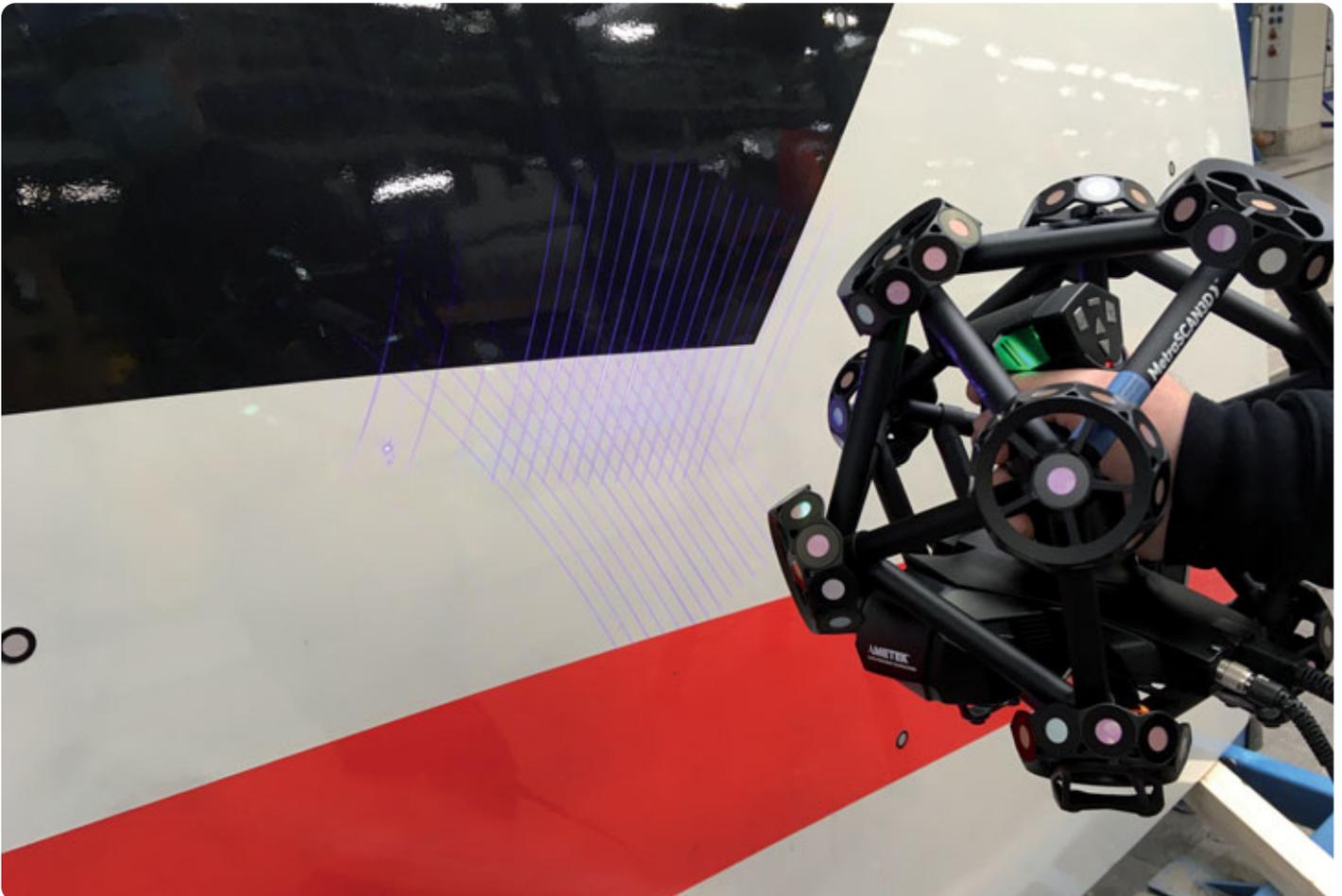
### ***Best practice?***

Definitely. In future, we will be able to use this approach for many other components for which there are insufficient drawings for engineering: in particular, GRP front cabs and front noses of other classes.

At this point, we would like to thank our specialists from the "Complete Vehicle Simulation" team and the joint accident centre that we operate together with DB Fahrzeuginstandhaltung in Krefeld for their substantial cooperation.



Photos: Patrick Raabe



## Alstom's Zefiro Express for Västtrafik Transport Authority, Sweden

Alstom is supplying fast regional trains of the type Zefiro Express to the Swedish transport authority Västtrafik.

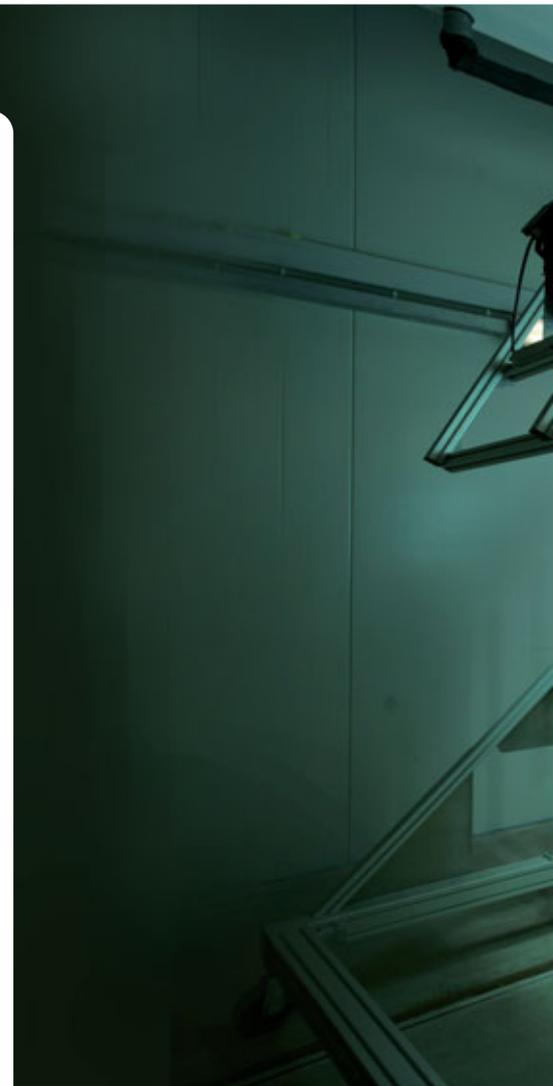
**In order to provide evidence of the air-conditioning comfort and to determine the k-value\*, corresponding tests were to be carried out on a driver's cab, an end car and an intermediate car in the MEiKE environmental chamber of DB Systemtechnik.**

After equipping the driver's cab and the passenger compartments with measuring instruments as well as equipment for simulating solar radiation and occupancy, climate tests were carried out in the driver's cab according to EN 14813 and climate tests in the passenger area according to EN13129. In addition, functional tests including snowmaking and icing were carried out. The tests were carried out at temperatures ranging from -20 °C to +40 °C.

The commissioned comfort and functional tests served as preliminary tests for the acceptance tests at the Rail Tec Arsenal vehicle test facility in Vienna. The tests enabled setting parameters to be determined for the acceptance tests, software optimisations to be carried out, and functional tests of the subsystems to be performed under extreme ambient conditions.

\* The k-value provides information on how much heat output per square metre is lost through the component at a temperature difference of 1 Kelvin between inside and outside..

Photos: Edgar Bernstein, DB AG/Hartmut-Joachim Sigrist





Driver's cab of the Zefiro Express with light panel switched on to simulate solar heating.

## Update of the manual for recording the climate functions of the TESIP

The manual for providing evidence of the climate functions of the technical safety plan (TESIP) according to the rolling stock safety directive (SIRF) requires revision due to the adaptations resulting from the 4th railway package.

**Within the framework of a working group of the Rolling Stock Steering Committee, experts from DB Systemtechnik – together with other representatives of the rail sector – have revised the manual accordingly.**

DB Systemtechnik researched relevant standards and the Technical Specifications for Interoperability (TSI) and helped to revise the manual. The working group coordinated regularly with the German Federal Railway Authority (EBA) and reported on the progress made. Subsequently, the agreed need for change was implemented.

The English translation of the manual was also prepared by DB Systemtechnik. The regular meetings and agreements within the working group enable the harmonisation of the interests of all industry representatives involved with regard to the changes to be coordinated.

Eliminating or correcting any misleading or outdated references and wording in this way generally results in better understanding. Similarly, in the area of "Functional Safety in Railway Vehicles", the relevant documents for furnishing proof of compliance with standards are now mutually compliant. The revised TESIP ultimately helps to simplify the future approval of vehicles and improves legal certainty.





## Speech intelligibility test with new Stadler trains of the Uetliberg Railway

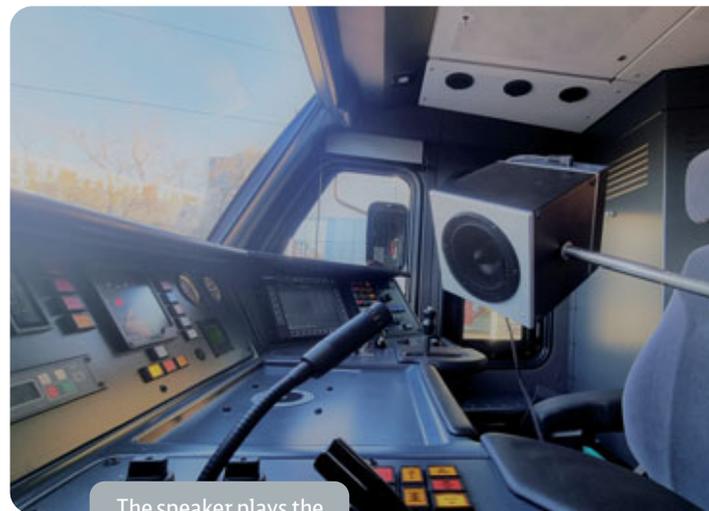
Photos: Stefan Dijkema

Since 2022, the five new Stadler Be570 multiple-unit trains of the Sihltal-Zürich-Uetliberg (SZU) railway in Switzerland have entered service on the Uetliberg and are transporting passengers up the mountain with the most beautiful view of Zurich. An important aspect in the development and approval of the vehicle from Stadler is accessibility for disabled individuals.

**DB Systemtechnik supports the approvals process with important acoustic tests for people with disabilities and limited mobility. For this purpose, excerpts of the TSI PRM 1300/2014 is applied.**

DB Systemtechnik's acoustics and vibration testing laboratory used microphones in the passenger compartment to measure the following for regulatory approval: the intelligibility of spoken information to the passenger (EN 60268-16), e.g. from the train driver, as well as announcements from the vehicle information system, and the door warning signals. For this purpose, a test signal was played into the public address system and the quality of the voice transmission was determined at various locations in the passenger area using a microphone.

Together with experts from Stadler and SZU, the DB Systemtechnik team was able to successfully carry out the measurements.



The speaker plays the test signal into the driver's microphone

Photo: DB AG/Michael Neuhaus



## Impact of high noise barriers on passenger safety

Partial or complete noise barriers are planned for the new platforms at 5 stops or stations on the upgraded Munich-Mühldorf-Freilassing (ABS 38) line. For each station, an assessment of the impact of noise barriers on the safety of passengers on the platforms when trains pass is required for planning purposes.

**The experts from DB Systemtechnik supported the DB Netz ABS 38 project with their aerodynamics expertise.**

Scientific studies using train models with similar configurations (platforms with noise barriers, measurement of train-induced airflow at different positions) were analysed by DB Systemtechnik. Earlier measurements carried out by DB Systemtechnik were used to assess the situation. The geometric conditions (length, width, spacing, etc.) on the platforms of the ABS 38 are also evaluated with regard to the influence on the train-induced airflow on the platforms. The assessment results are documented separately in a statement for each stopping point. Our analysis showed that there is no increased risk for passengers on any of the platforms.

Assessing the situation early on in the planning process contributes to the success of the project by eliminating risks to stakeholders by means of detailed documentation.



## Impact test for m<sup>2</sup>-Timber FLU (Freight Loading Unit)

The multifunctional and modular m<sup>2</sup> freight wagon offers a platform that is suitable for a range of different uses. The development of a Timber FLU facilitates the transport of stem wood.

**DB Systemtechnik was commissioned by DB Cargo to carry out a buffing impact test to test the platform in conjunction with the Timber FLU.**

The buffer forces, accelerations, speed and mechanical tension that are active during the buffing impacts are to be measured. In addition, the determination of the displacement of the stem wood load was requested after each buffing impact.

During the test, a wagon with a mass of 80 t is rolled into the stationary unbraked test object. This is made possible by the use of a hump. The test object was loaded with 55.2 t of stem wood and thus had a total weight of 80 t, including its dead weight. The impact speed was increased to 9 km/h on repeating the buffing impacts.



The mechanical tension can be recorded by the use of strain gauges. These were applied to the test object on the basis of finite element method (FEM) analyses carried out in advance.

With regard to the recorded measurement data, the maximum values that occurred during the buffing impact are considered. By analysing the buffer forces and accelerations, the measurement team obtains the load acting on the entire test object. With the help of the mechanical stress, a selective statement can be made about the loads on the individual vehicle components.

Finally, the measurement data and a test report were submitted to DB Cargo. The knowledge gained from the tests is now being used for the further development of the m<sup>2</sup> wagon and the Timber FLU.



Photos 3x: Maximilian Bechert

## Certification of MI-8 Transformer BSK brake test unit



Front view and rear view of the connected brake test unit MI-8 during tests

The electronically operating brake test unit of the type MI-8 Transformer BSK from the North Macedonian tester specialist EKA d.o.o.e.l. (Knorr-Bremse Group) was to be certified by DB Systemtechnik in the "Proof of suitability for rail use" process for the international use of braking tests on freight wagons with UIC brake systems.

**DB Systemtechnik was commissioned by Knorr-Bremse to carry out the necessary tests and, together with Knorr-Bremse, it tested various brake systems during the certification process in the period from 2019 to 2021.**

In addition to full compliance with the test specifications, special attention was paid to the reliable and unambiguous detection of faults. With the assistance of colleagues from Knorr-Bremse and EKA d.o.o.e.l., the software was corrected and optimised.

A reproducible brake test sequence and the associated result evaluation are permanently implemented in the software. The test steps and the results cannot be tampered with. Incorrect operation or misinterpretation of the results is largely ruled out. The individual test steps and their results are documented by the software as part of the test. All brake test results are automatically evaluated according to the relevant test specifications.

Within the scope of "Proof of railway suitability", the two software packages for the test specifications according to VPI 07 EMG from Br 0 to Br 3 and the UIC MB 543-1 with manual and automated test sequence were successfully confirmed and certified by DB Systemtechnik.

In the next step, the maintenance specifications according to Deutsche Bahn Guideline 900.0080 (DB Cargo) from Br 0 to Br 3 are also to be implemented. After successful certification, the brake test unit can be used in each and every respect for brake tests on freight wagons at Deutsche Bahn.



Photos 2x: Uwe Koppotsch



Test item:  
Electrical roof-mounted  
equipment of locomotives

Photos: DB Systemtechnik

Rohrmast



High-voltage generator in the loco-  
motive test shop of DB Fahrzeugin-  
standhaltung in Dessau

## High voltage calibration for the rail sector

No electric traction unit leaves the manufacturers' or maintenance workshops without insulation testing. Test voltages of up to 75 kV are used to test the roof-mounted structures of electric traction units with regard to their insulation and dielectric strength as well as the main transformers of the vehicles. The specialised companies have electrical test shops specifically for this purpose, in which the electrical parameters of the rail vehicles are determined and tested prior to delivery.

**The range of services offered by the DB Systemtechnik Calibration and Testing Centre covers all measured quantities that are important for operation and maintenance in the railway sector. A new addition to the services offered is the ability to calibrate AC voltages up to 75 kV and DC voltages up to 100 kV.**

Calibration can be carried out on site. The necessary standards are transportable. The measurement uncertainty at 75kV is approx. 680 V for calibrations in the field.

Working with such high voltages requires a great deal of specialised knowledge. It is needed, on the one hand, to carry out the calibration professionally and with minimum uncertainty of measurement and, on the other hand, to rule out any hazards during on-site tests. The measuring set-up must be implemented with corresponding care, paying particular attention to the insulation capacity of air. This depends on many factors, including the condition of the electrodes, the type of voltage (DC or AC) and the voltage shape (pulse or sinusoidal).

The reliable calibration and adjustment of the test systems used for this purpose also makes an important contribution to the safety of the customers and personnel on the rail vehicles.

## Determination of voltage for the DAC

For over a hundred years, rail freight transport has exclusively used the screw coupling, which has to be operated manually. The digital automatic coupling (DAC) is designed to automate the coupling process without the need for manpower.

Freight wagons with a digital automatic coupling require a powerful and reliable power supply for the functions of the highly automated rail freight transport of the future. The supply must meet safety requirements and a number of technical, normative and operational boundary conditions in order to be used interoperably throughout Europe. At the same time, a cost-efficient solution is sought, i.e. the smallest possible copper cross-section of the supply cables and a low number of contacts in the electric couplings.

**DB Systemtechnik, together with European partners, defined the relevant requirements as part of a joint project, the European DAC Delivery Programme (EDDP) as part of Europe's Rail, and took the lead in the selection process.**

Specialist knowledge from the field of electrical on-board power supply systems and the associated standards was brought into the selection process and a reliability assessment was prepared for different designs of the power supply.

From a large number of possible design variants, a preferred solution was finally developed that is based on existing standards and optimised for practical use in rail freight transport. With a minimum number of contacts and a small cable cross-section, high reliability and electrical performance is achieved on each wagon, with up to 50 wagons in a convoy with a length of up to 800 metres.



Photo: DB AG/Oliver Lang

## Automatic train operation with ATO and sensor technology in the heavy rail sector



Automated train operation (ATO) in the heavy rail sector requires an ATO system with a sensor system, which is to perform at least the equivalent of the operational tasks currently performed by the train driver.

The operational competence of train drivers and their senses of perception is gradually being replaced by technical solutions in "grades of automation". Depending on the grade, certain operational tasks are implemented technically and, depending on this, human senses are also being gradually replaced by suitable sensor technology.

Safe, reliable and available technical perception of the operational environment of the rail vehicle is therefore an essential requirement for automated train operation. The technical determination of the exact location of the rail vehicle (localisation) on the track is a further requirement.

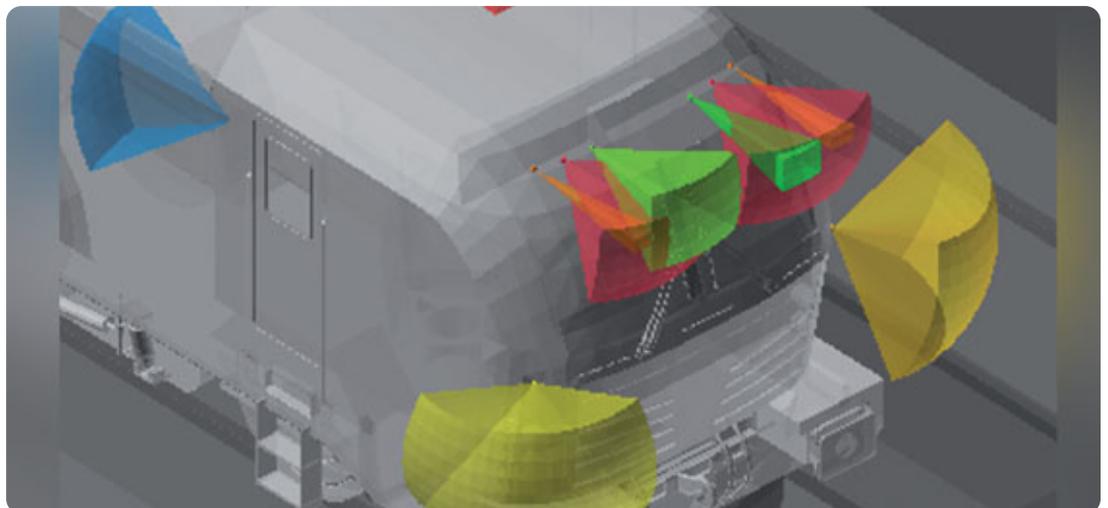
For perception and localisation, environmental data is collected via sensors, recorded and processed into high-quality information about the rail vehicle's surroundings using intelligent, software-based processes and algorithms. This information is transferred to the ATO system, where, depending on the operational situation, appropriate decisions regarding action to be taken can be made and automatically executed.

Data acquisition and information processing are implemented in a separate sensor system. Development, verification and validation of such software-based sensor systems require test and training data. Extensive data sets are also needed for furnishing proof of compliance with standards regarding the functional safety of such systems.

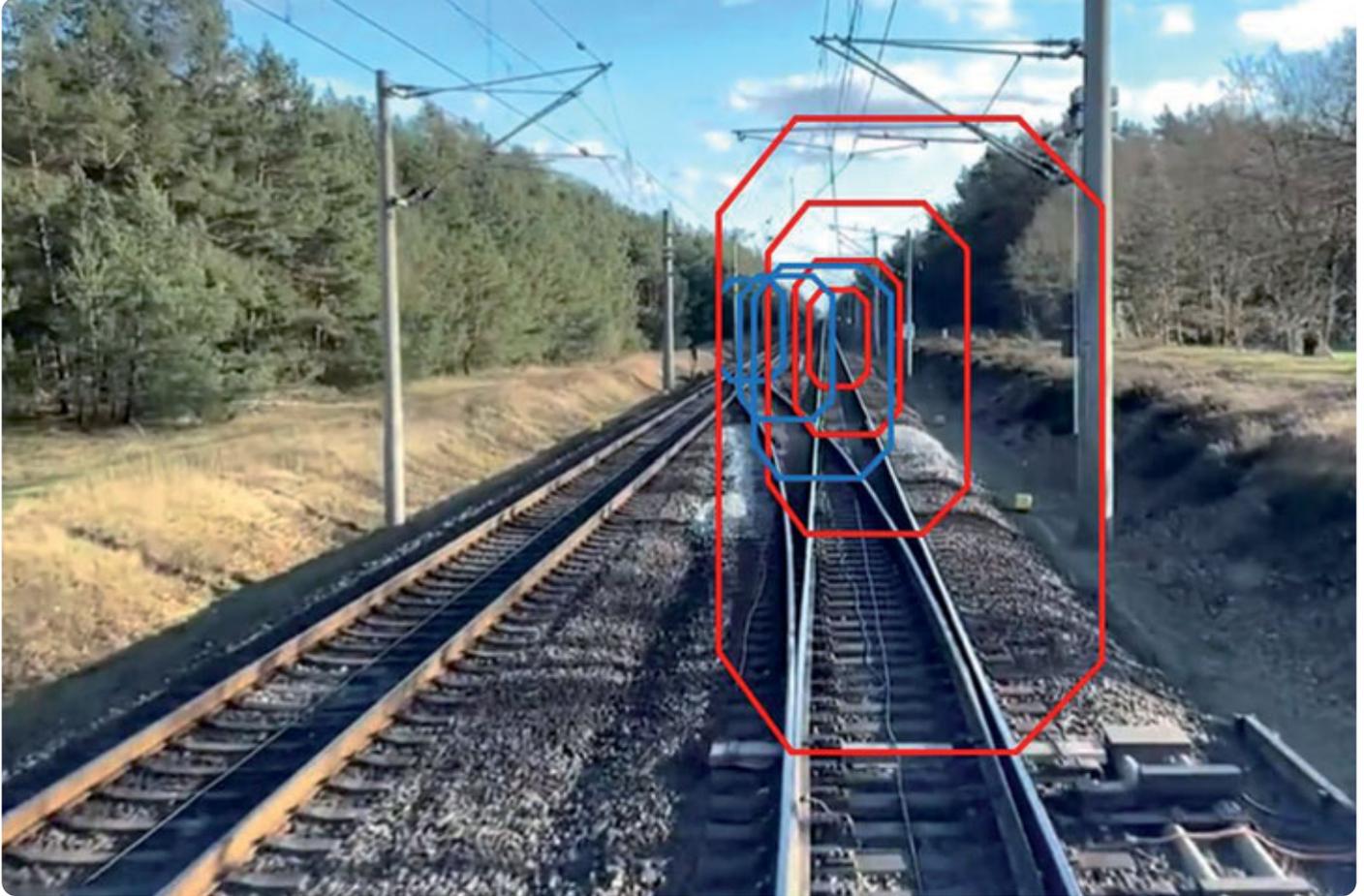
**Against this background, the German Centre for Rail Transport Research commissioned DB Systemtechnik to undertake the study: "Sensor technology as a technical requirement for ATO functions".**

DB Systemtechnik had worked on the research contract with two external project partners: the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation (IOSB) and the Institute of Industrial Information Technology at the Ostwestfalen-Lippe University of Applied Sciences (TH OWL).

The objective was the specification of a measurement system on the vehicle side, the later application of which will enable real test and training data to be collected from railway operations for the development and testing (verification, validation) of sensor systems. As a generally applicable platform for data collection (acquisition, recording and provision), the measurement system should be able to record real data from the operational environment in order to make it available to current and future development projects for sensor systems.



Photos/illustration: DB AG, DB Systemtechnik



One challenge was to define an approach to the solution that was as universal as possible so that suitable test and training data could be generated from the data that can be collected.

In technical terms, the measuring system must at least be capable of emulating the human perception of a train driver. The premise was the 1-to-1 replacement of human perception by the measurement system.

This objective is all the more necessary because a suitably sufficient method of equipping rail vehicles with sensor technology has not yet emerged from the diverse developments in rail and road transport.

One essential result is an overview of sensor systems available today for automatic train operation. The solutions available today were analysed and evaluated with regard to their state of development, market availability and suitability for the heavy rail sector of the rail system.

In addition, the feasibility of ATO solutions as a result of current and foreseeable sensor systems was included in this assessment. A conclusion showed which sensor and ATO solutions available today are suitable for automatic train operation and which technical requirements have not yet been met.

For the analytical consideration of available sensor systems, it was necessary to work out the essential characteristics of the current, conventional system in the context of the question. From this comprehensive description, standard operational tasks capable of automation were derived for the train operation system, as well as the perception and localisation tasks for the sensor system. The results were reconciled within the framework of a survey of the sector.

In the end, a specification of the measurement system could be described, which also takes into account the conceptual adjustments derived from the results of the sector survey. The specification of the measurement system is supplemented with an allocation of practical sensor combinations to the standard tasks of a technical driving system that have been worked out. The sensors considered relevant were specified in detail and evaluated in the context of operational use cases for an automated driving system.

The research contract was fully implemented within the scheduled 6 months from the beginning of August 2021. The contact persons of the DZSF were impressed that extensive results could be produced for the complex question within this short time.



## Metrological traceability

Reprofiling of wheelsets in heavy maintenance  
Below: Metrological feedback – calibration of an underfloor wheel lathes

Maintenance for rail vehicles and infrastructure is now decentralised. Measurement data is generated during operation and maintenance. On the basis of this data, decisions are made about asset conformity, maintenance deadlines and maintenance events. The measurement data is usually generated using a variety of measurement methods and measurement systems. The data was obtained at different locations and under different climatic conditions.

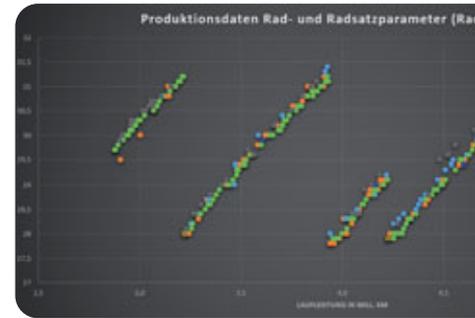
In order to optimise maintenance processes, the acquired measurement data is increasingly being transferred to databases. In this way, maintenance can be aligned with the condition of the assets.

**The requirements for ensuring that the measurement results are comparable and reliable and can be used for meaningful forecasts are established by DB Systemtechnik's calibration and testing centre.**

As an example, Figure on the right hand shows the history of the wheel flange height of a railway wheel in operation over a period of several years. The measurement data was obtained using different measurement systems at sites (STO) distributed nationwide and at different times of the year. The sudden reduction of the flange height is caused by reprofiling of the wheel, whereas the gradual increase of the wheel flange height is caused by the system-inherent wear of the running surfaces of railway wheels during operation

In order to transform the measurement process into a controlled measurement process, the characteristics, references and evaluation strategies were first standardised. The next step was to develop procedures for uniform metrological feedback. This laid the foundation for the comparability of the measurement results. During the metrological suitability tests, deviations and instabilities of the additional measuring systems were recorded and eliminated. To maintain the measuring system properties in the long term, regular calibrations are performed, as well as supplementary metrological suitability tests in the case of fundamental technical changes and metrologically relevant software up-dates.

The valid and precise measurement data enables the user to make reliable forecasts and ultimately to fully exploit the kilometric performance of the wheels.



## Battery tests during regular operation

**For many years DB Systemtechnik has been successfully providing comprehensive services for battery systems (stationary batteries as part of the uninterrupted power supply in signal boxes, traction batteries, starter batteries, on-board batteries) for battery manufacturers as well as for infrastructure and vehicle operators.**

Accredited tests are carried out in the battery laboratory in Munich as part of the approval of new battery types in accordance with EN 50547, EN 60896-11, -21, -22, and EN 60254-1. Furthermore, the services offer examinations of batteries in regular operation and in the laboratory.

In 2021, for example, two battery troughs from BR 412 and 401 multiple units were equipped with measurement technology and used in regular operation for several months. The measurements focused on the interaction of the batteries and the battery chargers with regard to the temperature-controlled charging characteristic, the distribution of the individual cell voltages and capacities as well as the influence of daily railway operations (transport of passengers, maintenance, stabling) on the service life of the batteries. The challenge here was to safely accommodate the measurement equipment for recording a large number of individual measured quantities (battery current, battery voltage, temperature and voltage of the individual cells) in the limited space within the battery container.

Within the scope of the same orders, tests were performed on the battery types used in the battery laboratory in Munich. Cells from different battery manufacturers were compared and evaluated with regard to temperature development, the dispersion of the individual cell values and the charging capacity.

The knowledge gained is used by the customer to adapt operational regulations, for fault analysis and for the evaluation of battery systems.



## Operator training wheelset lathes

The main purpose of underfloor and portal wheelset lathes is to renew the tread profiles on wheelsets as well as the surface of brake discs, inner and outer wheel rim faces, and the wear groove. Due to the safety-related aspect of this work on wheelsets (the only element of contact between vehicle and rail), the machines represent a valuable and critical production infrastructure for rail vehicle maintenance providers. From a technical viewpoint, the machines are therefore designed in such a way that they can process large volumes in a short time – but this requires appropriately qualified operators. The operators must be able to assess the machining requirements quickly and set up the system accordingly. They must also be able to intervene quickly in the machining process and efficiently ensure the quality of the results. In addition to extensive knowledge of vehicle, wheelset and machine technology, this also requires reliable mastery of the overall process: from delivery of vehicles and fine positioning to shut down, clamping, measuring and machining, right through to documentation and carrying out readjustments.

These demanding tasks require regular vocational training and professional development of the workshop staff on basic topics such as regulations, machining and wheelset theory, but also on current technical developments and practical operation of the systems engineering. The specialised knowledge of these topics and contents improves safety for the operators and thus raises the production quality of the depot performing the work, thereby also contributing to even safer rail traffic.



### Such specialist knowledge is imparted in a four-day training course developed by DB Systemtechnik.

The first two such courses took place in 2021 as a training model with a practical element between the classroom and the machine and met with a great response. In addition to acquiring and refreshing their specialist knowledge, the participants (generally staff from DB AG's maintenance depots: operators, plant managers, master craftspeople, maintenance technicians) made use of the opportunity to exchange specialist information across the boundaries of the respective company divisions and were thus able to expand their network. Following the positive experience in 2021, the plan is to offer the training regularly from 2022 and also open it up to participants from outside the DB Group.

All Photos: DB Systemtechnik



## Reference and setting wheel sets

Profile of setting wheelset and calibration of a wheelset on a large 3D measuring machine

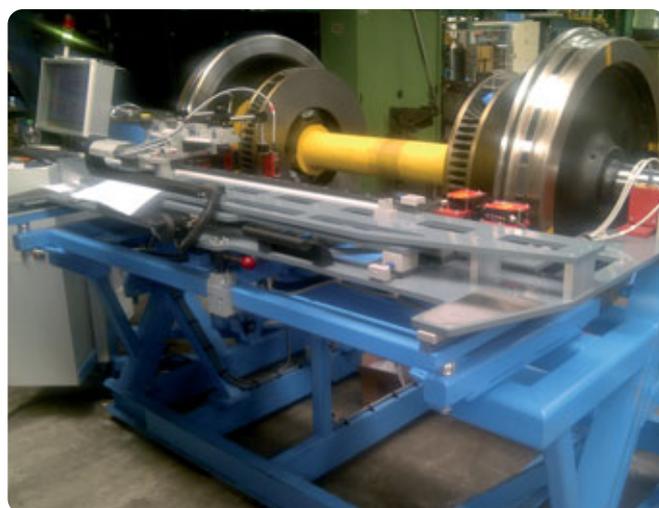
Wheelset lathes and wheelset measuring systems are used in the production, operation and repair of wheelsets. The lathes are used for the production and reprofiling of the wheelsets, while the measuring systems are used for production control and monitoring of the wheelsets in operation. Both are used to measure the geometric properties of the wheelsets and the measurement results are used for the conformity assessment of the wheelsets.

Wheelsets are measured not only when off the vehicle, e.g. during manufacture and heavy maintenance, but also when installed on rail vehicles in operation and during light maintenance. In the various installation situations, the wheelsets are subject to different forces, leading to their deformation. The challenge when measuring geometric characteristics of wheelsets is to design the measuring processes in such a way that the measurement results obtained are still comparable. This is achieved, among other things, by using reference wheelsets and setting wheelsets for metrological feedback and calibration.

**DB Systemtechnik has included these special wheelsets in its portfolio of rail depot measuring and testing equipment.**

Setting wheelsets are wheelsets used for setting and adjusting machines. These otherwise regular wheel sets are equipped with a wheel profile that deviates from the standard profile, but allows calibration and adjustment of machines with small measurement uncertainties.

Not all possible faults can be detected during testing of machines with setting wheelsets. For this reason, there are reference wheelsets with control profiles that take special account of metrological requirements. This is evident in the treatment of the basic reference elements for measurement, and of the surfaces, which can be adapted to a certain extent to the requirements of the measurement systems. Both types of wheelset are delivered fully calibrated so that they can be used immediately at the user's site.



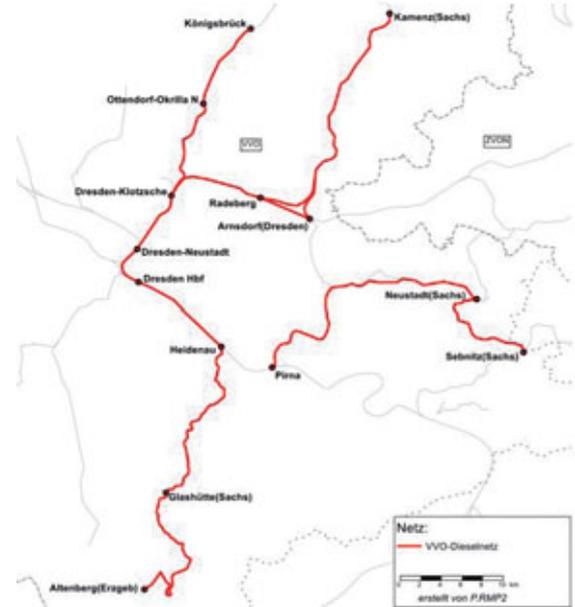
Alle Photos: DB Systemtechnik

The railway network that is to be operated with these vehicles in the future

# VT642 conversion project of the Upper Elbe Public Transport Authority

DB Regio will operate the VVO (Upper Elbe Public Transport Authority) diesel network for the next 10 years. This runs from Dresden to Kamenz and Königsbrück, through the Müglitz valley from Heidenau to Altenberg and between Pirna and Sebnitz.\* The transport contract started with the timetable change in December 2021. The redesign of the 21 vehicles of the VT642 class will be fully completed in December 2022.

DB Regio has commissioned DB Fahrzeuginstandhaltung to convert the vehicles in order to prepare them for the upcoming public service obligation contract (approx. 1.8 million km per year).



## DB Systemtechnik is responsible for the engineering and approval of the vehicles, with the latter being carried out in part by Railway Approvals Germany (RAG).

The aim is to convert the vehicles on schedule, to document the conversion and finally to provide verification in accordance with the requirements of the 4th railway package, including the corresponding approval. The redesign will adapt the existing BR 642 vehicles to the requirements of the passenger transport authority.

The vehicles are given an as-new appearance by means of thorough cleaning and repainting as well as new seat upholstery. In addition, they will be adapted to the current requirements of the TSI, the passenger information systems will be modernised and passenger comfort will be improved. The verification and approval process includes the following records, which were prepared within DB Systemtechnik by the expertise of the internal specialist departments: fire protection concept, EMC assessment, software classification, risk management, restriction assessment, various verifications of mechanical strength and approval documents.

### Mechanical and electrical engineering services in detail:

- Adaptation of the vehicle inscriptions inside and outside
- Retrofitting of thermal insulation glazing
- Replacement/installation of door opening buttons inside and outside
- Retrofitting of ramp compartment
- Adaptations to vehicle layout with new seat layout
- Retrofitting of armrests
- Retrofitting of changing table
- Retrofitting of USB sockets in the passenger area
- Retrofitting of tethers for bicycles
- Retrofitting of 21 storage surfaces (small tables)
- Retrofitting of coat hooks
- Retrofitting of two wheelchair spaces, including partition wall and intercom system
- Retrofitting of automated passenger counting system (APC)
- Replacement/installation of interior displays
- Retrofitting of the passenger information system with antenna
- Retrofitting of 17" information display
- Retrofitting of wifi

As the transitional provisions of the Implementing Regulation (EU) 2018/545 expired on 30 October 2020, this is the first redesign project to be fully processed and authorised under the 4th railway package.

Thanks to the pooled expertise within DB Systemtechnik, it was possible to provide the customer with a complete offer for vehicle engineering and approval. The client has one central contact who can be addressed on all matters relating to the redesign project and the client receives the majority of the documentation and records of the redesign from a single source. The first vehicle was handed over to the client at the beginning of February 2022, the remaining vehicles will be converted by December 2022.

\*Source: regional.bahn.de

## A new wheelchair lift for the ICE 3 neo



The steady rise in the number of long-distance passengers adds to the demand for new high-speed trains. In order to implement this, DB Fernverkehr AG would like in the short term to procure a total of 73 BR 408 (ICE3 neo) high-speed trains from Siemens. These trains are based on the BR 407. In order to carry mobility-impaired persons in wheelchairs, these trains, just like the ICE4 and the BR 407, will be equipped with wheelchair lifts.

As the operation of the previous wheelchair lifts is too complex and time-consuming, a new design is being used for the BR 408 trains. The special feature is that the lift is not stowed in a compartment in its parking position as before, but stands upright in front of the access door.

**The lift supplier must observe new requirements when designing these wheelchair lifts. In close coordination with DB Systemtechnik and DB Fernverkehr, efforts were already being made at the design phase to ensure that the concerns of disability organisations were taken into account.**

The clear opening width of the access door of 900 mm and compliance with the specifications of the minimum dimensions from the TSI PRM (persons with reduced mobility) pose a particular challenge. Accessibility for maintenance and servicing of adjacent components also had to be considered. For example, the accessibility of the display in the door leaf was not guaranteed by the lift positioned in front of it.

**With the help of the experts from DB Systemtechnik, a constructive solution was found which allows the platform, on which the person with reduced mobility is lifted, to be folded away with little effort.**

Within the scope of the type tests carried out and accompanied by DB Systemtechnik at various stages of development, optimisations were identified which are aimed at increasing the reliability of the lift in operational use (e.g. when stopping on a cambered curve at the platform).





Photo: DB AG/Claus Weber  
Illustration: DB Systemtechnik

## Energy analysis of a new air conditioning system in the ET440

In view of the F-Gas Regulation of 2014 and the associated reduction of available refrigerants such as R134a, air conditioning systems with natural refrigerants were tested in the DB project "Natural HVAC for vehicles"\* and measures were defined to ensure sustainable operation of DB AG vehicles.

As one measure, the switch to "natural refrigerants" was tested in cooperation with FTL/Wabtec. For the first time, an air conditioning system using the flammable refrigerant propane (R290) was tested in operation in the BR440.

**For the investigations, four data loggers and two energy meters were installed by DB Systemtechnik on the 440 038 multiple unit.**

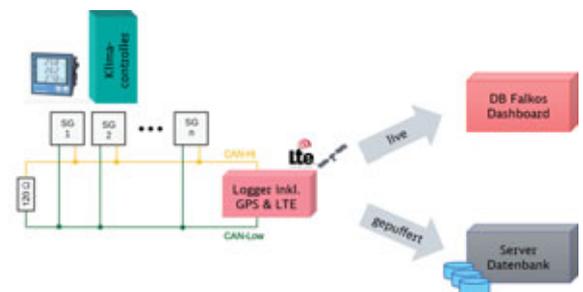
In close cooperation with FTL, it was also possible to keep note of the variables of the CAN interface of the climate control computer, so that the energy requirement could be allocated to the respective control commands and operating states. In addition, the events on the train could be given a geographical reference by means of GPS tracking. The data obtained in this way serves as the basis for modelling and simulation.

The advantage of taking measurements during operation is the direct feedback under actual conditions without the need to visit a depot and at relatively low cost.

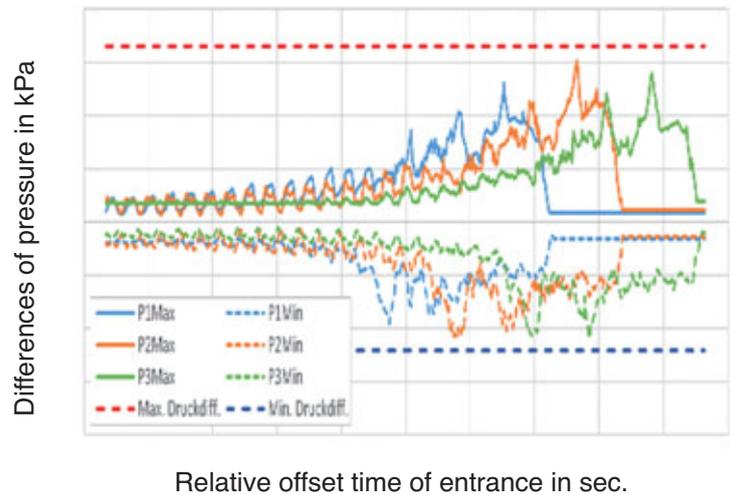
The measurement of the conventional R134a system also revealed an old weakness. This is now being investigated in a follow-up contract, where the potential energy savings of a new software package will be determined with the help of this data acquisition and extrapolated for the entire fleet.

### Advantages of mobile data acquisition:

- Fast feedback from operation and GEO tracking
- No workshop access necessary to read out the data
- Recording of real operating conditions outside Germany as well
- Comparatively low costs for a prototype or concept validation
- Relatively short development time due to proven and railway-certified measuring devices
- Large amounts of data possible, e.g. 500 variables from TCP/IP network
- Data from various sources, control and measuring devices



The logger (pink) receives the measurement and process data from the climate control unit (turquoise) and from a power meter via a bus system. The data is referenced with satellite positioning and reaches the DB Falkos dashboard via mobile communications. It is then buffered on a database server for in-depth analyses



## Aerodynamic aspects of the prohibition on trains meeting each other in the Aichelberg tunnel

According to the project's requirements specification, the new Wendlingen-Ulm line is intended for mixed passenger and freight traffic. During train encounters in double-track tunnels, the freight wagons are subjected to high pressure/suction loads which must not cause damage under any circumstances.

In the HGV 90 high-speed test campaign, an acceptable reference load level for freight trains was determined in the 1990s based on encounters between freight trains and high-speed trains in double-track tunnels with a nominal size of 82.1 m<sup>2</sup> on the Mannheim-Stuttgart and Hanover-Würzburg high-speed lines. Calculations we have carried out so far have not revealed any necessary restrictions for ICE trains at the maximum line speed of 250 km/h. However, for trains with a larger cross-section, such as TGV 2N2, restrictions on the maximum speed would be necessary in the 253 m long Aichelberg tunnel due to the smaller cross-section. Since train types cannot be distinguished on an operational basis and the meeting of trains could not be ruled out by the control-command and signalling, there was a significant risk for commissioning that had to be mitigated.

**DB Systemtechnik has therefore conducted an in-depth study on behalf of the DB Stuttgart-Ulm project to investigate in detail the aerodynamic pressure and suction loads that arise in the Aichelberg Tunnel as a result of trains meeting in the tunnel.**

For this purpose, the input data of previous studies, such as the measured pressure signature of the TGV 2N2, were reviewed and evaluated with a view to obtaining conservative results. Another numerical simulation tool was tested, validated and applied for the very short length of the Aichelberg tunnel. The new tool methodically opened up previously inaccessible parameter ranges. With the help of the simulation tool, it was possible to determine that the TGV 2N2 and all TSI-compliant trains can run on the line without restrictions and without exceeding the reference load level for freight trains. This means that no train-specific restrictions are necessary for trains such as TGV 2N2 on the new Wendlingen-Ulm line. It was therefore possible to demonstrate a rail service with mixed traffic and no restrictions.



## Enabling test runs at 360 km/h on the Nuremberg-Ingolstadt high-speed line

In 2021, a second measurement campaign took place with the Siemens single wagon test vehicle (EWET) and the ICE S on the Nuremberg-Ingolstadt high-speed line. The aim was to cover a section of the track at 360 km/h to test various technical capabilities of the EWET at high speed.

**The measurements were supervised and carried out by DB Systemtechnik.**

Between Nuremberg and Ingolstadt the experts collected data on running gear technology, brake equipment, the interaction of pantograph/overhead line and the aerodynamic and acoustic effects on the infrastructure.

As part of the statement on aerodynamics, the measures regarding the risk of the centre and edge absorber panels lifting off in the Euerwang and Irlahüll tunnels were evaluated by the DB Systemtechnik aerodynamics testing laboratory. For this purpose, a metrological monitoring concept was established with pressure and laser distance measurements, flanked by numerical simulations of the lift-off on selected panels. Lift-off was assessed on the basis of previous measurements. The results were then taken into account in the monitoring concept.

The adjusted measures, including those concerning the micro-pressure wave immission values, were included in a supplement to the risk management procedure for the infrastructure of the route covered.

The additional monitoring measures of the absorber plates have proven to be robust in terms of avoiding risks during trial operation. Furthermore, they can serve as a template for further test runs at high speeds on the high-speed line.

Overall, addressing the aerodynamic issues of how to deal with pressure waves in tunnels, loads on components, micro-pressure waves and specifically absorber plates in the selected tunnels has contributed to the success of the test runs at these high speeds.



Absorber plates with measuring equipment



## Lighting measurements after redesign and maintenance tasks

The vehicles of the 650.3, 648.25 and 425.3 classes have undergone adjustments and conversions to their interior lighting within the scope of redesign projects/maintenance tasks. In particular, the vehicles were converted to energy-saving LED technology.

After retrofitting, it is necessary to assess the interior illumination according to the Technical Specifications for Interoperability (TSI) and EN 13272, which specifies the performance requirements and recommendations for electrical lighting in public transport rail vehicles.

**DB Systemtechnik therefore carried out the following measurements and calculations on behalf of DB Regio:**

- Measurement of illuminance at measuring positions according to EN 13272 for general and emergency lighting
- Measurement in driver's cab, passenger area and WC
- Measurements at seats, in aisles and door areas, and on steps
- Calculating the uniformity of illuminance

The measurements were carried out using hand-held measuring devices and distance gauges in the workshops of DB Regio or in DB Fahrzeuginstandhaltung depots. In this way it was possible to perform the proof of compliance with the minimum illuminance for general and emergency lighting and uniformity of illuminance according to LOC & PAS TSI section 4.2.10.4.1(emergency lighting system), TSI-PRM section 4.2.2.4 (rolling stock subsystem) and EN 13272.

Above: Passenger area of VT650.12 with general lighting switched on after conversion to LEDs.  
Below: WC cabin of VT648.25 after conversion to LED lighting.

Photos: Kai Nowak

## New technologies for impact detection in rail operations

The introduction of fully automatic train operation is one of the most important spheres of activity of Digital Rail for Germany, a division of DB Netz. In addition to being equipped with modules for automatic train operation (ATO), trains are also equipped with state-of-the-art sensor technology that enables them to perceive their surroundings and find their location with precision. These technologies are currently being tested in various pilot projects (Sensors4Rail and Digital S-Bahn Hamburg).

In order to improve the quality of train operations and support train drivers with intelligent functions even more in the future, Digital Rail for Germany is participating in the funding project "AI methods in condition monitoring and needs-based maintenance of rail vehicle structures" (KI-MeZIS), which was launched at the end of 2021. The aim of the project is to tap the potential of artificial intelligence (AI) methods for monitoring train journeys. AI will be used to evaluate and interpret data from sensors at the front of the train and on the running gear.



An important component here is impact detection, which enables both collisions and impacts to be correctly classified and appropriate response for automatic train operation to be derived. This procedure is to be tested for the first time on the DB "Advanced TrainLab" test train.

**The Vehicle Design Department of DB Systemtechnik in Leipzig is supporting this project and has been commissioned to carry out the installation engineering for the sensor setup to develop this impact detection system,** as well as to support staff with technical questions and approval issues. On the basis of the system requirements, the colleagues work out the system integration in the "Advanced TrainLab" and create production documents for the conversion of the train. The KI-MeZIS funding project will be completed by the end of 2023.



Prinzipdarstellung der Unterflurratsatzdrehbank (URD) mit Kamerasystem

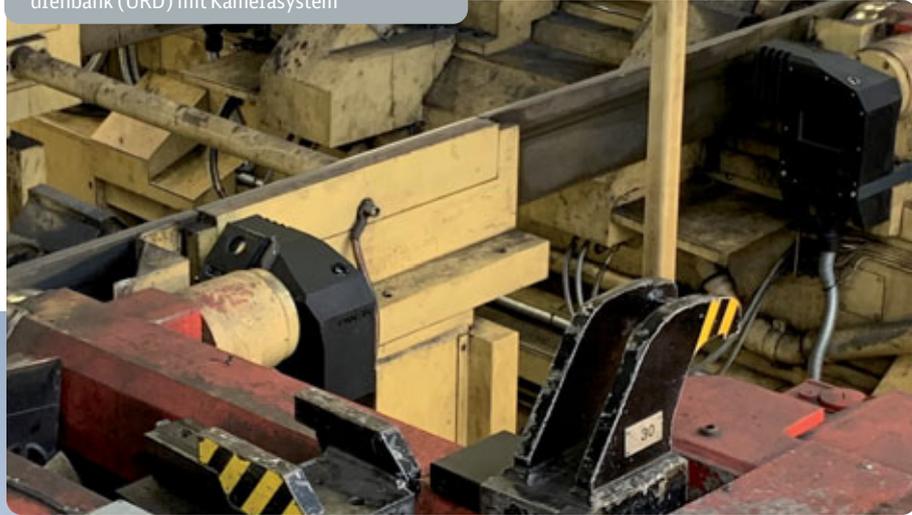


Image recording of tread with measurement of a defect

## Camera system replaces visual inspection

DB Fernverkehr AG launched the UWL Express pilot project in 2018. The aim of this project was to optimise individual processes in order to make the transition to a preventive reprofiling of treads.

This should dramatically reduce the amount of condition-related reprofiling that has been carried out up to now (usually after approx. 200–300 thousand kilometres). As a result, the capacity utilisation of the lathes for reprofiling is higher, but more predictable. A higher rate of utilisation in turn also requires the adaptation and optimisation of existing implementation processes.

One sub-project (TP6) is the transition from manual non-destructive visual inspection to camera-based visual inspection after reprofiling.

**The experts at DB Systemtechnik were consulted at an early stage to find out what had to be taken into account in a camera-based visual inspection.**

It was found that reference blocks are required for monitoring the system, analogous to the procedure for the mechanised ultrasonic test rigs.

As described below, a test wheel set was built with natural and artificially introduced reference defects. Its bright metallic surfaces quickly became dull and could not be kept in the same state as a freshly reprofiled tread. In the meantime, the experts have moved on to manageable reference blocks and test charts.

Last year, DB Fernverkehr issues the mechanical approval and DB Systemtechnik the test engineering approval for trial operation. This trial operation includes comparative tests on at least 300 wheels in terms of manual and camera-based testing.

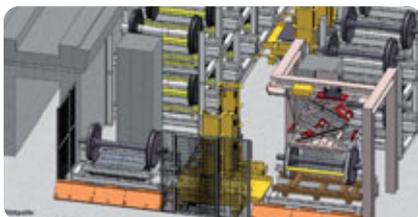
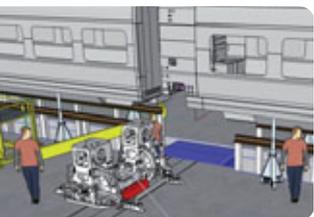
On completion of the trial operation this year and the subsequent presentation of the system with a safety case in the Vehicle Maintenance Programmes expert group, a decision will be made on the commissioning of further camera-based visual inspection systems. Among other things, the further development and integration of artificial intelligence is also being planned.



## Low floor in the workshop: Launch support for ICE L

Rendering and Illustration: DB Systemtechnik

It all starts with the vehicle technology: as successors to the Eurocity passenger trains, the fleet of ICE L trains will enter service from 2024. The "L" stands for "low floor entry", in other words vehicles with unhindered, step-free access at platform edge level. To this end, DB Fernverkehr is breaking new ground and purchasing the train system of a Spanish manufacturer with unusual running gear technology: this features "Rodals", in which the wheels are not mechanically coupled via an axle, but rotate independently of each other on short single-axle stubs in support frames lying transverse to the direction of travel. The spacing of these Rodals in the convoy is 13.3 m, which corresponds to the intermediate car length in the convoy, which is up to 311 m long and whose vehicles will enter production at the manufacturer in 2022 following the final design phase in 2021.



For vehicle maintenance in DB's workshops, these are decisive changes to which the maintenance workshops must adapt in good time in terms of production technologies and equipment.

**DB Systemtechnik in Kirchmöser was therefore commissioned by DB Fernverkehr to carry out an interface analysis in order to obtain systematic adaptation requirements for the workshops from the new vehicle technology and to identify possible solutions for necessary changes.**

Based on this, specific adaptation projects regarding the content, budgets and implementation times were formed in site-specific feasibility studies. DB Systemtechnik's workshop ex-

perts prepared these for the Berlin Rummelsburg and Dortmund-Spächenfelde sites and provided technical support for the studies for Hanover-Pferdeturm and Hamburg-Eidelstedt.

The main focus of the adaptation projects is the standardisation of existing conventional ICE workstations to the system dimensions of the new low-floor vehicles and their electric locomotives:

- Realisation of low-floor access from the driver's level by installing additional extensions
- Ensuring safe access to the roof assemblies by installing barriers
- Longitudinal adaptation of the supply and waste disposal systems, instrumented track sections and wheelset replacement points
- Finding and designing the technology for the Rodal replacement and implementing it in the elevated production track

For the ICE L, the Rodal replacement represents the counterpart to the wheelset replacement process on the ICE multiple unit and must be carried out reliably in a short production time. To implement this demanding technological process, a special replacement and transport technology had to be developed due to the confined space. Its functionality will be tested using a prototype in 2022 and, once validated, the construction and installation of the mechanical systems for the large wagon shed in Berlin will be put out to tender.

According to the current planning status, the Rodals will be overhauled at the DB Fahrzeuginstandhaltung maintenance facility in Neumünster. Following the feasibility study, planning will also begin here in 2022, so that the components and complete carriage units of the ICE L can be produced. Using the knowledge from the interface analysis of the vehicle technology and the infrastructure projects of DB Fernverkehr, DB Systemtechnik accompanies these plans from the viewpoint of vehicle and machine technology.



Photos und Illustrationen: DB Systemtechnik

## Rail base spalling on new rails for single-track line 5832

In October 2020, new rails (flat bottom rails) were installed on the single-track line between Passau and Neumarkt-Sankt Veit from km 63 to km 76. In order to resume regular operations on the line as quickly as possible, the installed rails were initially only secured with fish-plates and then gradually welded together until mid-December 2020. During the welding work, material spalling was detected in the rail base at the ends of three rails, which required the immediate removal of the rails. Further defects in the form of longitudinal cracks in the rail base were found during the technical acceptance of the track.

**In order to clarify the cause of the fractures and cracks in the rail base, a material damage investigation was commissioned, which was taken over by the inspection body of DB Systemtechnik accredited in accordance with EN ISO 17020 – material and failure analysis inspection area.**

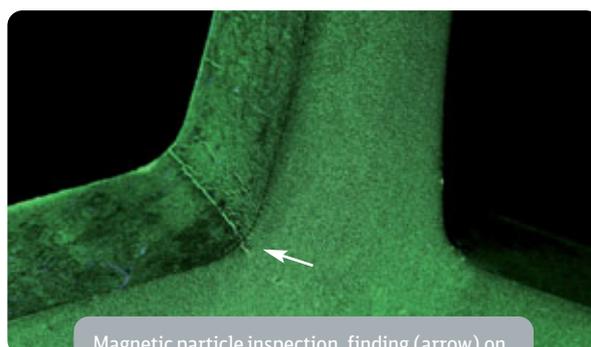
The following examination methods were used:

- Magnetic particle testing
- Ultrasonic testing
- Fracture surface examination (fractography)
- Macroscopic microstructure examination
- Microscopic microstructure examination
- Charpy impact test

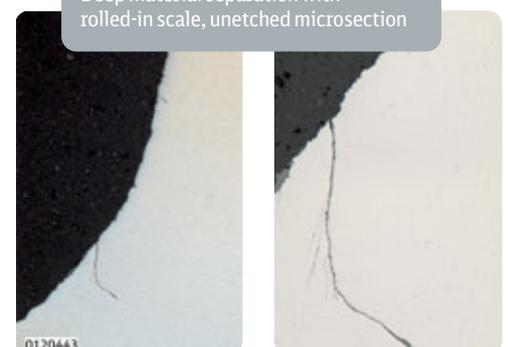
The results of the individual inspections were evaluated and documented in an inspection report. The investigations determined that the fractures and cracks in the rail base had undoubtedly originated from a rolling defect originating in the manufacturing process, which had remained undetected during the manufacturer's quality control. The rolling defect, which is inadmissible according to standard EN 13674-1 and is approx. 1 mm deep, was on the side of the hot stamping (batch number) in the transition from the rail web to the rail base over the entire length of the rail.

Since, according to EN 13674-1, defect depths of "hot damage and overrolling-like irregularities on the rail surface" are only permissible up to a maximum of 0.5 mm, the normative requirements for the surface condition of a flat bottom rail were not fulfilled.

The investigation results provided by DB Systemtechnik significantly strengthened the position of the client vis-à-vis the rail manufacturer with regard to the actions to be initiated.



Magnetic particle inspection, finding (arrow) on macro cross-section, image taken under UV light



Deep material separation with rolled-in scale, unetched microsection

## Overhead wheel-rail contact



In the summer of 2020, the press reported on massive disruptions to the Wuppertal suspension railway, which forced its operator – WSW mobil GmbH (WSW) – to suspend operations on weekdays, Monday to Friday, for a year, starting in August.

**As a result, DB Systemtechnik's Running Equipment and Materials and Joining Technology departments received a request to provide specialist support at short notice with their expertise on the subject of wheel-rail wear and to assist with the analysis of the wheel-rail problem on the Wuppertal suspension railway.**

The Wuppertal suspension railway is a different kind of wheel-rail system where the passenger sits below, the wheels and rail are above, the wheels have double flanges and each running gear unit has only two wheels.

As from September 2019, the Wuppertal suspension railway operated exclusively with the new GTW2014 class vehicles, causing a huge increase in wheel-rail wear – accompanied by an enormous increase in noise, especially on curved sections.

The wheels had to be reprofiled at ever shorter intervals, which considerably limited their mileage. Workshop capacities also reached their limits, so that vehicle availability became more and more of a problem. All this eventually led to a decision with drastic consequences for the region: to maintain passenger services only at weekends. By that time, WSW had already set up a project whose organisational structure also included external experts from a wide range of disciplines. DB Systemtechnik took over the project management.



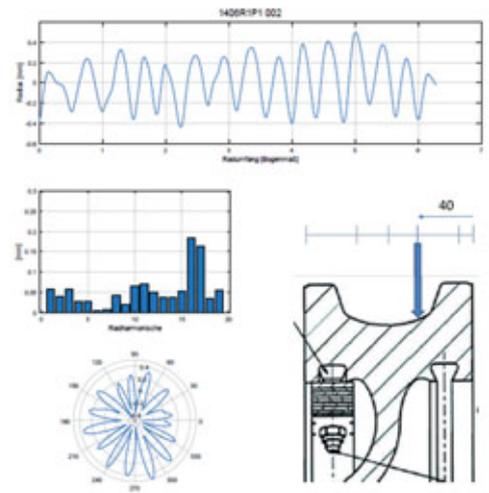
The experts from DB Systemtechnik started with an on-site visit and prioritised and added work packages to the current project with the following focal points:

1. **Wheel-rail lubrication system and material testing of the wheels**
2. **Measurements of the wheel and rail profiles as well as the concentricity of the wheels**
3. **Clearance profile, multi-body simulation, wheel-rail wear**

The topics of ETCS, permitted running speed and return to the tired wheel could be put aside after initial analytical considerations.

Maintaining and securing operations at the weekends was the first priority, then in the second step the resumption by August 2021 of stable operations with long-term security was to be rapidly pursued in order to finally devote the last phase of the project to optimisation and a return to an improved normal state.

Staff from the running equipment department in Minden took over the measurements of the rail cross-section on several sections of the track and the concentricity measurements on the wheels. In addition, the results of wheel profile measurements already carried out were analysed and evaluated in terms of contact geometry. The work eventually led to the development of a new wheel profile.



The materials and joining technology colleagues from Brandenburg-Kirchmöser analysed the results of material tests already carried out on the wheels, but also carried out their own tests. As a result of the investigations, they were able to establish a close connection between the existing structure and the out-of-roundness of the wheels.

Against this background, they evaluated the manufacturer's specification of the wheels and made recommendations on the manufacturing process and material. Necessary quality requirements for wheels and rails for future procurements were also looked at in more detail.

As from August 2021, it was possible to resume the operation of the Wuppertal suspension railway on weekdays as well. The measures introduced at short notice regarding the lubrication system and the new wheel profile had a positive effect on both wear and noise reduction. The medium-term measures such as the procurement of new wheels under changed quality requirements should contribute to a further stabilisation of the service. This has been a success story to which DB Systemtechnik made a decisive contribution.



Photo and illustration: DB Systemtechnik

## Generic checklist to an occupancy-dependent outdoor air supply

By adapting the climate control system in Regio vehicles, the amount of fresh air is to be regulated in conjunction with a measurement of the CO<sub>2</sub> content in the room air, depending on the occupancy and with the absence of feedback. As less fresh air needs to be heated or cooled, savings can be made in terms of electrical energy and thus costs.

Depending on the vehicle type (e.g. double-decker coach), the flap position or the fan stage of the supply fan (e.g. ET423) is controlled on the basis of the CO<sub>2</sub> content detected in the room air. This requires adaptations to the hardware and/or software of the air conditioning system and imposes corresponding demands on the approvals process.

**The checklist prepared by DB Systemtechnik** helps with implementation by providing an overview of the generic hardware/software requirements that are relevant when converting Regio vehicles to an occupancy-dependent outside air supply from the point of view of approval and taking into account the changes introduced by the 4th railway package. The records and work packages needed to meet these requirements are presented generically and placed in a process-related context.



The primary engineering services required, potential risks and the records required for the approvals process are identified. DB Systemtechnik also communicated with the relevant interfaces (vehicle manufacturer, engineering and approval experts). Finally, the results were presented graphically in an overall process diagram.

The results provide a solid basis for effective and efficient project planning/coordination of the retrofit project and form the basis for the fastest possible implementation of the measure and for the associated energy and cost savings in operation.

The amount of work and expense for future retrofits of an occupation-dependent outside air supply on Regio vehicles can be determined more quickly and accurately by using this generic checklist.

Through the energy savings that can be achieved, the project also makes an indirect contribution to achieving the Group's environmental goals in every future application.

DB Regio plans to use the checklist in the future as a guide for other comparable energy-saving projects that are planned, thus enabling a faster and more accurate determination of the work and costs involved.

## CBM data path at DB Cargo

DB Cargo's condition-based maintenance (CBM) activities began back in 2012 with the "TechLok" project, in which a large number of locomotives were equipped with sensors and telematics devices. This was followed by the CBM and CBM 2.0 projects, the objectives of which were to tap potential, establish a suitable organisation and create the technical infrastructure for collecting and analysing CBM data.

A uniform IT architecture consisting of a network, IT components and the AIC (Asset Intelligence Centre) analysis module was developed for the collection, storage and processing of the data, the central data link of which was referred to as the "CBM data path" in the course of the project. The purpose of the CBM data path is the transmission, enrichment and evaluation of CBM data (sensor or measured values, diagnostic data, GPS data) for use in various CBM use cases.

**To ensure that the CBM use cases can also be transferred to the regular process of DB Cargo's operations and maintenance, DB Systemtechnik worked alongside DB Cargo to develop a generic safety case for data transfer in accordance with EN 50126 and EN 50657.**

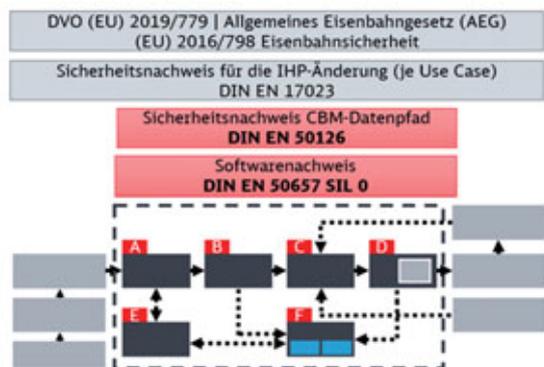
With a view to the requirements of the CBM use cases classified at that time (e.g. diesel particulate filters), the required software integrity level (SIL) was set to SIL0 (basic integrity) as part of the risk management procedure, thus defining the scope of the documents to be generated in accordance with EN 50657 for the software developed in the CBM project.

DB Systemtechnik's task was then to request these documents and records required by the standard from the project or to prepare them, to evaluate and assess their quality and consistency in the form of verification reports and to ensure adjustments were made.

Feedback was also provided to IT managers about the requirements of higher SIL classifications for other future use cases.

Relevant standards and regulations for the changeover from scheduled to condition-based maintenance.

Source: DB Systemtechnik



The CBM algorithm triggers a maintenance order to clean out the DPF on 29 November 2021

Source: DB Cargo



A framework of existing result documents and modules set up by DB Systemtechnik's experts ensures that, in the future, adaptations to the documents or the necessary creation of new documents are reduced to a minimum through reuse of existing ones.

Shortly before the official end of the CBM 2.0 project at the end of 2021, an important milestone was celebrated when the first locomotives of the 261 and 265 classes registered themselves automatically in the DB Cargo workshops via the CBM data path using diagnostic codes.

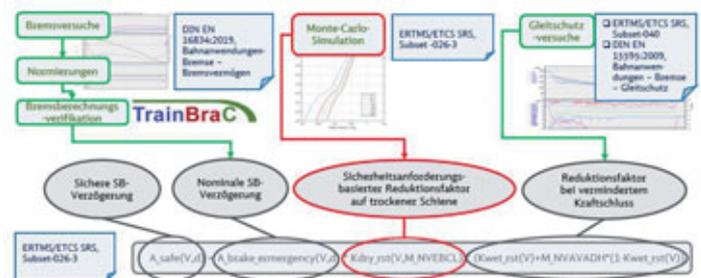
# ETCS Monte Carlo Simulation Tool V2.0

The calculation and monitoring of braking curves are essential and safety-relevant components for the European Train Control System (ETCS). It must be ensured at all times that trains do not exceed permitted speeds and that braking is initiated in good time before dangerous points.

On-board ETCS braking curve parameters for Gamma trains (which include multiple units with a maximum speed of over 200 km/h) include the equivalent brake response time, the nominal emergency braking deceleration and the two safety requirement-based correction factors (Kdry and Kwet). Kdry is used for braking on dry rails and Kwet takes into account the reduced adhesion on greasy rails. The correction factors are to be determined in such a way that the gamma train under consideration does not fall below the safe deceleration with a given probability (defined via the so-called Emergency Brake Confidence Level) during emergency braking. The correction factor Kdry must therefore take into account all scattering and failures of those parameters or components that have an influence on the brake force and ultimately the deceleration of the train. The statistical method of Monte Carlo simulation is used to determine Kdry.

**DB Systemtechnik has been determining ETCS braking curve parameters for years and offers a complete package, starting with the execution of the test, through the analysis and provision of the nominal values, to the determination of the correction factors.**

A Monte Carlo simulation tool developed by DB Systemtechnik is used to calculate the correction factor Kdry. A currently emerging Euronorm for determining the ETCS braking curve parameters and the increasing complexity of the brake system architectures made it necessary to modernise the tool. In the period from 2021 to 2022, this was realised as part of an internal innovation project. In addition to EN standardisation, the extension leads to a reduction in computing time and greater flexibility in the mapping of arbitrarily complex brake system architectures. The tool, which has undergone further development, is already being used in current projects for the digital node Stuttgart.



Photos: DB AG/Frank Kniested, DB AG/ Barteld Redaktion



## EBA research contract for the Systematisation of infrastructure maintenance planning

The German Centre for Railway Traffic Research (DZSF) of the Federal Railway Authority commissioned the experts at DB Systemtechnik to undertake a 7-month research project, the aim of which was to find examples of applications for predictive maintenance in the railway infrastructure and to find out what need there is for adaptation in maintenance planning. Along with DB Netz, DB Systemtechnik aligned itself against eight specialist competitors in the tender process for this medium-term R&D innovation project.

Together, the colleagues from the Maintenance Technology and the Digital Products and Services business lines, as well as Bid Management, developed a work concept that convinced the evaluation committee to carry out this comprehensive and strategic maintenance task.

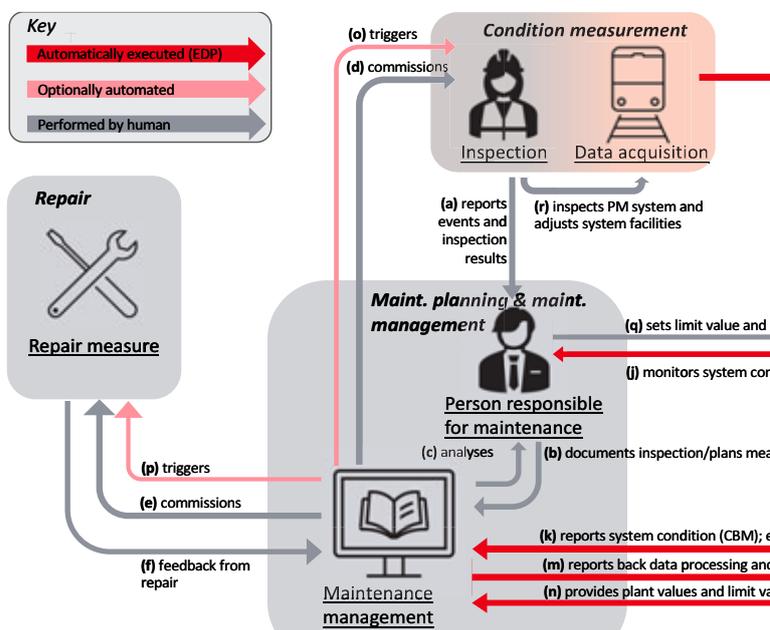
### From preventive to predictive maintenance

The objective was to focus on developing the maintenance of infrastructure in the rail sector from the current scheduled preventive maintenance to predictive maintenance (PM), as well as to further advance the data-driven maintenance approach to practical and functional application maturity.

- Here, the particular conceptual focus is on the broadly applicable planning processes and on dovetailing the maintenance across the entire infrastructure.
- Furthermore, the possible range of use and costs as well as technically promising development paths and prospects are to be determined.

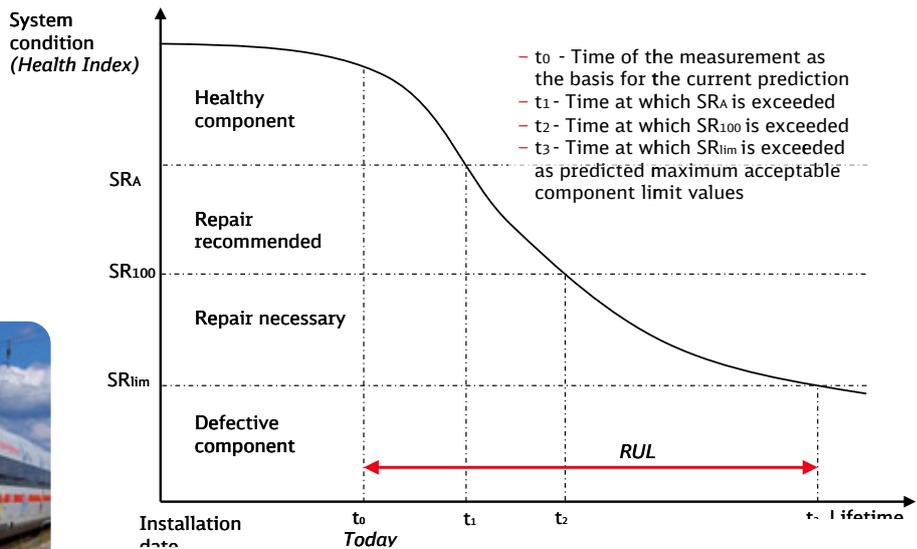
DB Systemtechnik's own developments for monitoring rail infrastructures (CTM, ESAH) or rail vehicle (CIM) monitoring developments (CTM, CIM, ESAH, etc.) also come into play here in particular. Developments in the DB Group relating to condition-based maintenance are also included.

### Information flow in the PM system



Photos: DB AG/Uwe Miethe, DB Systemtechnik  
Graphics: DB Systemtechnik

**System condition over time: Health Index RUL**



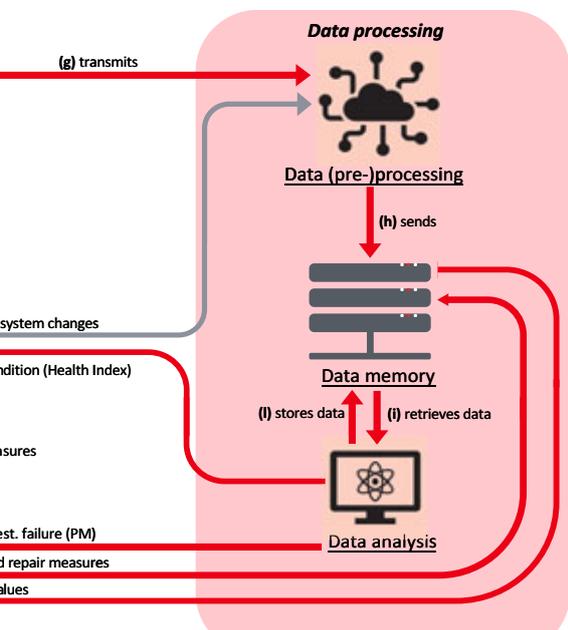
Content of the study:  
**"Application of predictive maintenance in rail infrastructure with adaptation of planning and control"**

At present, maintenance in industry and railway engineering is mainly carried out as planned preventive maintenance. This means that repair work is only carried out when an inspection has determined that a limit value has been exceeded. The limits are set in such a way that components function safely even if the limit values are slightly exceeded. If the inspection carried out by a human being is replaced by automatic, sensor-based monitoring of the component condition (health index), this is called condition-based maintenance (CBM). The data generated by the monitoring can be processed by algorithms. These can then calculate the remaining useful life (RUL) of the component, based on digital models. In this case we speak of predictive maintenance.

Based on the processes of DB Netz AG, proposals for implementation were drawn up for long, medium and short-term planning as well as for the operational working level of the railway infrastructure. The advantages of PM for the respective planning levels were indicated. Overall, research has shown that PM increases the planning lead time in all infrastructure disciplines by predicting the RUL, which leads to an increase in quality. This can reduce costs (e.g. arising from actions that are too late or unnecessary), resulting in an increase in path capacity. Opportunities related to the introduction of PM were highlighted, in particular indicating that PM requires several companies to work together and that the introduction itself and thus the change of processes cannot happen in the short term. The results were presented to the DZSF, DB Netz AG and DB Systemtechnik in 2022, both in-house and to an expert audience. The study is available for reference on the DZSF website.

**Georg Ermer is in charge of the research contract for the DB Systemtechnik team:**

"We are now developing the PM scenarios for the Federal Railway Authority in the form of a manual. It can then be used to guide both rail infrastructure companies and developers of PM solutions to implement more advanced applications of PM in practice."



## Condition monitoring of transformers

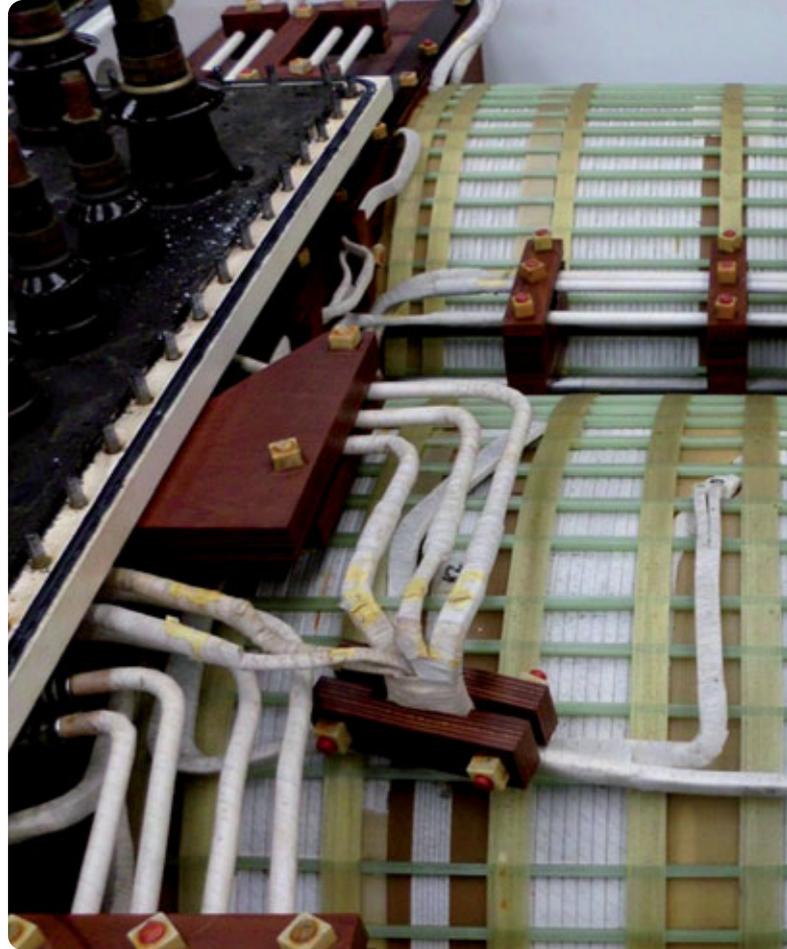
The main transformer is one of the most important and also most expensive components of an electric locomotive. For this reason, special attention is paid to this component. In every case, the failure of a main transformer will result in total failure of the vehicle. Above all, damage to the transformer leads to very high repair costs and long downtimes.

Until now, the analysis of transformer oil samples (routine tests and gas-in-oil analysis) has been used to monitor the condition of transformers in their installed state in order to detect damage. If damage is detected via the oil analyses, an extremely expensive rewinding of the coil package is usually unavoidable.

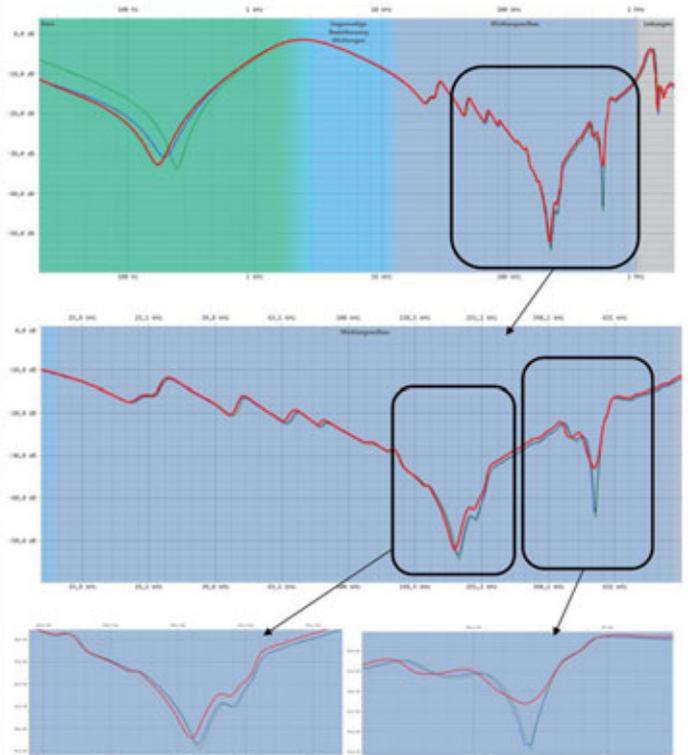
**In cooperation with Dessau depot of DB Fahrzeuginstandhaltung, DB Cargo and DB Systemtechnik, a new procedure has now been developed on behalf of DB Cargo to assess the condition of transformers in their installed state.**

The frequency resonance analysis (FRA) enables displacements of the windings to be detected in the core-and-coil assembly of the transformer. Such displacements occur due to the loosening of the core-and-coil assembly, which in turn is generated by vibrations and oscillations of the vehicles during operation. As a result, damage to the insulation can occur, which can lead to turn-to-turn faults or short circuits, which result in expensive repair.

In frequency-resonance analysis, the respective winding of a coil is made to oscillate via a measuring device. The vibrations sent (input vibrations) are compared with the vibrations measured at the other end of the winding (output vibrations). The different input and output oscillations (known as the frequency response at the transformer) is characteristic for a particular type of transformer. A characteristic vibration curve, the so-called reference curve, is recorded on new or rewound transformers. Now, when measuring a transformer installed in the vehicle, the reference curve can be used as a comparison curve. If there are deviations between the two curves, this indicates a loosening of the core-and-coil assembly and the displacement of individual windings in the coil package. Depending on the size of the deviations, it is possible to assess whether the transformer has to be taken out of service immediately, or can remain in service until the next planned delivery to a maintenance depot. In contrast to an oil analysis, it is not only possible to detect damage, but also the degree of damage. Early detection of even slight displacements can also avoid expensive repairs. Often the core-and-coil assembly can be "retightened", which is much cheaper than rewinding the coil package. Regular FRA measurement at intervals of 5 to 7 years allows the transformer to be assessed over its entire service life.



The "core-and-coil assembly" of the BR 145 transformer



The measurement results: One graph is the reference graph, which was recorded by measuring on identical intact transformers. The other graph shows the measurement result on the measuring object. If there are significant deviations between the graphs, this indicates damage.

## Deutsche Bahn procures 14 wheelset diagnostics systems

Close condition monitoring of wheelsets is a fundamental part of rail vehicle maintenance. As part of the group's digital vehicle maintenance (DIFa) programme, Deutsche Bahn AG published a market enquiry in November 2020 for the procurement of wheelset diagnostics systems for the workshop area. Subsequently, discussions were held with 15 international suppliers on the technical and economic boundary conditions of the systems. On the basis of these discussions, the DB Group Management has launched a project for the procurement of wheelset diagnostics systems.

The assignment was to identify the needs of the business units and to procure appropriate equipment suitable for measurement tasks.

**This required specialist expertise and the team was therefore joined by other experts – including those from DB Systemtechnik.**

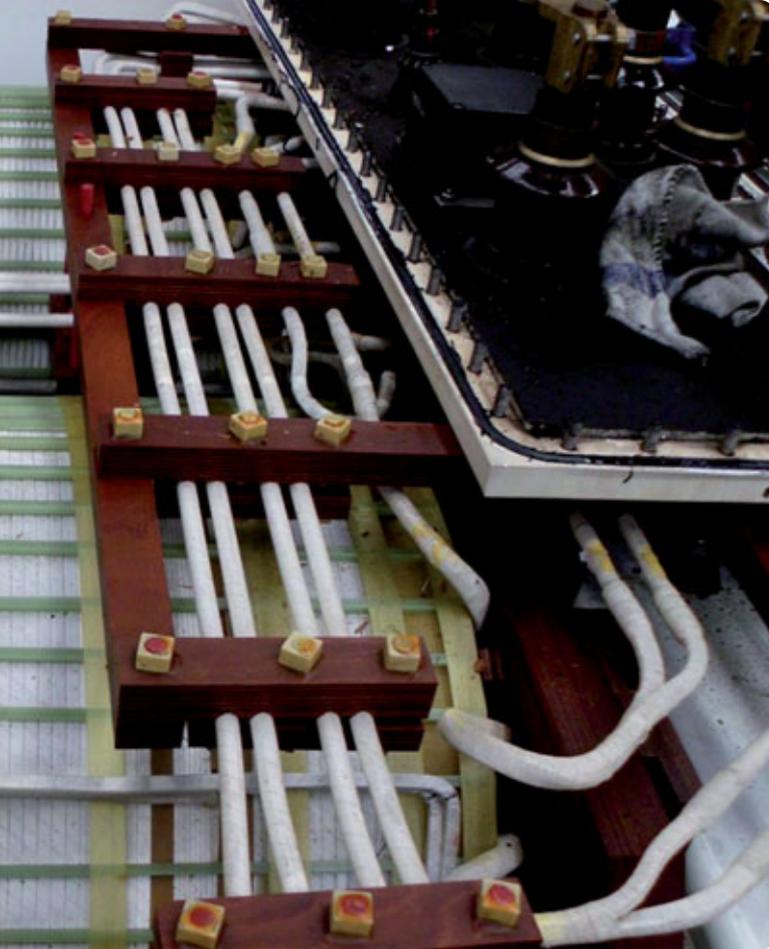
Within the DB Group, the requirements for wheelset diagnostics systems were pooled together and specifications were drawn up together with DB Systemtechnik GmbH, which meet the technical requirements of the DB Regio and DB Fernverkehr business units.

Five companies from Germany and neighbouring European countries have applied for the bidding process initiated within the framework of an EU contract award procedure. After publication of the specifications, three bids were submitted.

On the basis of the bids submitted, a total of three clarification meetings were held with each bidder. Both technical and commercial aspects were negotiated and the project team succeeded in reducing the procurement price by more than 30% while maintaining the same technical boundary conditions. The system procured most recently in 2019 was used as a reference.

Hegenscheidt MFD was awarded the contract for a framework agreement with a term of five years and the delivery quantity of up to 14 drive-over measuring systems.

Four systems are to be installed in the workshops of DB Fernverkehr and DB Regio as early as 2022, and in the following year a further three systems; further locations and quantities are being planned. The creation of competition, coupled with the well-founded statement of work, excellent implementation of the tender and professional negotiations have ensured success for DB.



The new assessment method improves vehicle availability and significantly reduces maintenance costs. The measurements can be carried out by the Dessau depot of DB Fahrzeuginstandhaltung as well as by vehicle operators with the necessary equipment.

The new procedure has been fully applied to all transformers of the BR 145 (DB Cargo) and is now to be extended to other DB Cargo vehicle series (electric locomotives). The measurement of the entire BR 145 vehicle fleet has been prepared and implemented by the project team (consisting of DB Fahrzeuginstandhaltung, DB Cargo and DB Systemtechnik) and was realised within a very short time. As a result of the measurements, an overview of damage including a corresponding recommendation for action was created.

If FRA measurement results and experience are available for an entire vehicle fleet, it can be assessed over its entire life cycle. Preventive actions for the maintenance of transformers can be developed from this for new and subsequent vehicle generations.

With its specialist expertise, DB Systemtechnik supports the continuous development of condition monitoring of transformers and the assessment of damage through to the development of repair concepts. In doing so, it works intensively with the repairer and the vehicle operators.



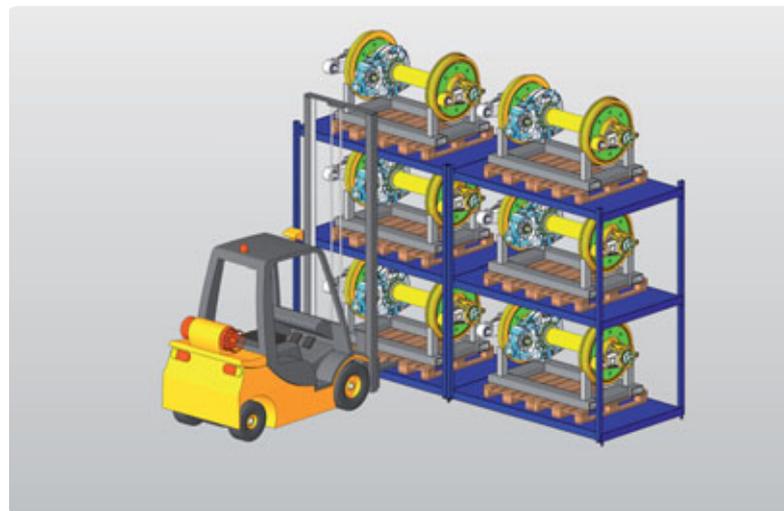
## Compact wheelset storage in the ICE depot at Munich central station.

At the ICE depot in Munich, the wheelsets of various ICE classes are stored in smaller storage areas in the basement of the maintenance shed. Block storage of wheelsets basically leads to a greater demand for storage space and requires more effort when searching for wheelsets to retrieve from storage.

**As part of a concept study for the ICE depot in Munich, at least 100 storage spaces for wheelsets were to be implemented in a contiguous storage area in the basement of the ICE shed.**

The requirement calls for high-density storage of the wheelsets on two levels. The wheelsets are stored and retrieved in specially developed storage modules by a stacker crane. Thanks to automated process sequences, the storage and retrieval, the regular rotation of the wheelsets and the provision of the wheelsets on special wheelset replacement pallets can be carried out in a fully automated process. The request to store or retrieve the wheelset is made by the warehouse management system. The storage space is allocated by the wheelset storage facility's internal control and management system. A modular design ensures that the wheelset storage facility can be expanded flexibly.

The compact and automated storage of wheel sets eliminates the accident-prone and time-consuming manual operations of forklift transport in the warehouse. Employees are then able to focus more on value-adding activities, thereby reducing costs



Above: a device for exchanging the wheelset pallets  
Below:  
Stacker crane for storing and retrieving the wheelsets in the respective storage module.  
View of the automatic wheelset storage facility with flexible option for expansion with storage modules



All graphics: DB Systemtechnik

**DB ESG**  
**reference projects**  
**2021/2022**

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## DB ESG wins project with Transport for Wales



Transport for Wales (TfW) had a requirement to have an additional four 5-car sets of MK 4 coaching stock operated with a Class 67 locomotive and a Mk4 DVT. This unit formation was not compatible and so modification work was necessary to facilitate their operation in revenue earning service.

**In 2021 DB ESG received a contract for the design, approvals, supply, installation and testing of the required rolling stock modifications, together with all necessary vehicle transportation, to allow Mark 4 (MK 4) coaching stock to be operated by Class 67 locomotives and driving van trailers (DVTs).**

This project not only involved compatibility modifications, but also reconfiguration of the CCTV and Passenger Information System to allow them to be fully functional in passenger service. This work commenced in April 2021 and was completed in March 2022.



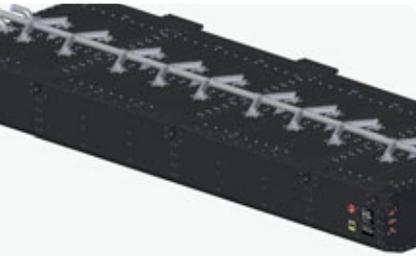
## Battery System for AT 300



## CTM 2.0 for Network Rail in the UK



Photos: Hitachi Rail, DB ESG, DB Systemtechnik



**In March 2021, Hitachi Rail Ltd. contracted DB ESG to undertake a concept development exercise that considered the feasibility of producing a battery raft to house five tonnes of battery modules.**

This battery raft was to be attached to the underframes of the AT300 vehicles in place of the original generator, with a new cooling system fitted to the vehicle roof. Each battery raft was to originally house 18 independent battery units (BU), together with a box to house switches and electrical controllers. Every BU was to also be enclosed within its own fireproof pocket and connected to a coolant circuit, with each containing its own closed-circuit force air cooling system, using the supplied coolant to cool the air within the battery unit.

DB ESG, together with the expert support of DB Systemtechnik, initially reviewed and determined the feasibility of Hitachi's battery concept and considered the best approach to develop this concept further. This initial work was completed in July 2021. Subsequently, Hitachi Rail asked DB ESG to develop this feasibility concept into a fully-fledged design, with detailed manufacturing drawings, enabling the production of three prototypes. On-site support in Italy was provided to Hitachi during the manufacture, installation and testing of these prototype battery rafts.

DB ESG was responsible for managing this project, delivering the design and structural assessment work. DB Systemtechnik specified the high voltage switching technology, and all the project aspects related to fire.

**In July 2022, DB ESG, together with Turntide (Battery Unit Supplier), received a 'Partner Award' in Sustainability from Hitachi Rail for this battery systems design project, selected from Hitachi's global supplier network, which represents thousands of businesses around the world.**

**DB ESG received a contract from Network Rail to deliver the DB Systemtechnik Continuous Track Monitoring product (CTM2.0) for a operational trial in the UK during 2021/22. This project is part of the wider In Service Monitoring trial being led by Network Rail's Research & Development team, looking at a number of train-borne track measurement/ monitoring systems on in-service vehicles. In total, eight supplier solutions were selected to run trials.**

This trial has enabled Network Rail to assess the suitability of DB's system in helping them to reduce the number and impact of service affecting failures, including predicting future condition to enable preventative maintenance actions to be implemented.

For this project, DB Systemtechnik (DB ST) provided the CTM2.0 equipment on a loan basis. They then monitored remotely, for the 6 month duration of the trial, analysing the data and supplying Network Rail with regular reports detailing the actual track condition and predicting future track conditions.

DB ESG was responsible for the vehicle design modifications required, all necessary approvals, material supply, installation of the CTM equipment, and testing and commissioning of the system.

DB ST's CTM2.0 equipment was installed onto a Mark 3 driving van trailer (DVT), which was operated in normal passenger service by Chiltern Railways, on the Birmingham to London Marylebone mainline.

The minimal CTM2.0 equipment consisted of external vehicle mounted sensors and an antenna, connected to an equipment enclosure inside the vehicle. The sensors measured the longitudinal level, track twist, dynamic alignment, ride comfort, cyclic top, speed and the vehicle's motion response. The antenna transmitted the data to a land-based computer platform, which received, stored, processed and reported on the data.

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# DB ESG and Railway Approvals



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