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Autonomous track measurement and condition-based track maintenance at Zentralbahn.

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Lausanne, 12.09.2023

Agenda.

Autonomous track measurement and condition-based track maintenance at Zentralbahn.

1. Overview of the Zentralbahn.
2. Starting situation.
3. Goals.
4. The project.
5. The system structure.
6. Measured parameters.
7. Software: Operation and evaluation.
8. The impact to track maintanance (after 5 years).
9. Insights / Conclusion.

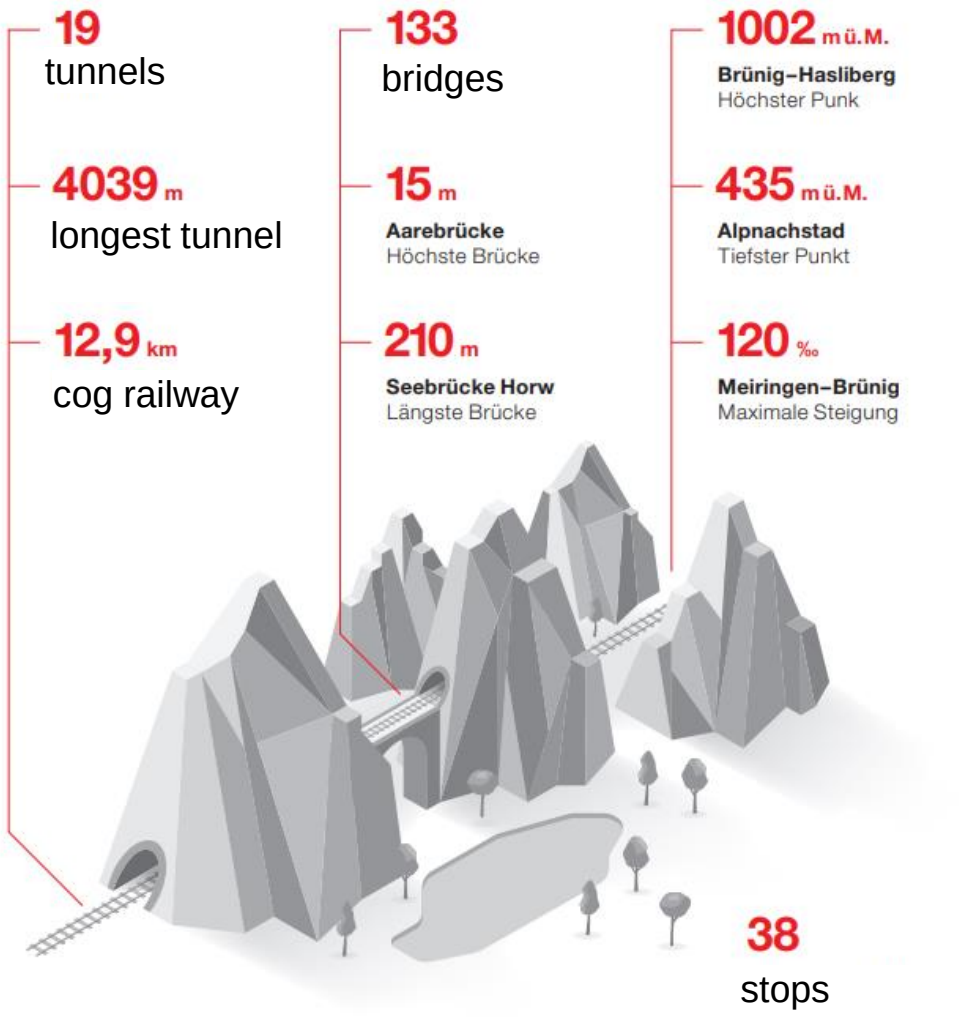
1. A short overview of the Zentralbahn.

The Zentralbahn connects Central Switzerland with the Bernese Oberland.

Our route network comprises 38 stops spread over 102.7 km.

The Zentralbahn at a glance.

Our tunnels, bridges and routes.



The Zentralbahn has a well-developed meter gauge network, which is constantly being modernized and expanded.

Rolling stock of the Zentralbahn.

10 of the type «SPATZ»

- Only on flat lines (not suitable for cog railways)

11 of the type «FINK»

- In use for all kind of services over the whole network)

4 of the type «ADLER» Luzern – Interlaken Express

- In use for the fast train Lucerne to Interlaken

3 of the type HGe-GSW-Pendel Luzern – Engelberg Express

- In use for the fast train Lucerne to Engelberg

3 HGe-Pendel

2 Railcars

Other key figures

Trains traveled in 2022:	122,516
Trains per day	336
Number of seats:	6,495

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2. Starting situation.

Starting situation.

From track runner to automatic track measurement.

- Track condition is visually inspected by track runners in the unloaded state.
- Before: Individual measurement runs with tamping machine at low speeds (< 10 km/h), at intervals of one to two years.
- Strategy of Zentralbahn: Be the most innovative meter gauge railway in Switzerland. Use of digitalization to increase the effectivity.

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3. Goals.

Track diagnostics on a regular passager train – vehicle-based track monitoring.

Framework.

Conditions for automatic track measurement at our network.

- Relatively small network.
- The same types of vehicles in use throughout the network.
- Mainly single-track sections.
- Combination of adhesion and cog railway.
- Meter-gauge connection only to the BOB-railway in Interlaken Ost.
- Operationally, only short intervals for maintenance are available (4 to 6 hours).
- High renovation rates of the tracks are necessary because of week subsoil > frequent measurements desirable.

Goals.

Objectives of automatic track alignment.

- Measurement of the network at line speed during regular operation.
- Recording of current track conditions with high resolution.
- Prognosis of the track condition.
- Derivation of maintenance and renewal needs (early; short, medium, long-term).
- Use of the data for the network status report according to RTE 29900 (relevant for the authorities).
- Use of data in asset management (tool «zedas», in operation since 2020).
- Combination of automatic surveying, inspections of the track runner and feedback from engine drivers for comprehensive track condition (aggregation of the track grade centrally in "zedas").
- Focus on condition-based and predictive maintenance.
- In the medium term: cost reduction in track maintenance (instead of time based maintenance).
- Evaluation of the rail profiles to evaluate the interaction between rail and wheel (side wear and rail head profile).

Solution variants.

Variant for automatic track measurement.

- Diagnostic vehicle for meter gauge:
  - The company Sersa has developed one later. Problem: the meter gauge networks are not connected. Therefore the transfers are expensive – and the measurements cannot be done very frequently.

- Measurements by tamping machine:
  - Interruption of regular traffic necessary.
  - No frequent measurements possible (about once every 1-2 years).

- Measuring system on the passenger train:
  - Continuous measurements for forecasting possible.
  - Available at very short notice in case of track deficiencies.

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4. The project.

Track diagnostics on a regular passager train – vehicle-based track monitoring.

Project participants (in 2018).

- Zentralbahn: Owner
  - Infrastructure: Responsible for the tracks and purchaser of the measuring system.
  - Production + rolling stock: Responsible for the installation of the system and regular maintenance.

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- Infotrans (Samara, Russia): Supplier
  - Supplier of the measuring system and the tools for evaluation and forecasting.
  - Supplier of the measuring technology of the gDFZ of the SBB (towed diagnostic vehicle).
  - 25 years of experience with track alignment systems in trains.

INFOTRANS

ИНФОТРАНС

- STADLER: Supplier
  - Supplier of the vehicle.
  - Responsible for adjustments to the vehicle for the installation of the measuring system.

STADLER

Project scope.

- Dates:
  - Project start: November 2016
  - Commissioning: September 2018
  - Project completion: December 2020

- Cost of the project:
  - Investments: CHF 750 000.- (excl. Adaptation of software, maintenance, etc.)
  - Running costs: Licenses approx. CHF 25,000 p.a.
  - Maintenance of the system approx. CHF 5,000 p.a.

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5. The system structure.

Track diagnostics on a regular passager train – vehicle-based track monitoring.

System structure.

Server for data storage.

Cellular network

Installation on the train
Short time date storage

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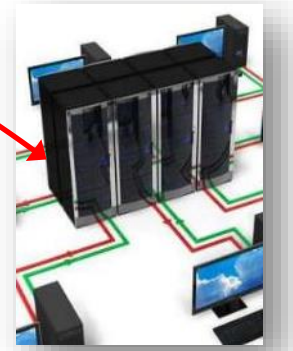
Stansstad (office of Zentralbahn):
Data preparation and analysis
Longtime: data storage

Internet

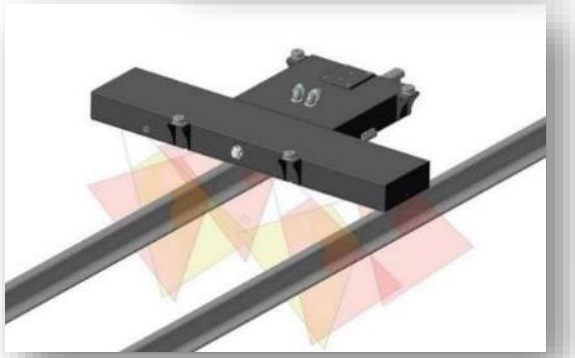


Supplier: technical support

System.

Overview.

- MIBIS measurement platform:
  - Measuring unit consists of 6 lasers.
  - Various sensors for localization (Xpos like at SBB).
- Control of the measuring system:
  - Hardware for data acquisition and evaluation.
  - 5 TB file server on the train.
  - Connected to Zentralbahn via mobile network.
- Challenges:
  - Low-floor vehicle: generally little space for installations (measuring platform and cabinet).
  - Elimination of two seats in favor of the rack.



System.

Installation variants for the measurement platform.

- Variant 1: Installation of the measuring platform on the frame of the bogie (approx. 250 kg):
  - Would be best technical solution to cover tight curve radii and range of influence of the load.
  - Rejection due to conflict when changing bogies and confined spaces (low-floor vehicle).

- Variant 2: Installation of the measuring platform inside the bogie:
  - Very complicated technical solution.
  - Unsuitable for maintenance (access).

- Variant 3: Installation of the measuring platform on the car body (analogous to the Sapsan):
  - Comfort solution for the Zentralbahn: Distance of the scanner to the rail is 520mm.
  - Tight curve radii: Compromise in relation to the field of view of the laser > 30% tolerance.
  - Suspension on the sprung car body is compensated by software ("smoothing").

- Variant 4: Installation of the measuring platform on the car body with additional mechanics for horizontal displacement:
  - Technically better solution for installation on the car body.
  - Distance of the scanner to the rail is 230mm (minimum distance to the rack).
  - Expensive installation.

6. Measured parameters.

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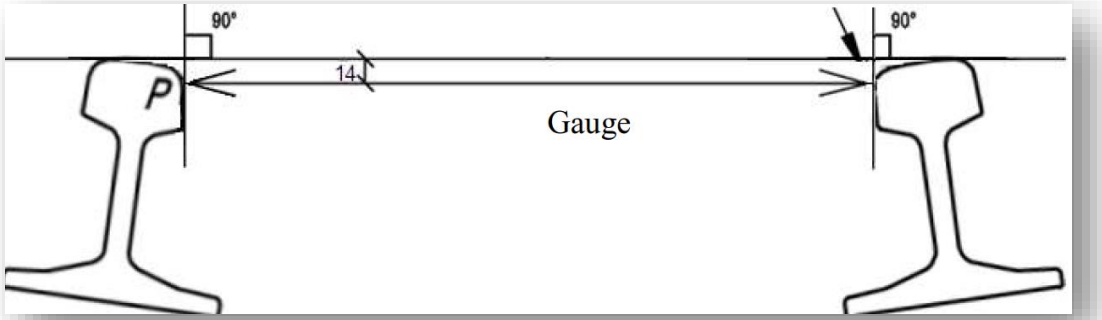
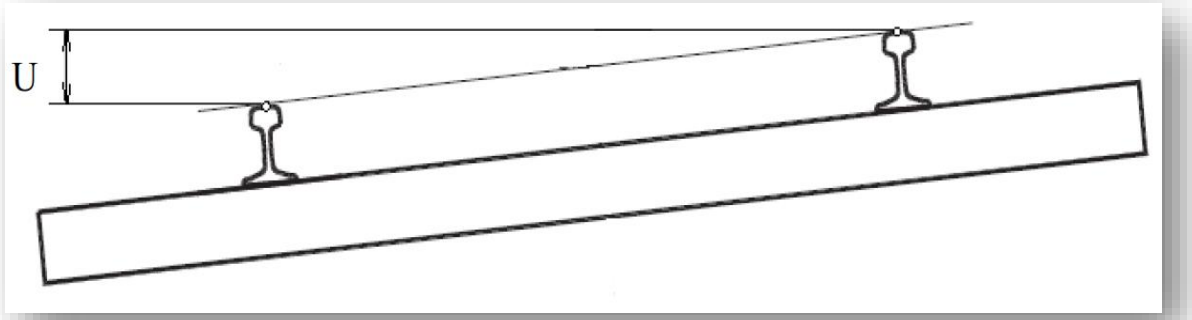
Measured parameters.

Required geometry parameters according to RTE 22540.

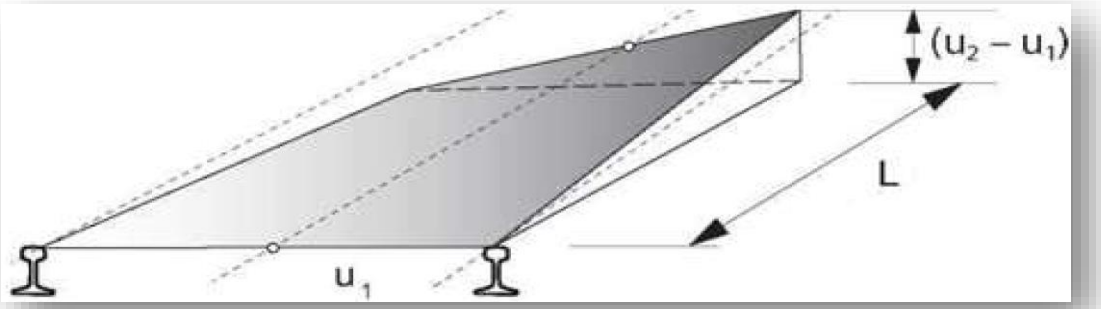
Gauge



Cross level



Twist

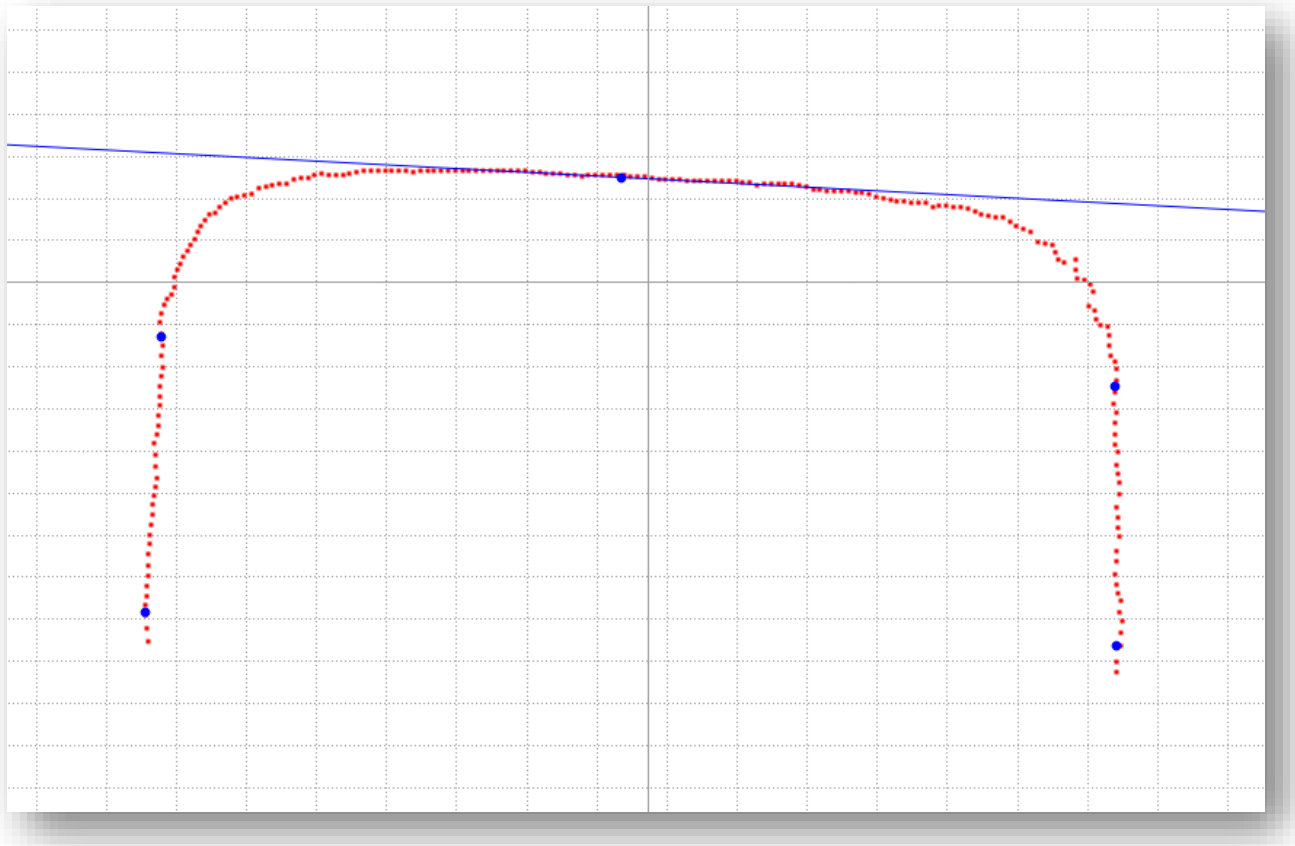


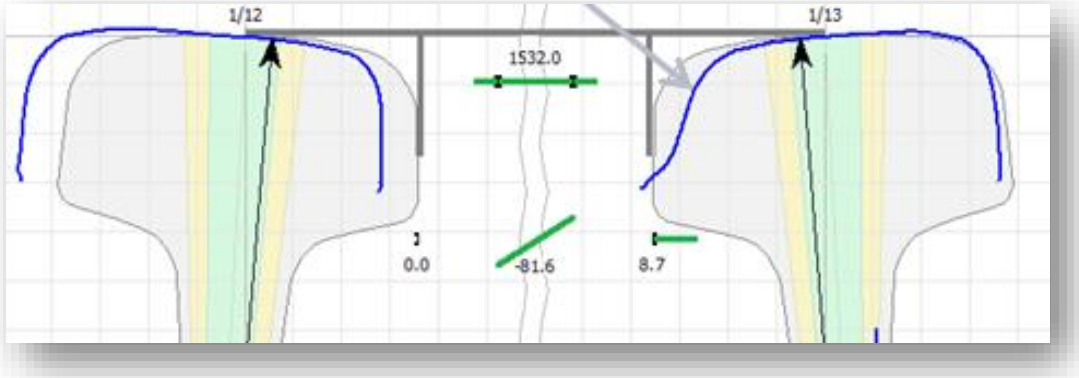
As well as

- Horizontal track geometry
- vertical track geometry
- Temperature

Measured parameters.

Rail head profile.





- Wear of the rail head
  - Tread of the rail head
  - Side wear of the rail

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7. Software: Operation and evaluation.

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Service.

Planning of the measurement runs.

- Manual.
- Tailored to vehicle scheduling.
- Operation via web browser.

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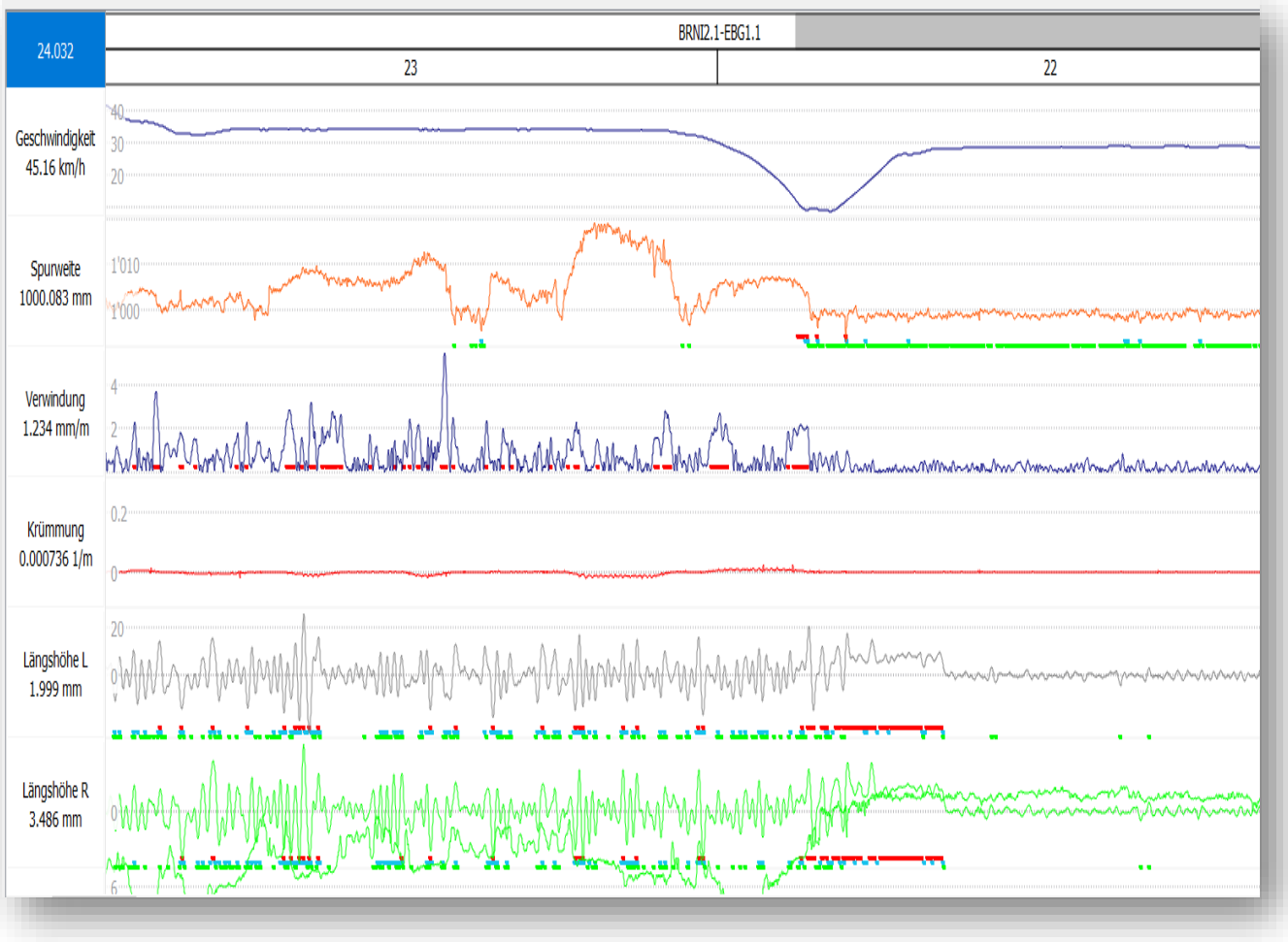
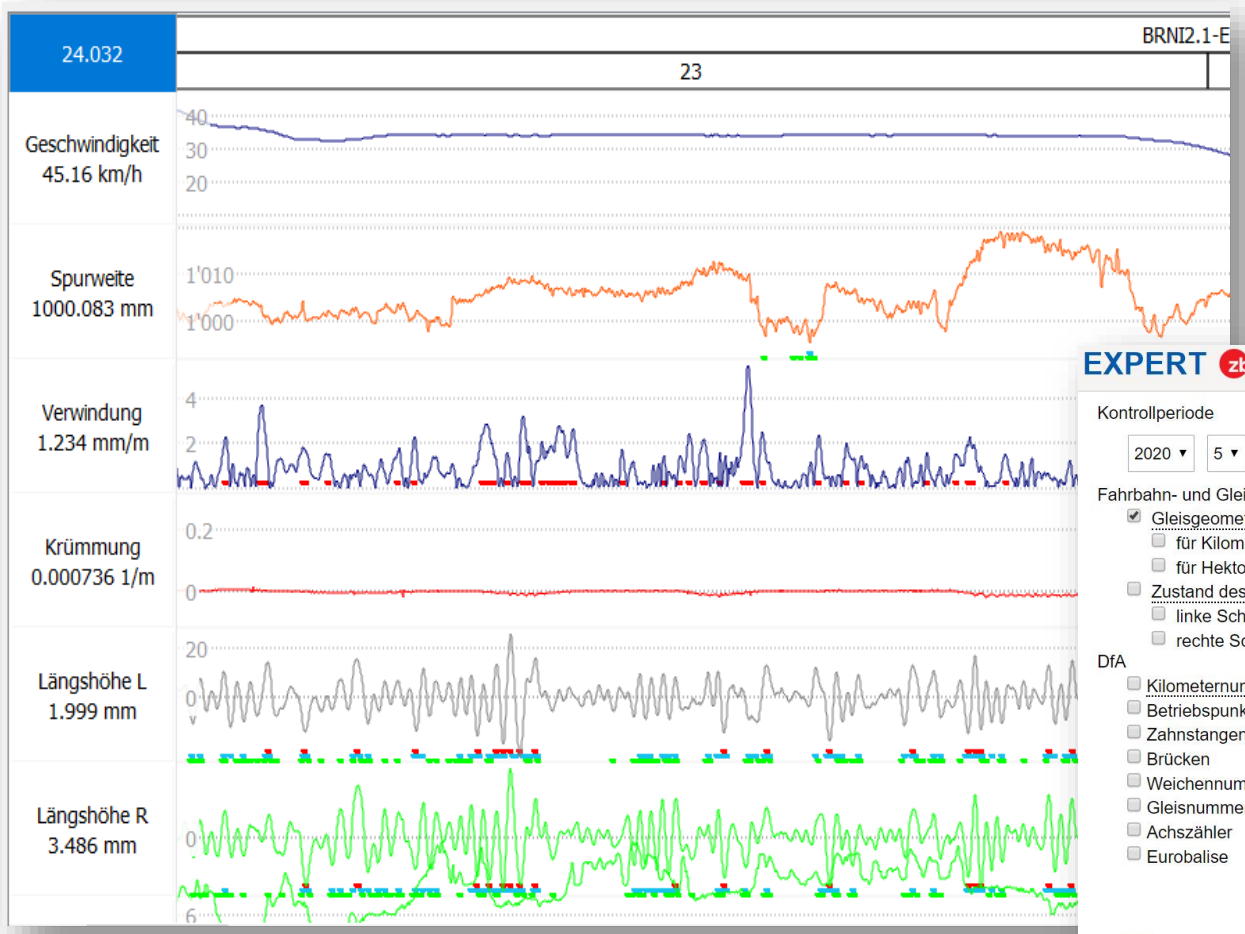
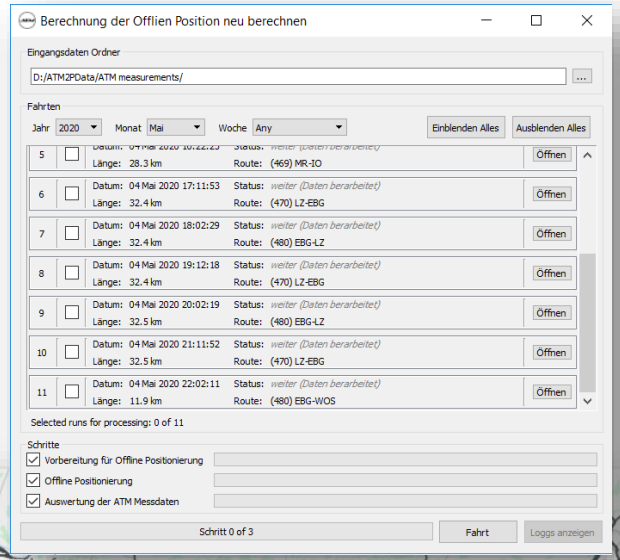
Tools for data processing and evaluation.

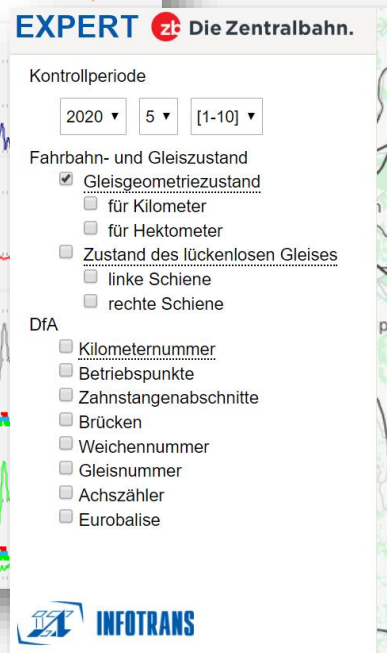
- Server at Zentralbahn:
  - OLauncher: for data preparation and positioning.
  - OViewer: Evaluation of the measurement results incl. detailed deviations, consideration of limit values and observation of the rail profiles.
- FTP-server at Zentralbahn:
  - For data transfer to supplier.
- Expert: Summary of results and prognosis:
  - Web-based; Server at supplier (will be installed at Zentralbahn in the near future).

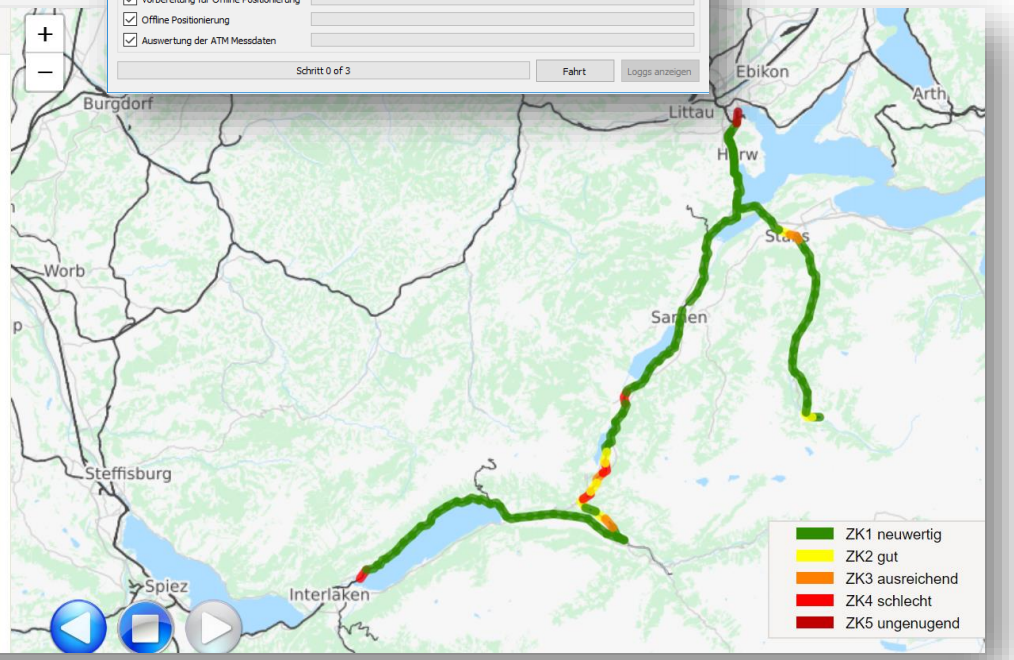


Tools for data processing and evaluation.









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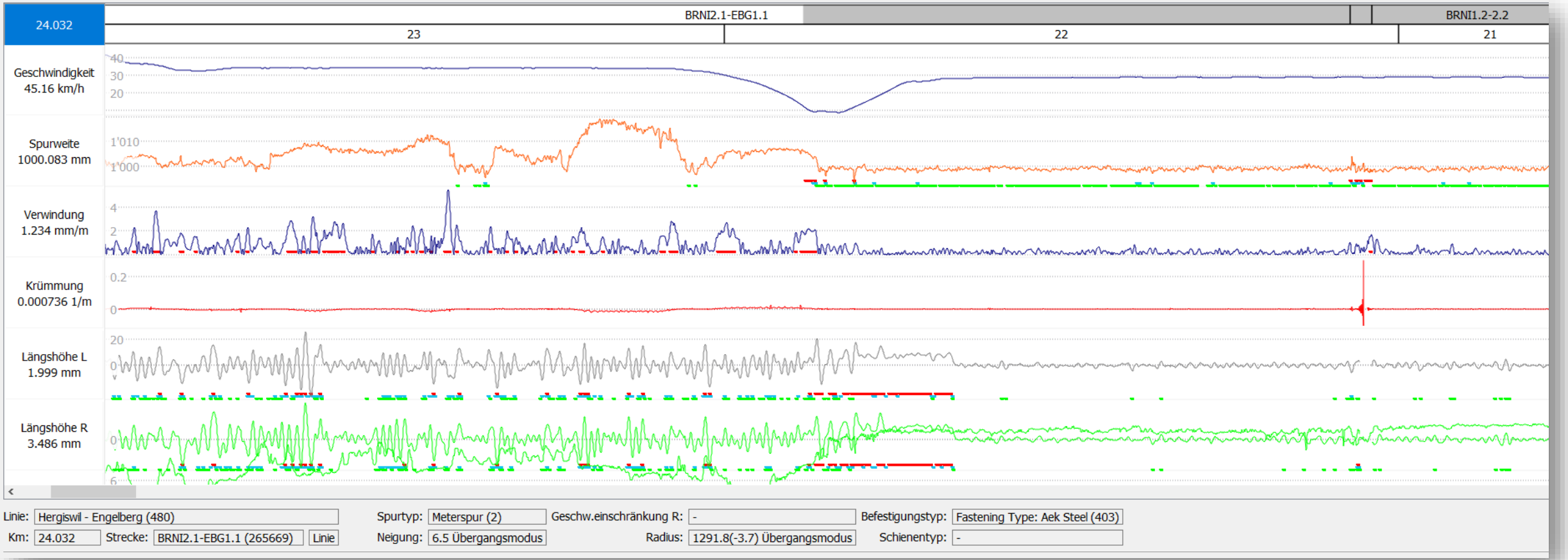
Evaluation.

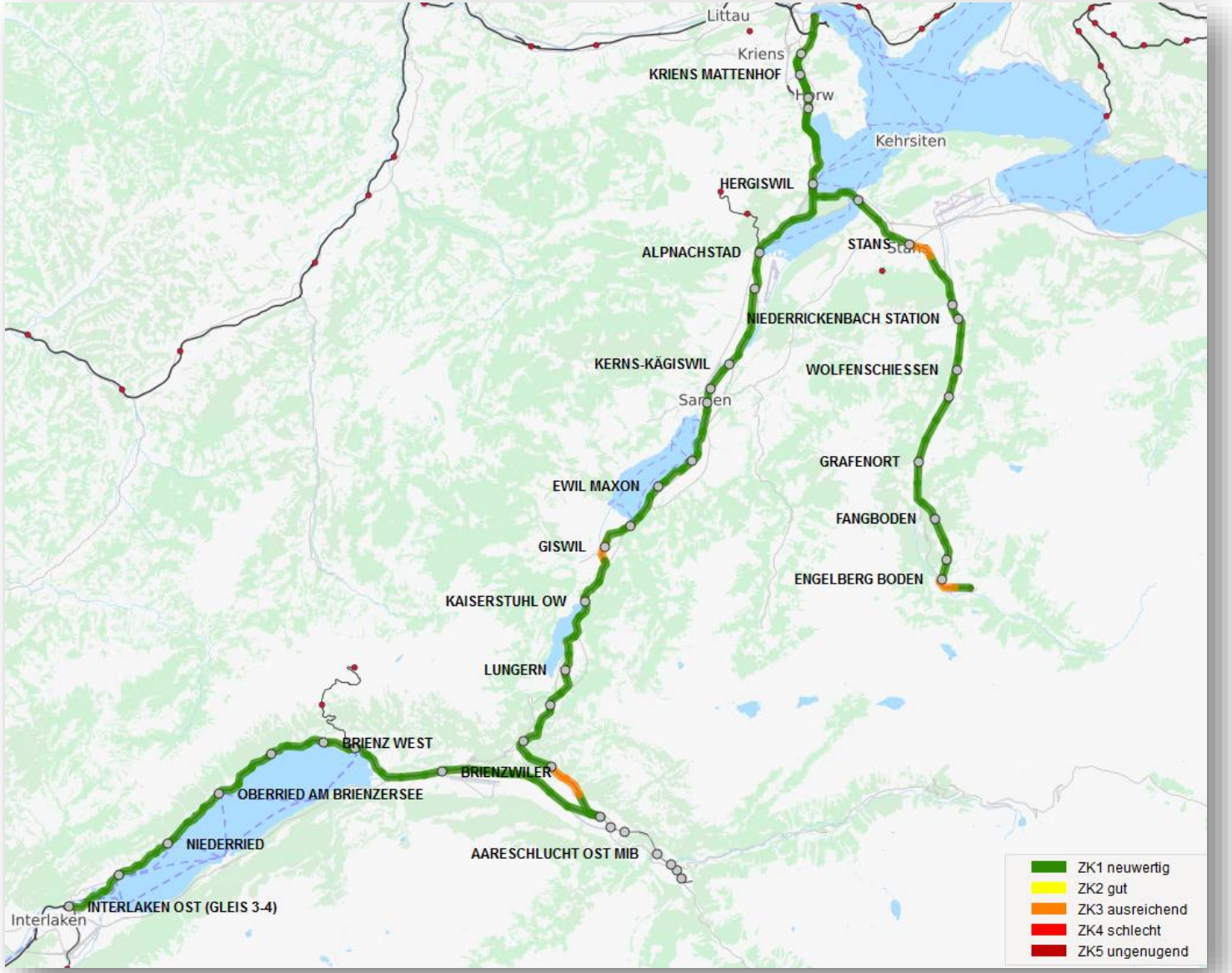
OViewer - Display of measurement results.



Evaluation.

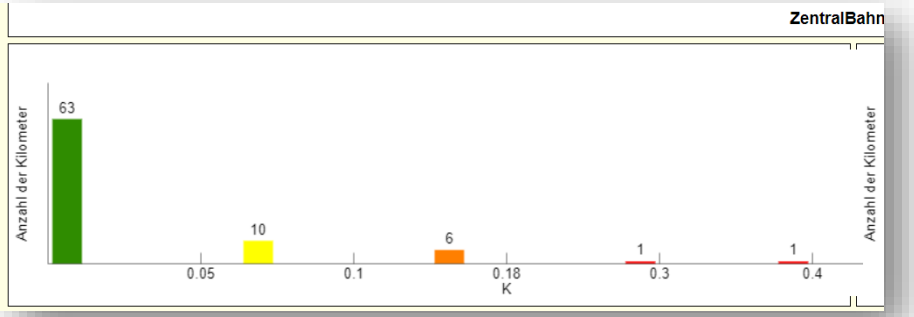
Expert – Forecasting.

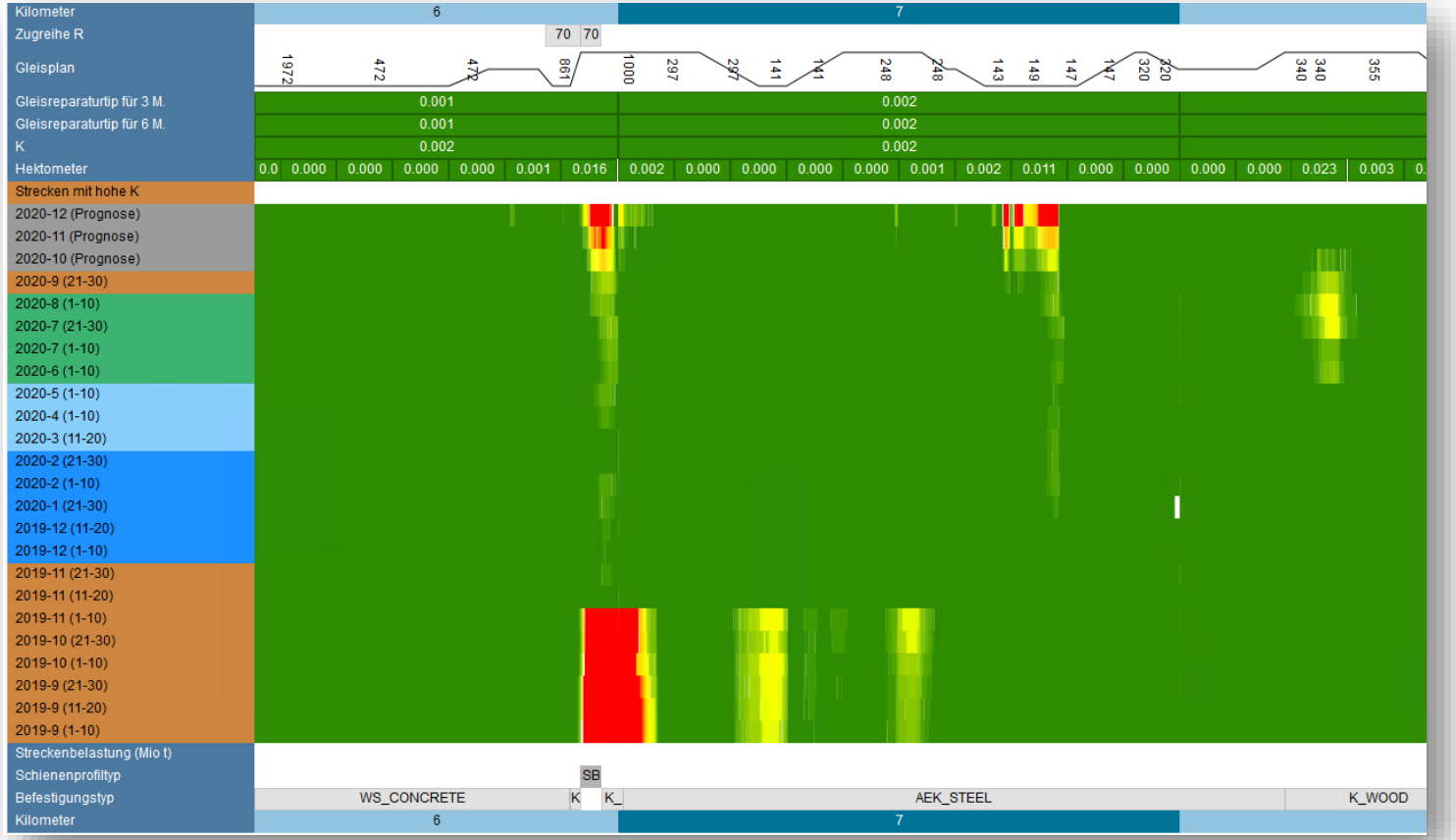
Current and future condition of the tracks.



Evaluation.

Expert – Forecasting.





8. The impact to track maintanance (after 5 years).

Track diagnostics on a regular passager train – vehicle-based track monitoring.

Influence of the on-board monitoring.

Changes in maintenance and renovation planning and connected processes.

- **Evaluations are incorporated into medium- and long-term project planning.**
  - Investment planning:
    - Project-specific planning until 2028.
    - Within the projects, there are adjustments or shifts in time prioritization due to the measurement data.

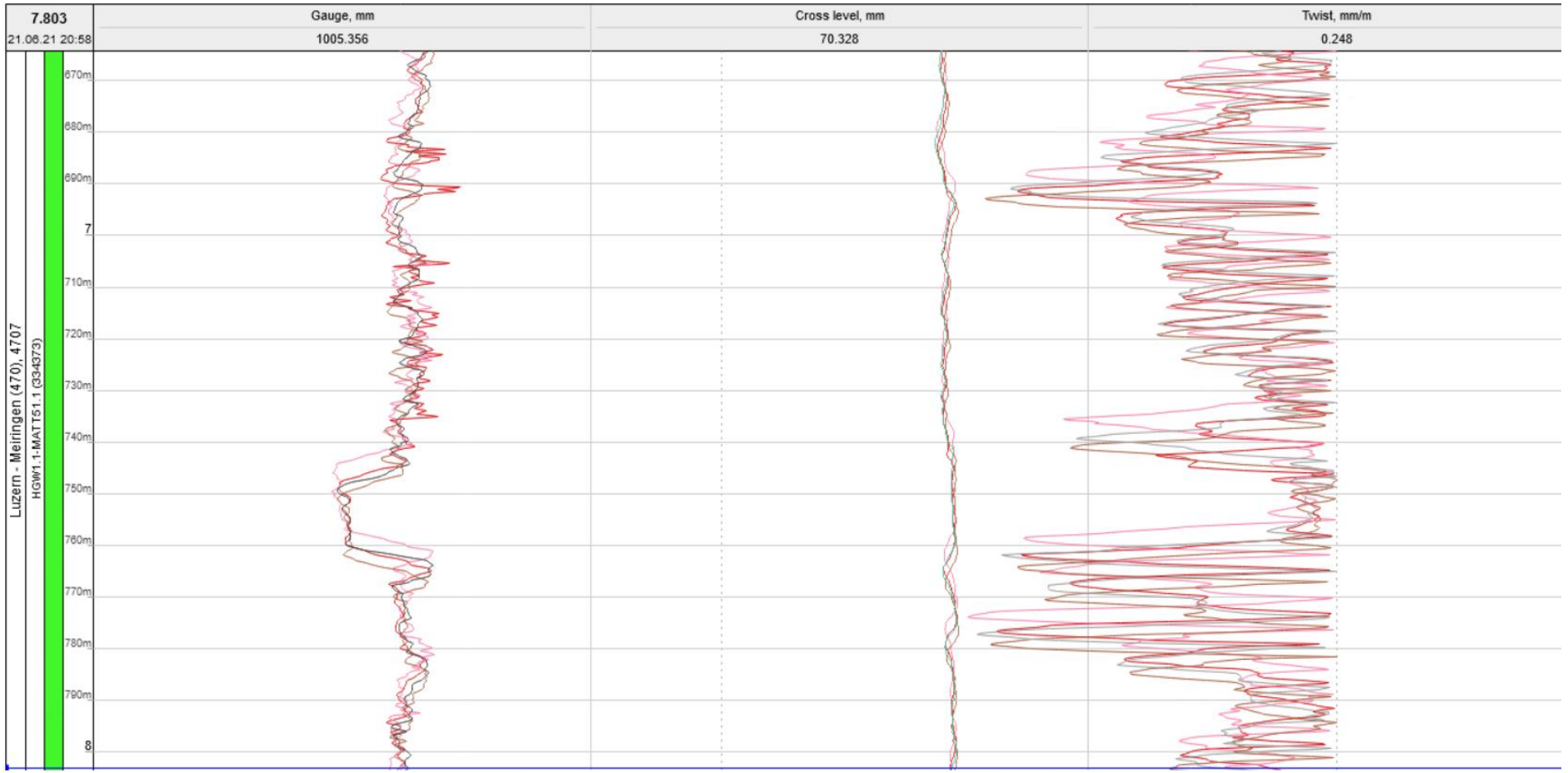
- Maintenance planning:
  - **Change from regular (time based) to condition-based maintenance.**
    - Has not been fully implemented yet.
    - In the medium term, cost savings in maintenance and further improvement in track conditions.

- Detecting faults in the track at an early stage:
  - Displacements of rails at neuralgic points in the network (tight radii).
  - Monitor construction sites close to the track (third-party buildings that cause damage to the tracks).
  - This is possible thanks to relatively flexible scheduling and frequent inspections.
  - Acceptance runs after closures due to construction works.

Influence of on-board monitoring.

Example of monitoring at neuralgic points in the network.

Linie 470: Horw – Hergiswil; Steinibach curve R = 149

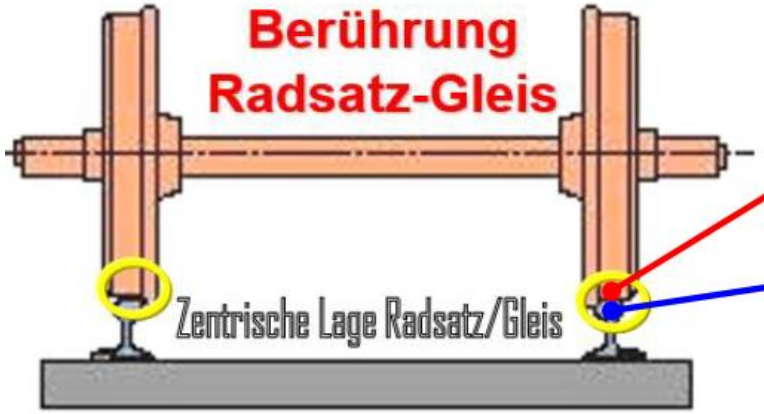


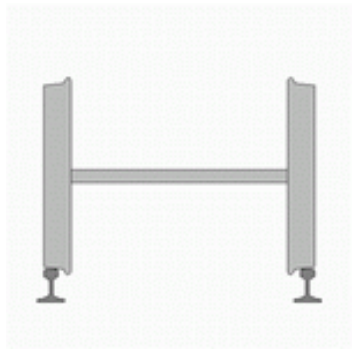
Software adaptations for comparisons of time-following measurements and comparison of individual geometry values.

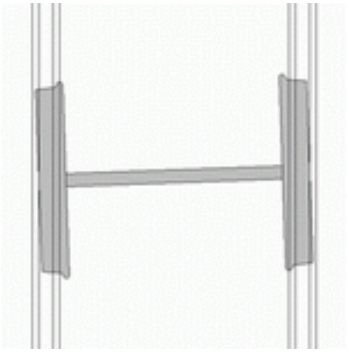
Analysis of the contact geometry of wheel and rail.

Where does a wheel run on the rail head? In the straight? In the bow?

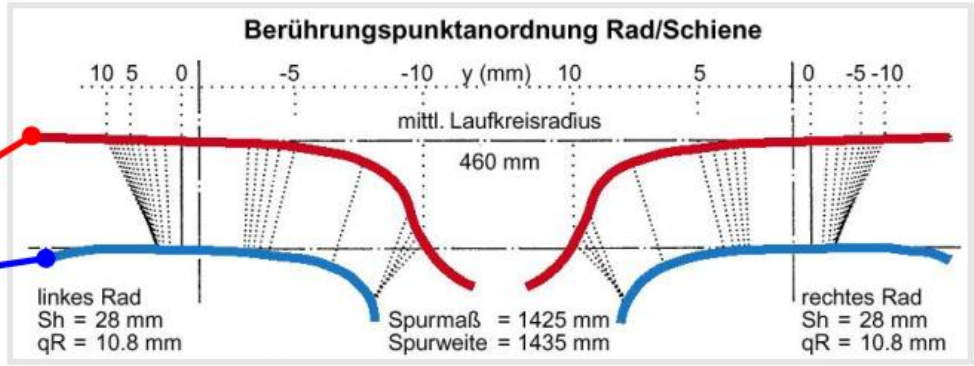
- Both the wheel and the rail have a defined wear-optimized profile.
- For an optimal wheel-rail contact, the contact geometry must be correct.
- In the straight line, a wheelset runs in sinusoidal mode (animations).
- Depending on the radius of the bow and the cross level, other points of contact are set in the arc.
- Due to wear and tear during operation, the profiles of the wheel and rail change.

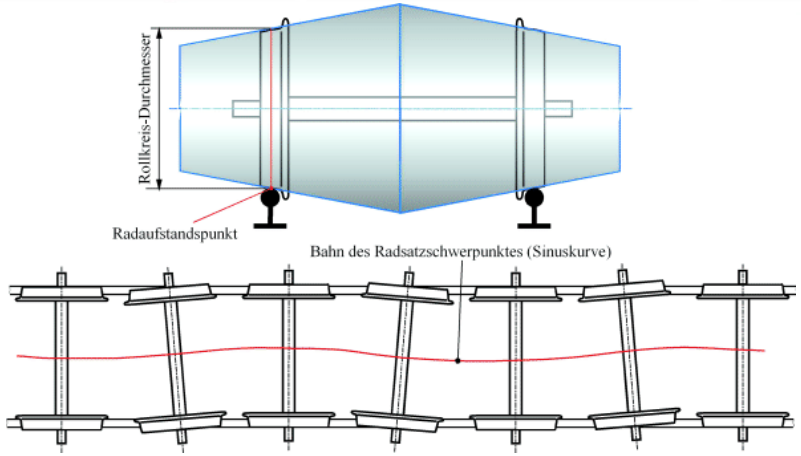






Touch geometric interaction



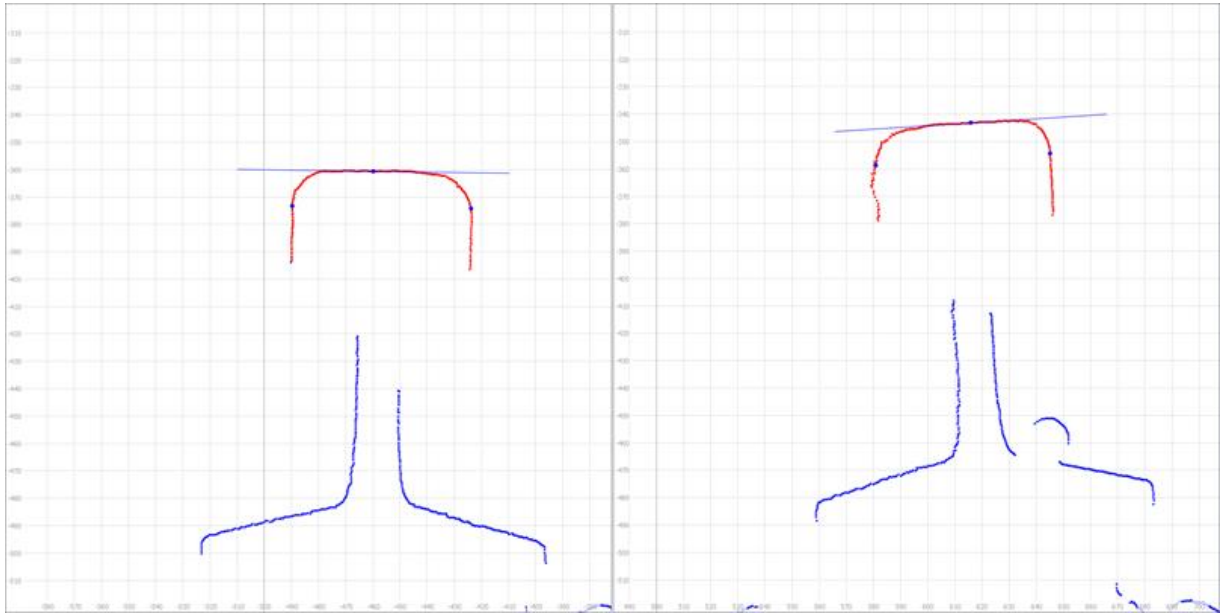


Grafiken: Roland Müller (Gleislauftechnik) & Wikipedia

Track diagnostics on the regular train.

Example of the interaction of wheel and rail (touch geometry).

- For a touch geometric analysis, both real wheel and rail head geometry data are required.
- The wheel profiles are measured in the workshop during periodic maintenance.
- ATM measures the rail head geometries throughout the whole network.



Inside of the curve

Outside of the curve

Measurement as of October 11, 2022, 9:14 p.m.
Line 470 – Km 7.695 Steinibachkurve
Right-hand bend with radius 149m
Track gauge of 1003,857 mm

9. Insights / Conclusion.

Track diagnostics on a regular passager train – vehicle-based track monitoring.

Cognitions.

- The Zentralbahn network has some sections with faults in the superstructure. However limit values for intervention thresholds are not fully defined.
- By measuring under load, weak points were found that were previously unknown.
- The system allows measurements with high accuracy during regular operation.
- For optimal forecasting, data of at least two years must be stored.

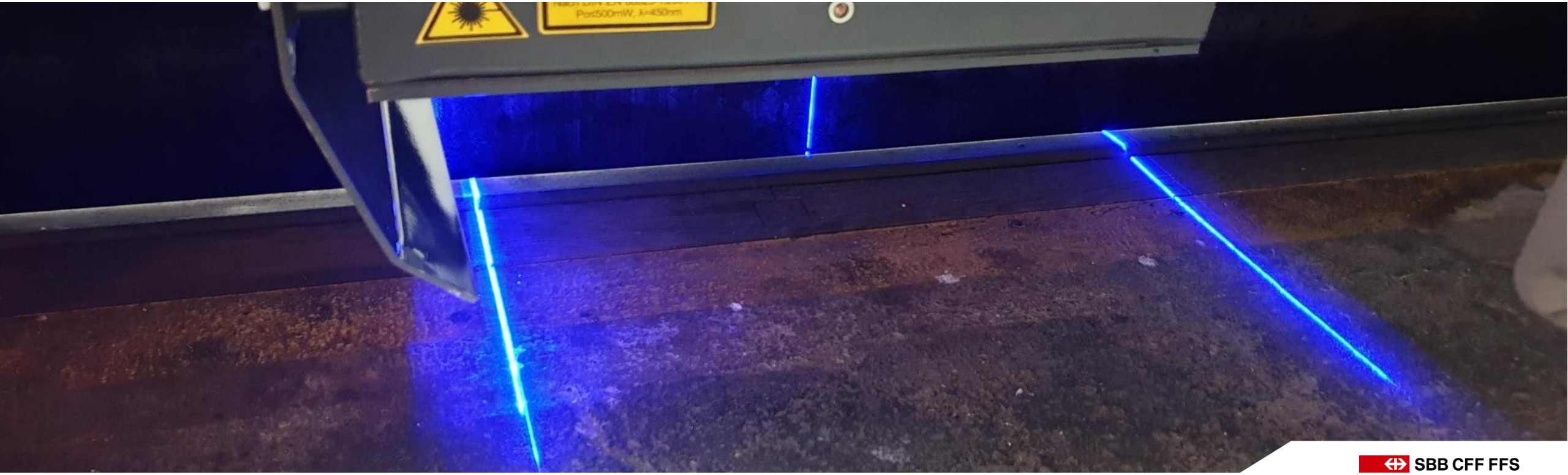
Result.

Advantages.

- Operation and data transmission is carried out from the office.
- Convenient tools make it easier to interpret the data.
- Maintenance can be carried out on a condition-related basis instead of a time base.
- Better condition of the superstructure.
- Reduction of maintenance costs in medium terms.

Next steps.

- Further improvement of internal processes to deal with the high amount of data.
- Improvement of the positioning system by integrating GPS-signals.
- Change of the system for forecast to become independent from the Russian supplier.



Thank you very much for your interest and attention.