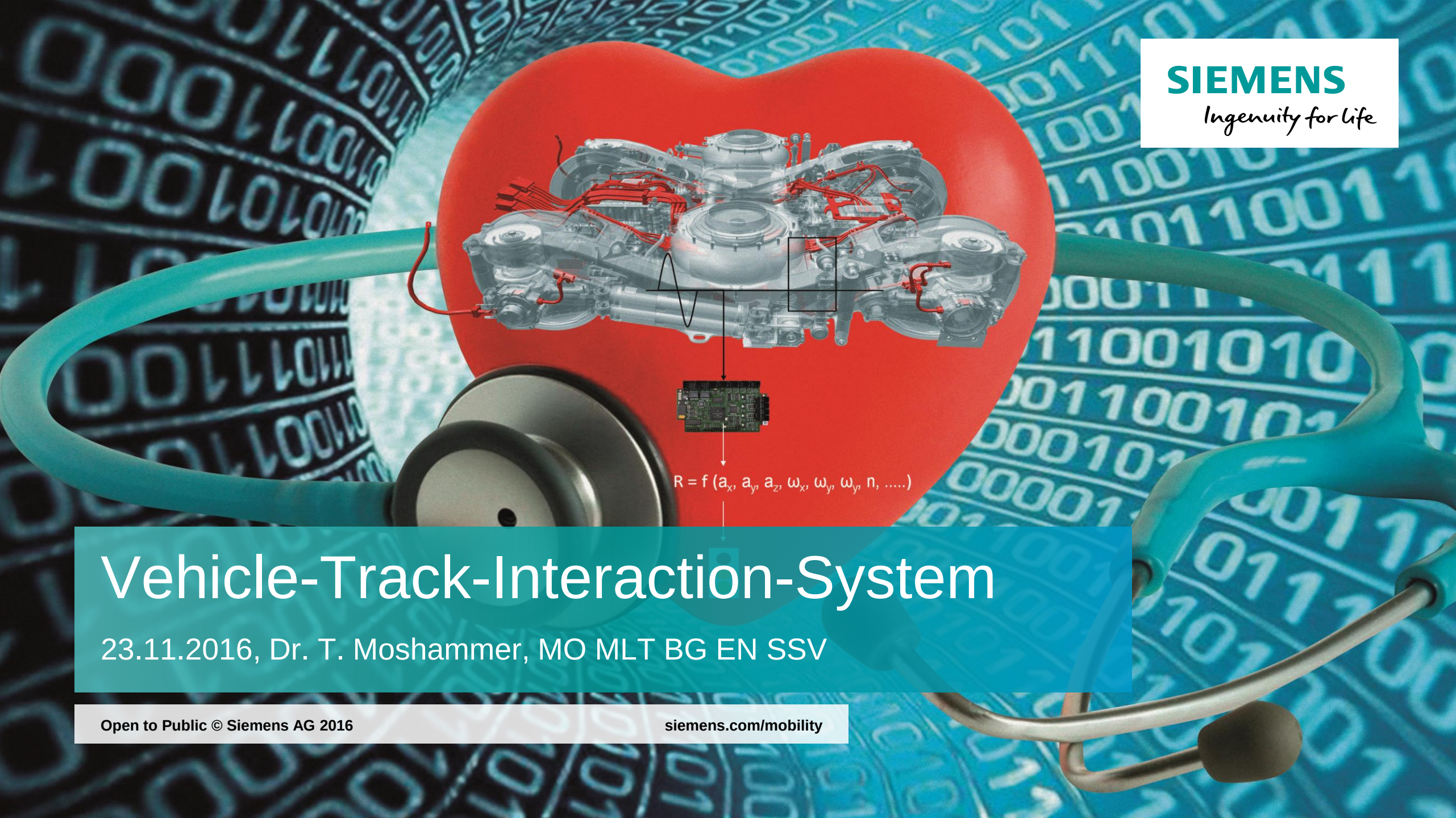

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Ingenuity for life

Vehicle-Track-Interaction-System

23.11.2016, Dr. T. Moshammer, MO MLT BG EN SSV

Dr. Thomas Moshammer: Vehicle-Track-Interaction-System
Contents

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CONTENTS:

- The history in the development of the SIEMENS Vehicle-Track-Interaction System…
- Why is a Track-Vehicle-Interaction so important?
- What is a Vehicle-Track-Interaction Monitoring System?
- Why might it be interesting to have a Track Monitoring System on a Train?
- What are the restrictions of such a Monitoring System?
- Summary

There is a long History in Development of Bogie Monitoring & Diagnostics Systems at SIEMENS! We are ready to use this Expertise!

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1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020

PC based System | **Generation 0.5** | **Generation 1.0** | **Generation 2.0**

1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019

First **Functional Prototype** in **ICE** between 2001 - 2004.
2 bogies equipped with sensors.
Data transfer with GSM

ICE 2, ICE 3 Roller Dynamometer

RUBIN Nürnberg
(driverless Metro operation)
Electronic Derailment Detection
Electronic Obstacle Detection
(SIL 3)
In operation since 2005

ÖBB 1116 (Taurus)
In operation 2008 - 2013

Metro Warshaw

Metro Munich C1

Metro Munich C2

Velaro RUS
2010-today

Velaro D

Velaro Eurostar*

Metro Klang Valley

Charger Locomotive

Metro Riyadh

PKP

Icx*

RRX

Why is the Vehicle-Track-Interaction so important?

Why is the Vehicle-Track-Interaction so important?

- The **vehicle-track system** has to be **maintained** that **save operation** is possible and **guaranteed**
- **Unsave** in this context **means high forces, high wheel unloading**, **high strike angles**, **high slippage** in the wheel-rail contact
- Essential is the **wheel-rail-interaction** because it determines the **height** of the **interacting terms** (forces, slippage, accelerations, etc.)
- That makes **measurements** of the **interaction** of **vehicle and** track essential for maintenance
- Diagnostics of the vehicle track interaction would help to make an **accurate prediction** of the development of this interaction behavior possible

The Traditional Approach

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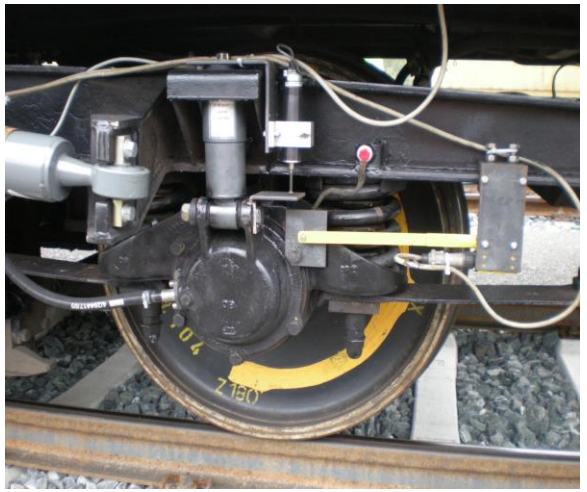
Vehicles are assessed separately…

- **Testing** for the acceptance of running characteristics of railway vehicles according to **EN14363**
- **Periodical Maintenance** Intervals according to the maintenance handbook
- **Visual Inspection** of parts
- **Measuring** of wearing parts (e.g. wheel) and crack detection
- **Exchange** of **Components** according to the maintenance plan or after measuring
- **Test drives** after maintenance works
- …



The Traditional Approach

…Tracks are assessed separately

- **Visual Inspections** of tracks
- **Observations** by the **train driver** and the train crew
- **Measurements** of **track geometry** with **track recording cars**
- **Measuring** of wear of the track, switchings, etc.
- Crack detection of components of the track...

The Traditional Approach

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Vehicles are assessed separately …

…Tracks are assessed separately

Rarely consideration of the interaction between vehicle and track,

rarely permanent diagnostics

The traditional way of diagnosis of the interaction between train and track shows the opportunity of improvement

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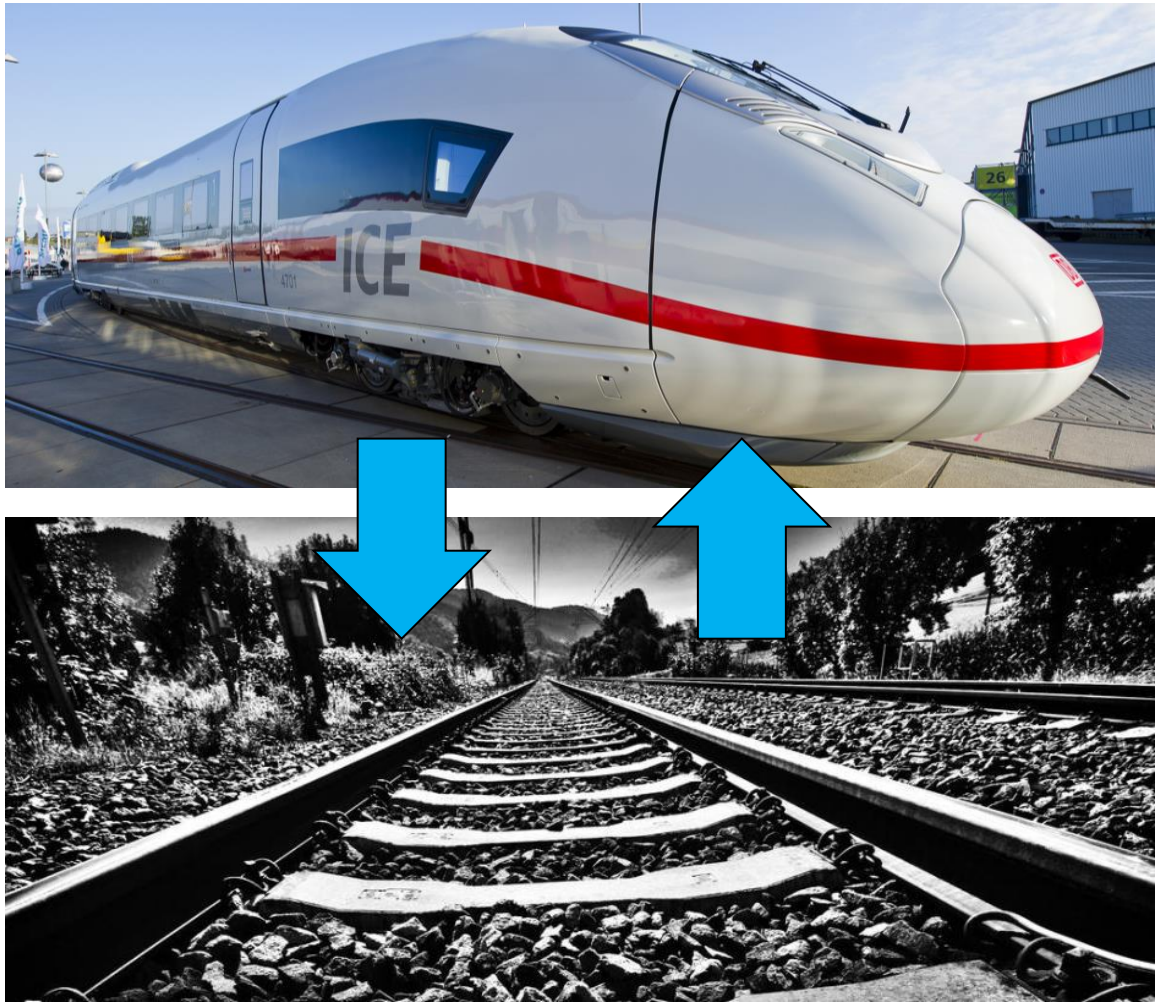
- **The two subsystems vehicle** and **track** are considered **stand alone**
- **Diagnosis** is **not** performed **continuously** but in periodically defined time schedules
- **Not** the **interaction** itself is **considered** but quantities which are assumed to affect the interaction between vehicle and track

- **It would be perfect to have a permanent diagnosis of the interaction between vehicle and track.**



There are several possibilities to diagnose several aspects of the interaction permanently

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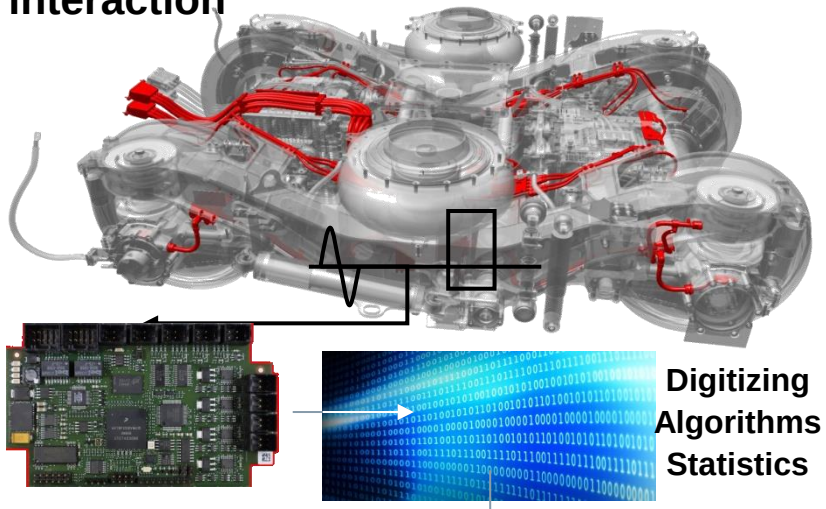
The SIEMENS Bogie Diagnostics System (SBDS) is a sensoric system for the identification of the behavior of the system bogie and the vehicle track interaction



$R = f(a_x, a_y, a_z, \omega_x, \omega_y, \omega_y, n, ...)$

State Predictions,
Maintenance Instructions

„It would be perfect to have a permanent diagnosis of the interaction between vehicle and track."

Approach: Bogie Diagnostics and Vehicle Track Interaction System

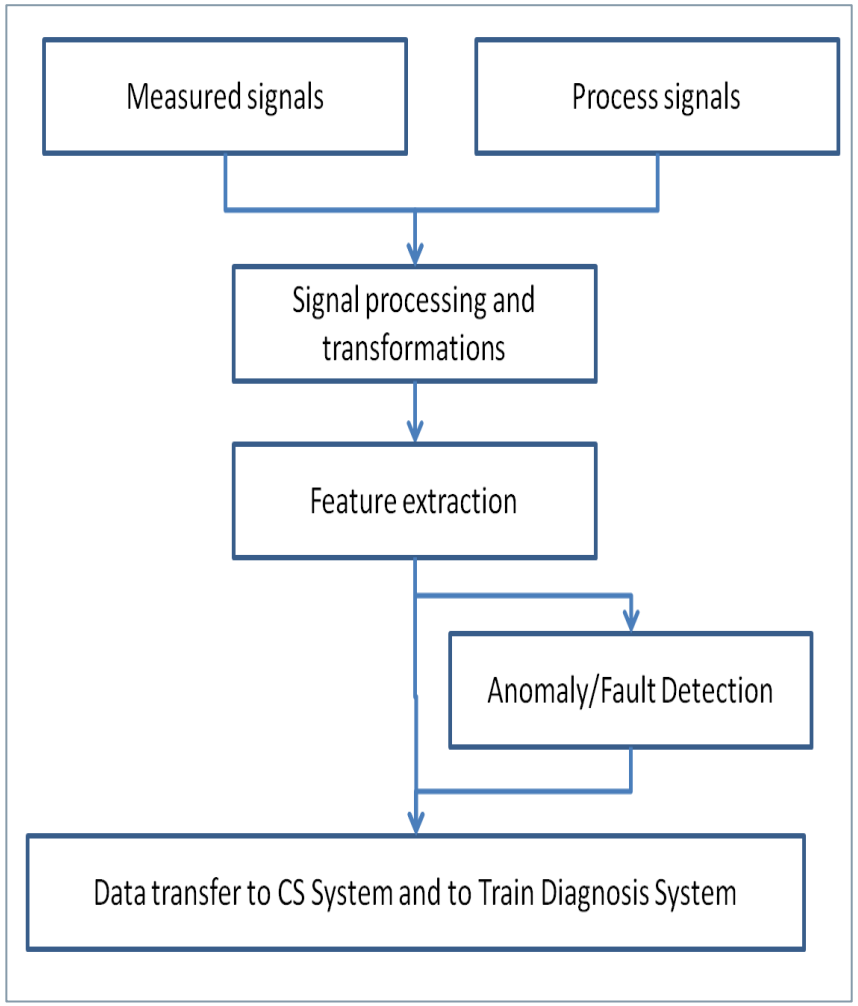
- Bogies with sensors which measure significant movement quantities and thus capture the impacts of the interaction between vehicle and track.
- With this Vehicle-Track-Interaction-System abnormal behavior is detected.
- Changes in the behavior of bogie components are detected as well.

Main benefits:

- Condition-based maintenance of bogies becomes possible.
- Corrective maintenance measures become predictable.
- Components can be used for a longer period (utilization of the individual service life)

Side Effect: Interaction-relevant condition of the driveway is recorded!

The development of efficient diagnostics Systems is complex and challenging



In the development of an **effective diagnostics system** a set of **interdisciplinary competences** are necessary:

- Development of **“rail-operation-resistent” Sensors** and **Electronics**
- Modern methods of **signal processing** and anomality/fault detection
- Knowledge of the **system behavior** of rail vehicles
- Knowledge of the operational necessities and technical possibilities for the **optimization of maintenance processes**

The way from OnBoard Diagnostics to Maintenance Process Optimization needs a full IT-Integration of the Diagnostic Data in the Maintenance System

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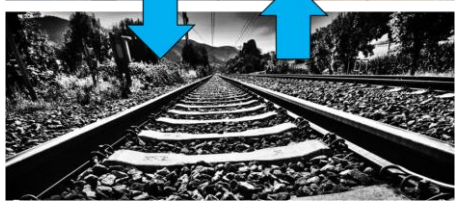
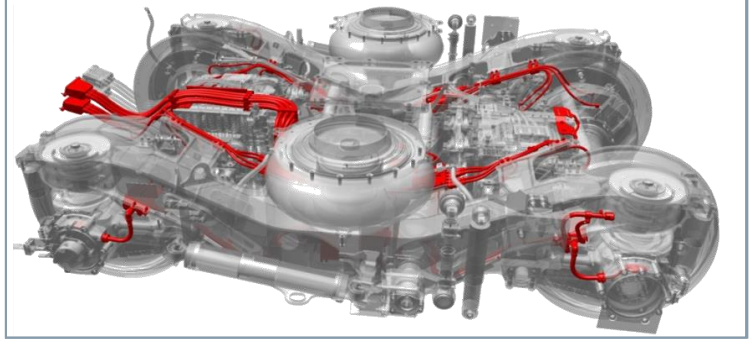
OnBoard Diagnostic Systems

Vehicle-Track-Interaction


Bogie-Diagnostics



Diagnostics Infrastructure

Data Transfer to Landside

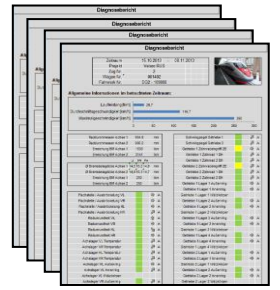
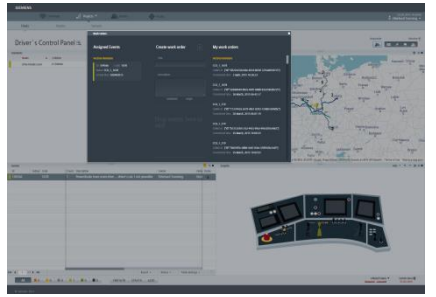
Cellular Infrastructure

Landside IT Infrastructure

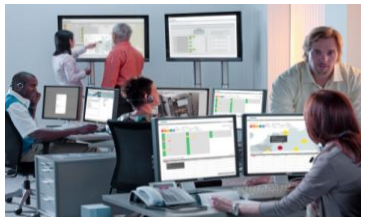
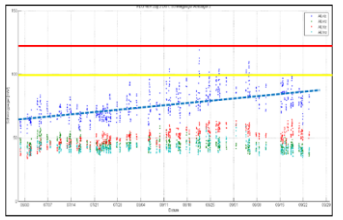
Human Machine Interface for Diagnostics Personal


Maintenance Process Optimization

Fleet Analysis/Diagnostics Reports

Trend Analysis/Prognostics models

Maintenance Orders/Maintenance Measures


Siemens Bogie Diagnostics including the Vehicle Track Interaction System provides a wide range of functions

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SIEMENS Bogie Diagnostics and Vehicle Track Interaction System Functions

BHC Bogie Health Check

	ID Code	Function
✓	BFP	Bogie Finger Print
✓	RCD	Ride & Comfort Diagnostics
✓	EID	Early Instability Detection

FOD Field Operation Diagnostics

	ID Code	Function
✓	FOD	Field Operation Diagnostics

APF Advanced Prediction Functions

	ID Code	Function
✓	BWP	Brake Wear Prognostics
✓	WPP	Wheel Profile Prognostics
✓	RLP	Rubber Lifetime Prognostics
✓	LoCCo	Load Cycle Counter

WAD Wheel & Axle Diagnostics

	ID Code	Function
✓	ABD	Axle Bearing Diagnostics
✓	WD	Wheel Diagnostics

GMD Gear & Motor Diagnostics

	ID Code	Function
✓	GBD	Gear Box Diagnostics
✓	MBD	Motor Bearing Diagnostics

ACD Advanced Component Diagnostics

	ID Code	Function
✓	YDD	Yaw Damper Diagnostics
✓	ARDD	Anti Rolling Device Diagnostics
	WSGD	Wheelset Guidance Diagnostics

TSI Supervision

	ID Code	Function
✓	HBD	Hot Box Detection
✓	WMS	Wheel Monitoring System
✓	URD	Unstable Running Detection

GOAx Supervision

	ID Code	Function
	EDD	Electronic Derailment Detection
	EOD	Electronic Obstacle Detection

GID Gravel Impact Detection

	ID Code	Function
	GID	Gravel Impact Detection

TCI Track Condition Indicator

	ID Code	Function
✓	TCI	Track Condition Indicator

Siemens Bogie Diagnostics including the Vehicle Track Interaction System provides a wide range of functions

OnBoard and Landside Solutions are needed!

Landside Diagnostics systems

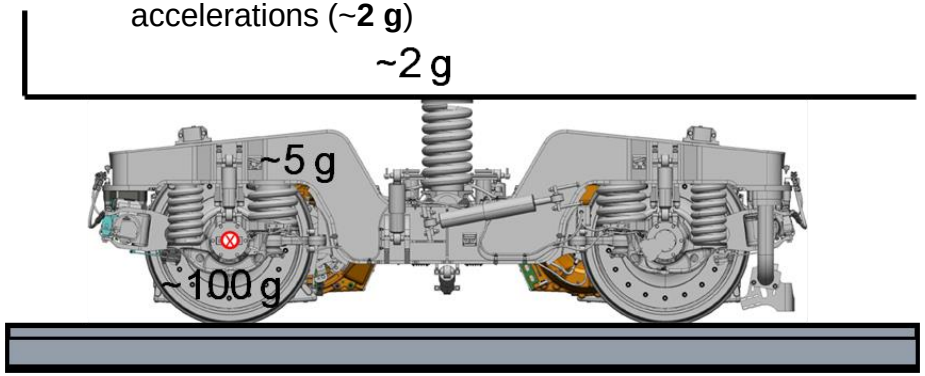
	ID Code	
✓	TDS	Train Diagnostics System
✓	CM	Configuration Management System
✓	BDES	Bogie Diagnostics Expert System
✓	TCIS	Track Conditon Indication System

5 Categories of Functions have to be distinguished

Acceleration and rotational speed sensors let the bogie „feel“

3 levels of acceleration:

- **Unsprung masses:** The area of the wheelset including the axle bearing box as the contact to the rail is the area of highest impacts to any bogie (~**100 g**).
- **Primary spring:** The frame and all frame mounted parts still have high accelerations (~**5 g**).
- **Secondary spring:** The carbody has low accelerations (~**2 g**)



Processing the measured data to messages (based on adjustable low/high levels) let the bogie „talk“.

- **Diagnosis of Components**
  - Algorithms detect defects of components
  - Examples: Axle Bearing Diagnostics, Wheel Flats, Polygonization of wheels, ...
- **Diagnosis of the System Behavior**
  - Algorithms analyze the dynamic behavior of the vehicle
  - Examples: Bogie Finger Print, Early Instability Detection, ...
- **Prognostic Models**
  - The wear influencing and component damaging quantities are measured and with models the remaining service life are estimated.
  - Examples: Brake Wear, Wheel Wear, …
- **Vehicle-Track-Interaction Diagnosis**
  - Accelerations in 3 Vehicle Levels (unsprung, primary spring, secondary spring level) are recorded and analyzed, high levels are transferred with GPS position to the landside
- **Supervision Functions**
  - TSI / GOA4 / Gravel Impact Detection

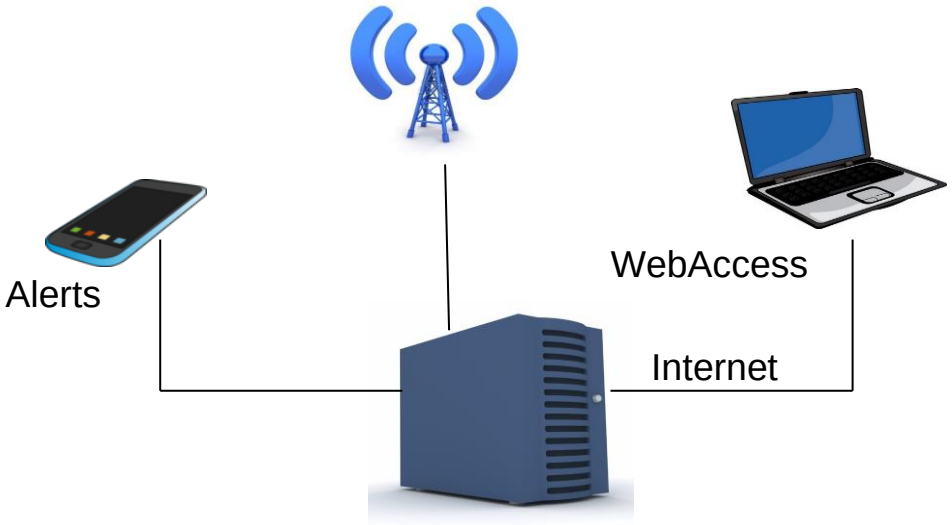
US Locomotive: Simple Vehicle Track Interaction System

OnBoard: Vehicle-Track-Interaction-System

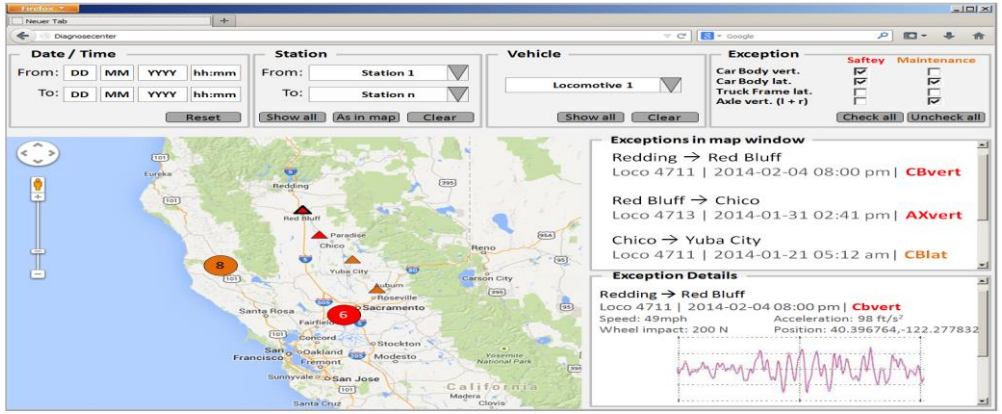
Cellular Infrastructure

Track Condition

- Sensors
- BMD — Bogie Monitoring & Diagnostics Electronics
- RDA — Global Positioning & Data Provider System



Landside: Vehicle-Track-Interaction-System



US Locomotive Charger: Simple Vehicle Track Interaction System

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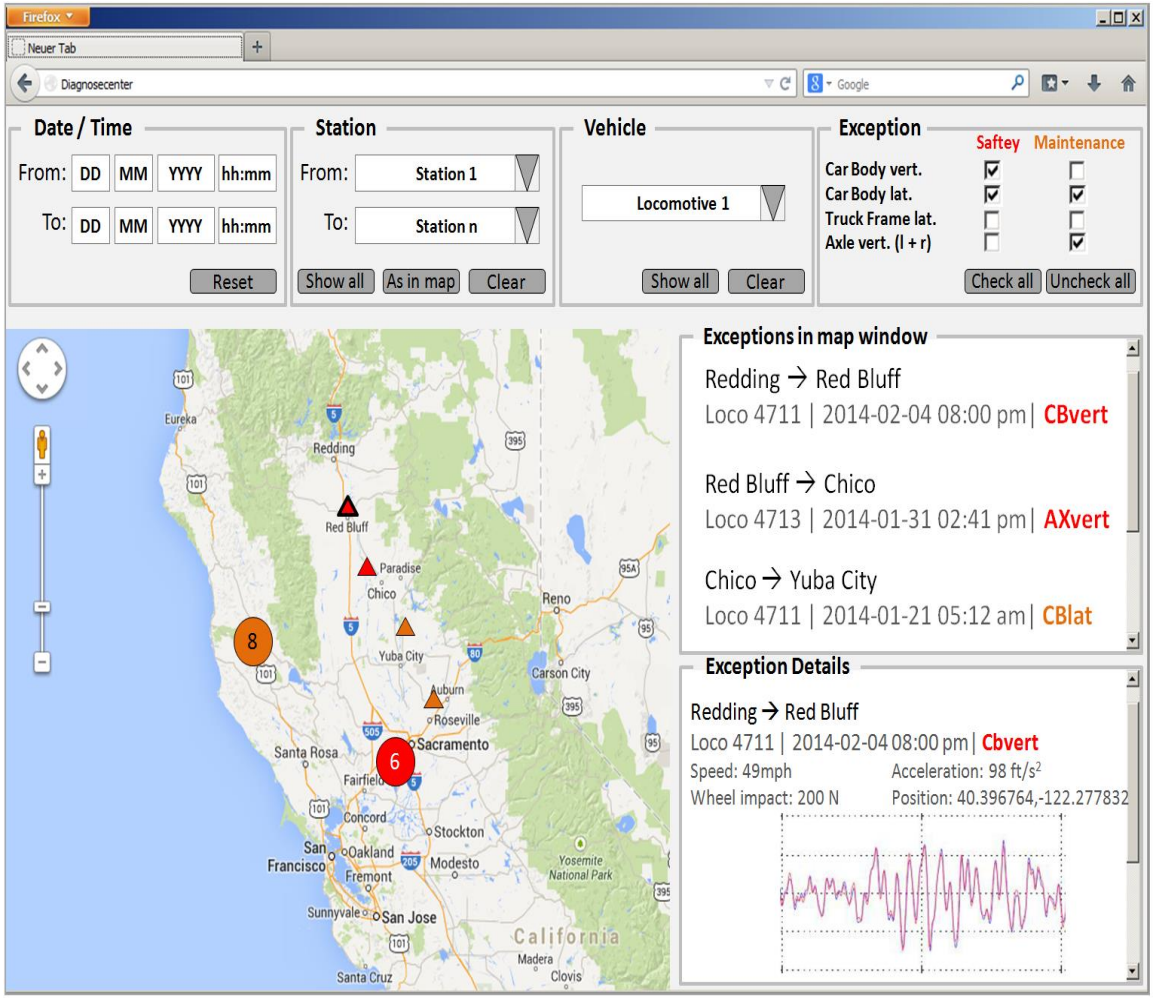
Vehicle-Track-Interaction-System Functions?

- Certain **acceleration limits (**Level Low / Level High) can be set individually for
  - Car Body vertical
  - Car Body lateral
  - Truck Frame lateral
  - Axle vertical left side
  - Axle vertical right side
- If this limit is reached in one of the positions this is sent to the **landside system** including additional data (raw data, velocity, GPS position, etc.)
- On the landside system **filter functions** help to visualize this information on a map or look on certain events.
- Additionally the **time history** is important to optimize track maintenance efforts



Landside: Vehicle-Track-Interaction-System (example)

Metro Operation: Vertical Error and Statistical Vehicle Values give valuable additional information analyzing the track

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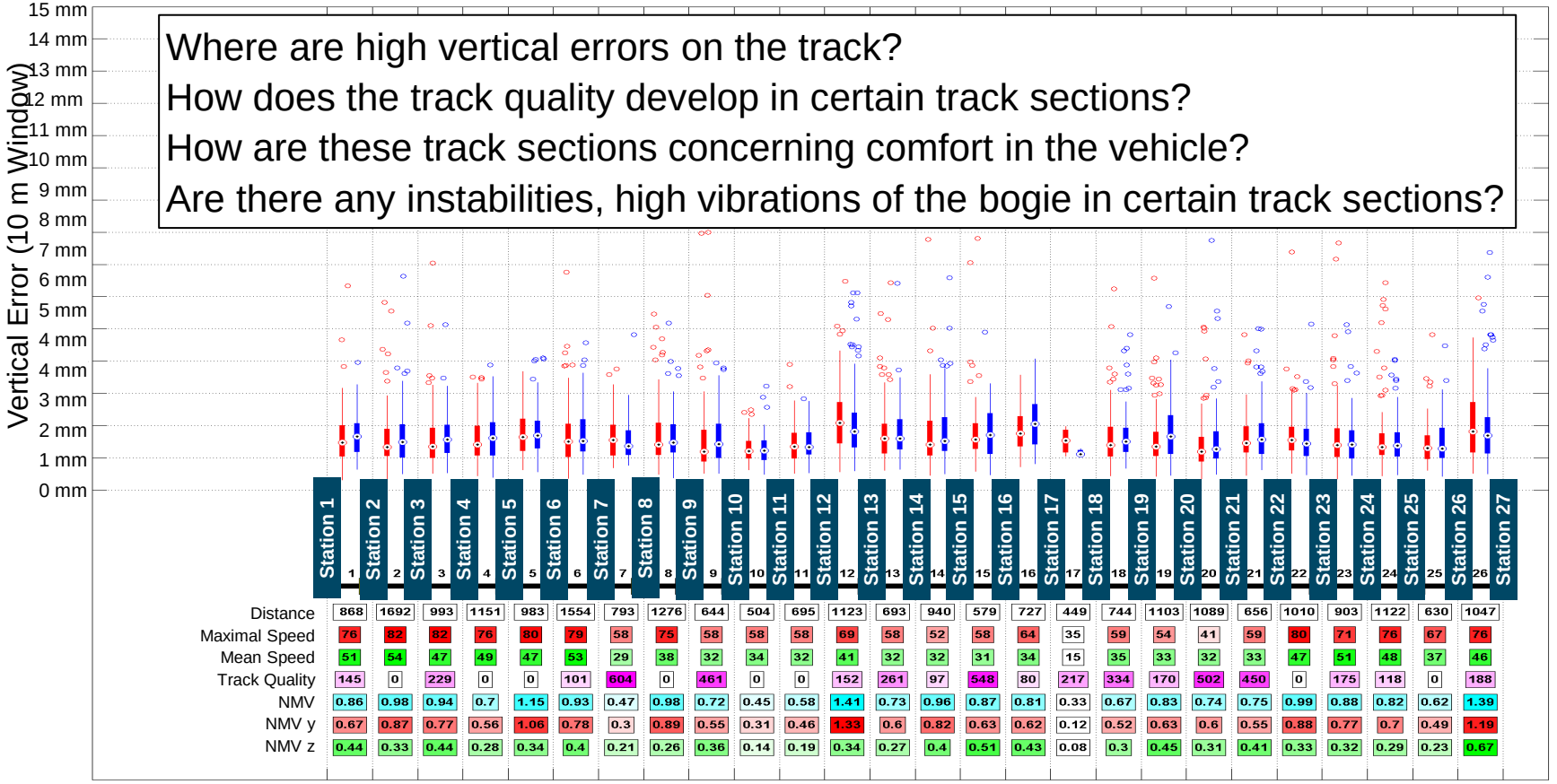
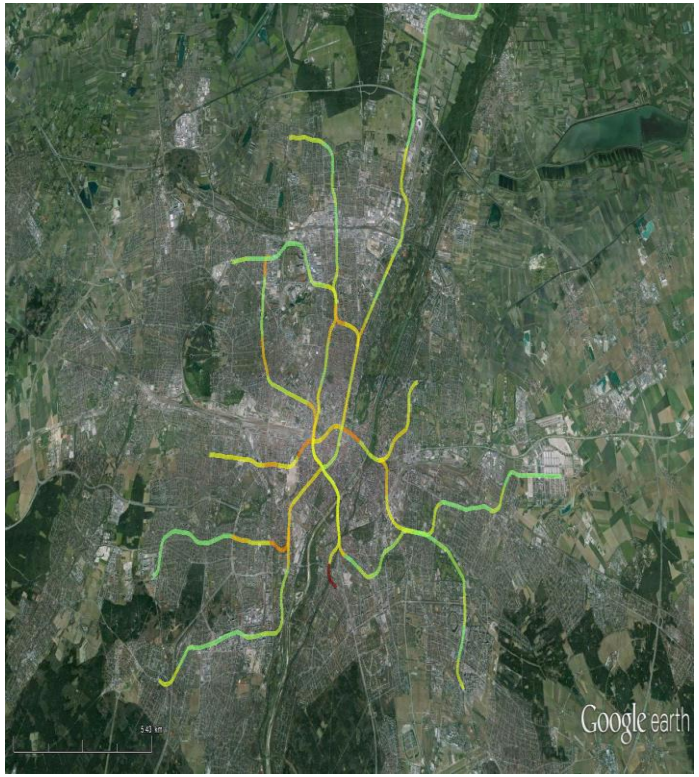
Statistical Vehicle Values give Additional Information Analyzing the Track

Where are high vertical errors on the track?
How does the track quality develop in certain track sections?
How are these track sections concerning comfort in the vehicle?
Are there any instabilities, high vibrations of the bogie in certain track sections?



Vertical track error (left side)



Metro Operation: Corrugation Characteristics can be determined and Grinding Results are rated

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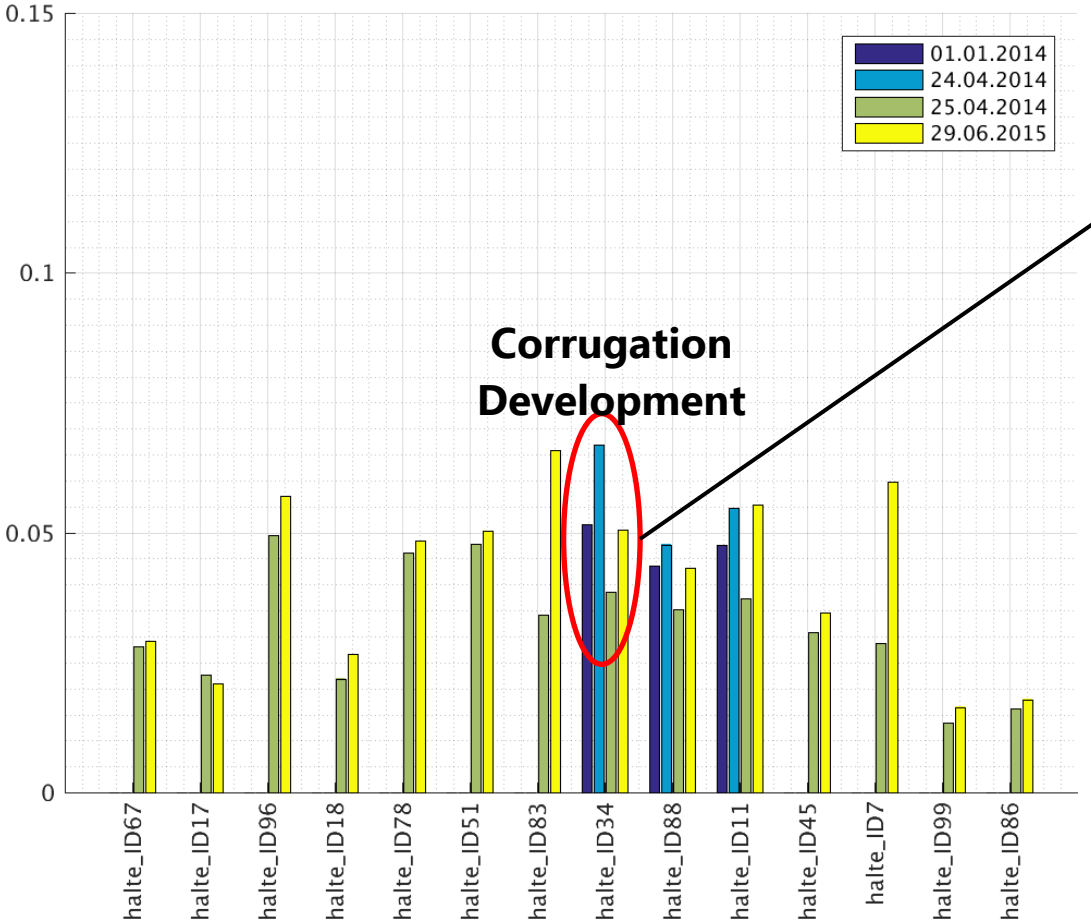
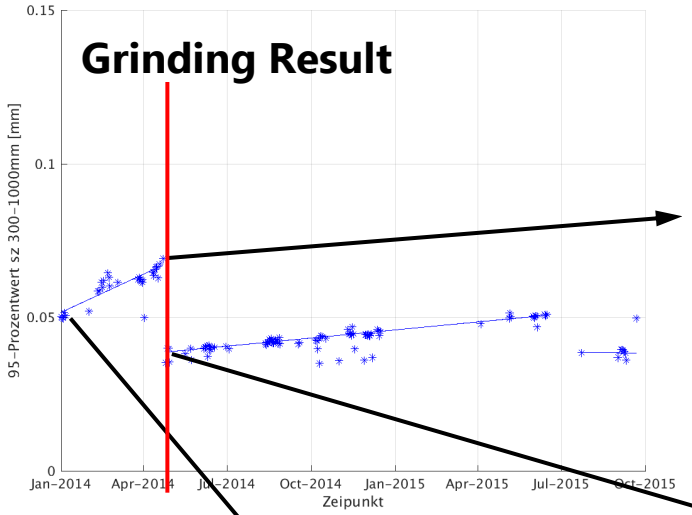
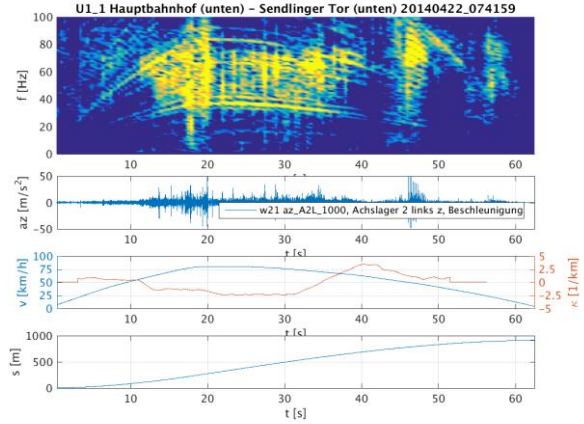
Corrugations: shorter wavelengths

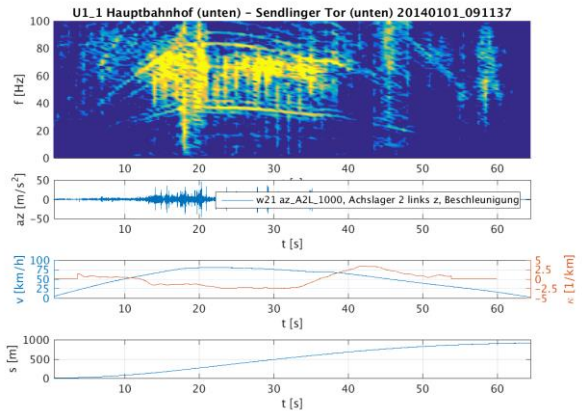


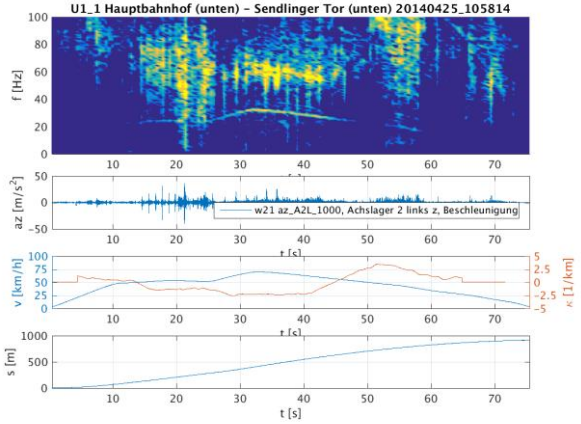




Before Grinding

After Grinding





Russian High Speed Train: Track Geometry Analysis according to Russian Track Maintenance Rules (Vertical Error)

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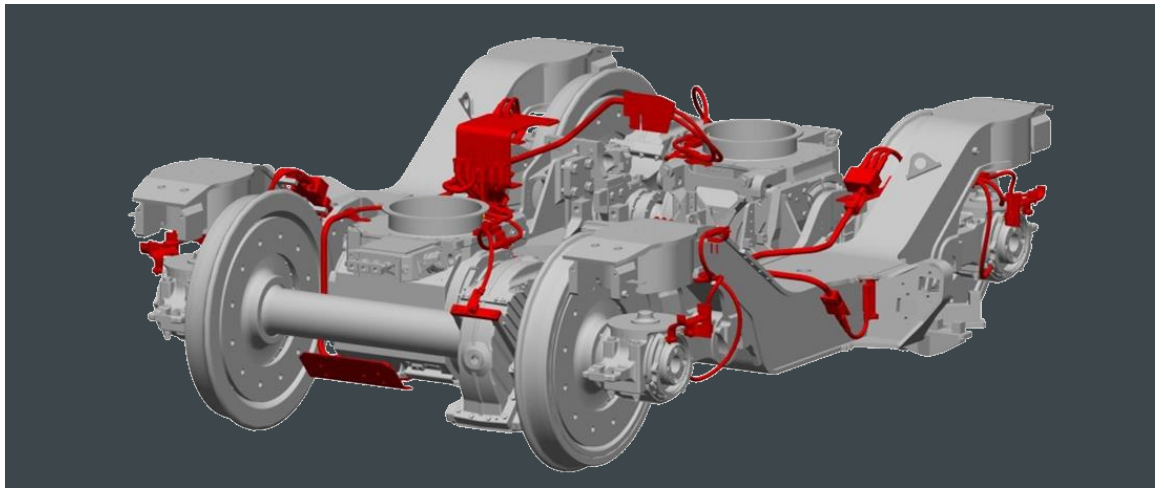
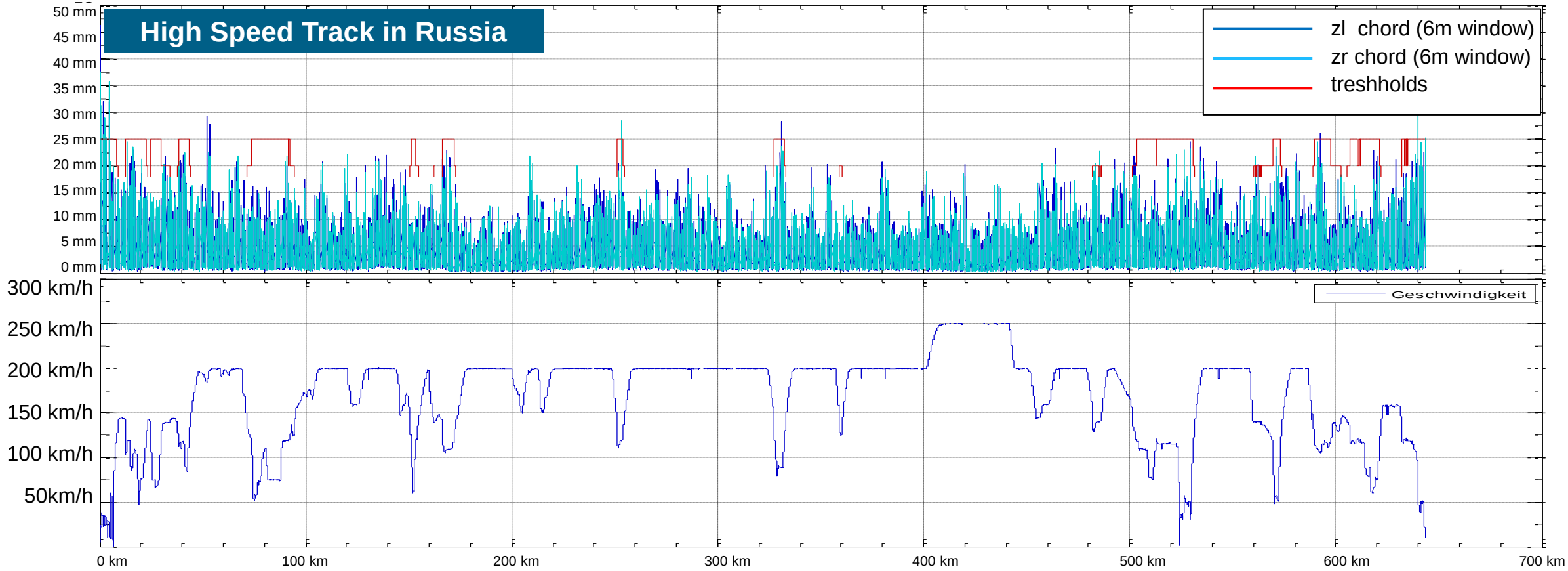
Typical Results from Track Analysis:

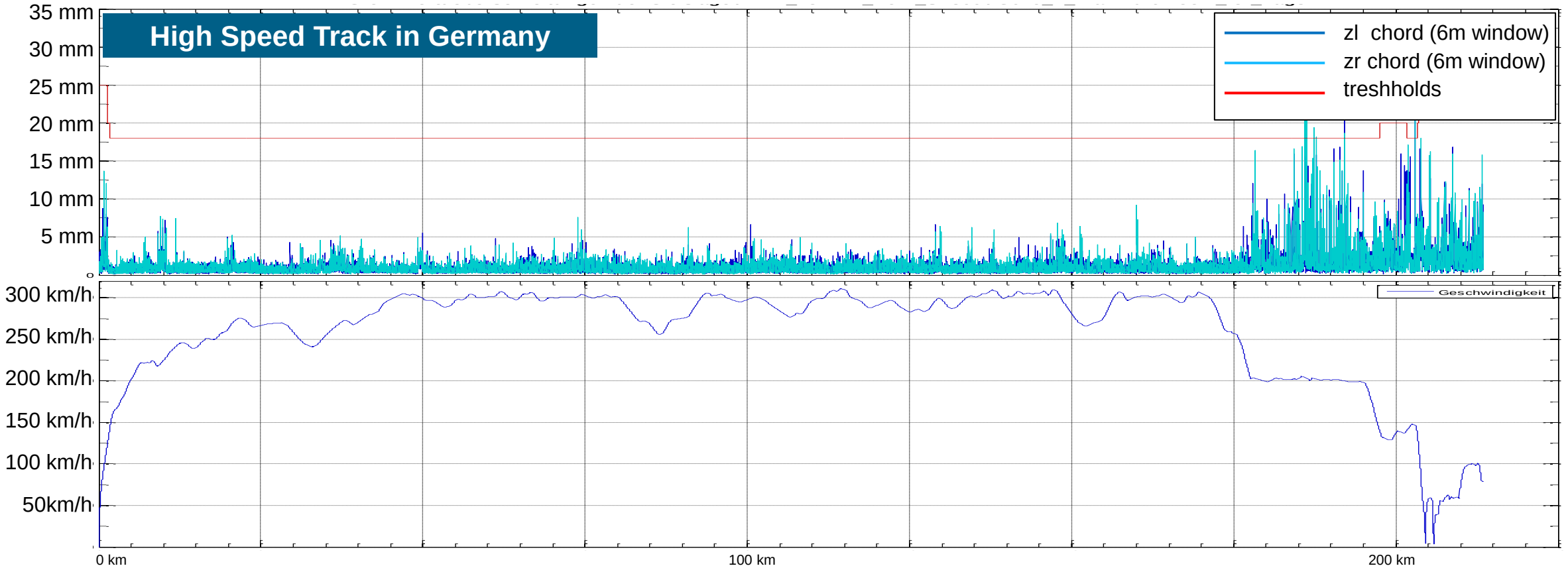
- The **acceleration** signals of the axle bearing housing are **double integrated** and the **vertical track error** is **calculated** with this procedure.
- These vertical errors are **analyzed according** to the **Russian chord measurement method** and are **rated** according to normative regulations **concerning track maintenance limits.**
- **Visualization** of track positions where the maintenance limits are exceeded.



Track Geometry Analysis: Vertical Error on a Sleeper Track



Track Geometry Analysis: Vertical Error on a Slab Track



High Speed Train: Track Geometry Analysis according to Forces on Components

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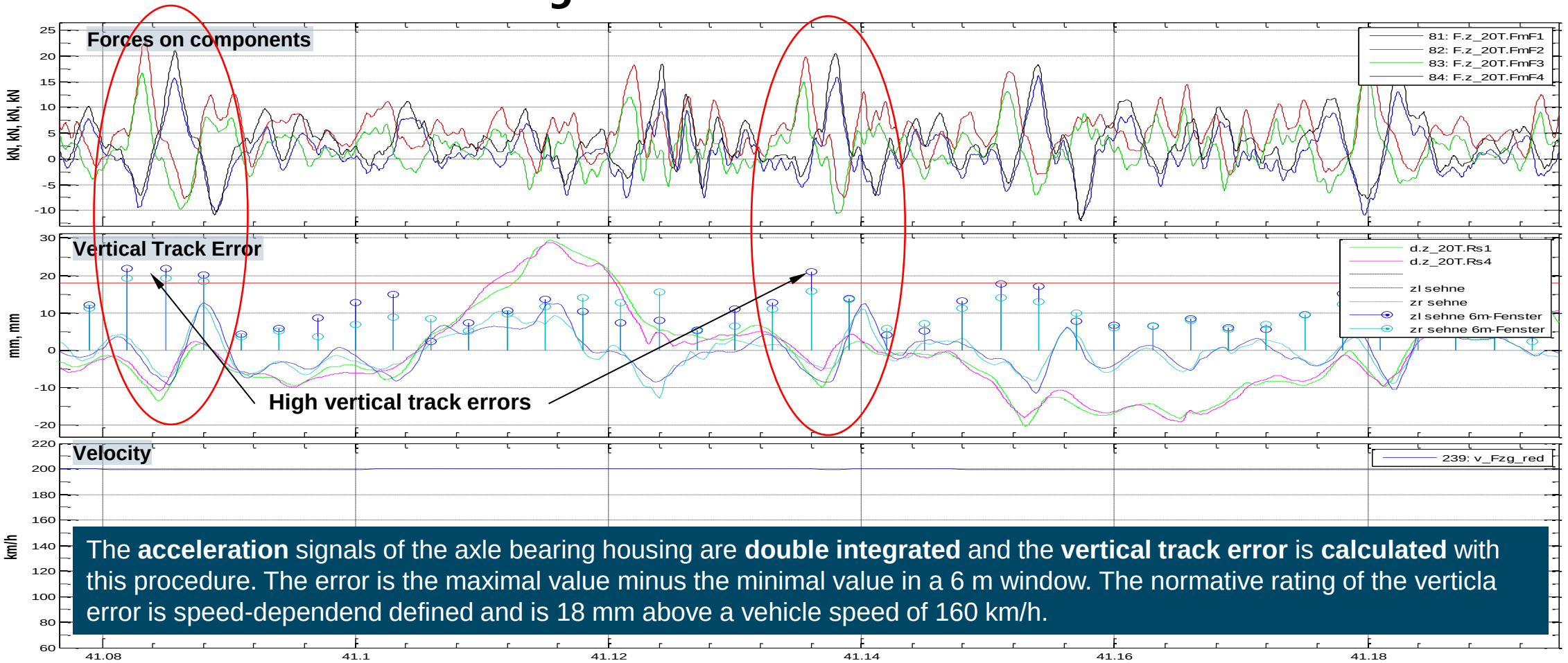
Vertical Track error according to the chord measurement



The **acceleration** signals of the axle bearing housing are **double integrated** and the **vertical track error** is **calculated** with this procedure. The error is the maximal value minus the minimal value in a 6 m window. The normative rating of the verticla error is speed-dependend defined and is 18 mm above a vehicle speed of 160 km/h.

High Speed Train: Track Geometry Analysis according to Forces on Components

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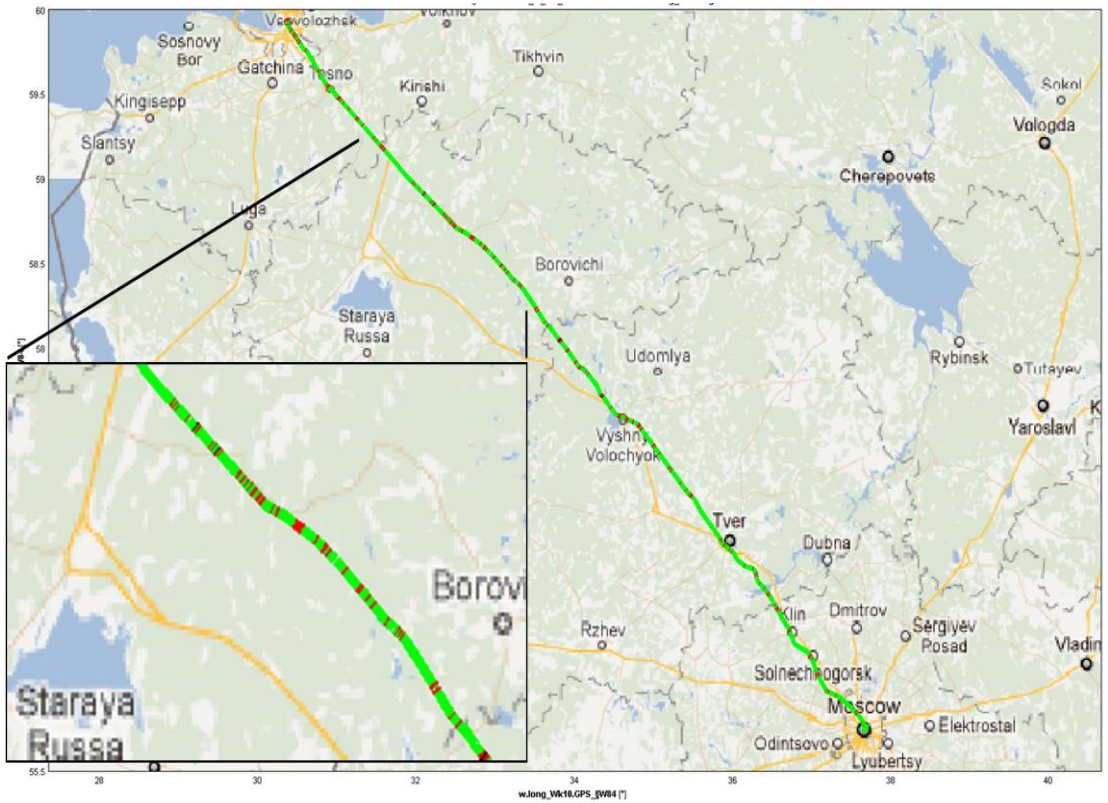
Vertical Track Error > 10mm



High Forces on Component > 15 kN

Not all high vertical track errors produce high forces on the leaf springs

→ wave length dependency

High Speed Train: The Vehicle Reaction on the Track changes

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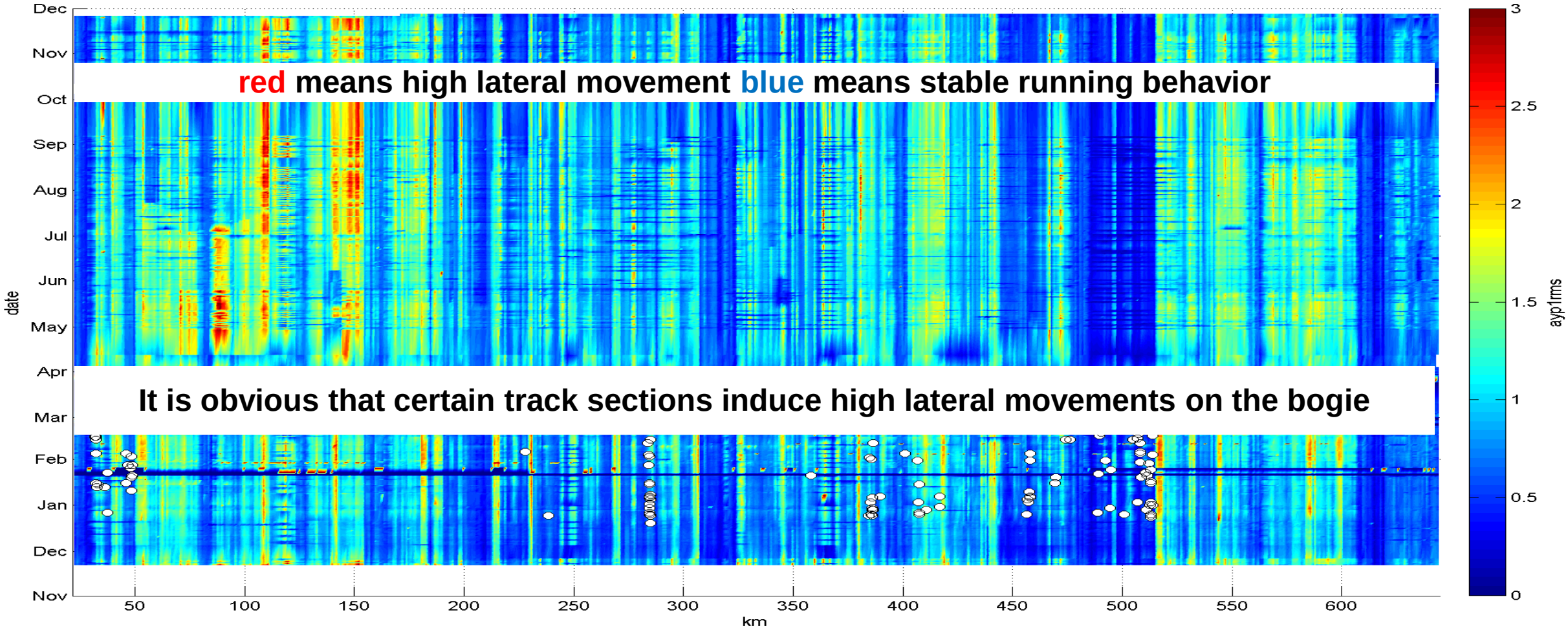
Vehicle Reaction: Lateral Acceleration (1 year observation period)



What are the restrictions of the Vehicle-Track-Interaction Monitoring System?

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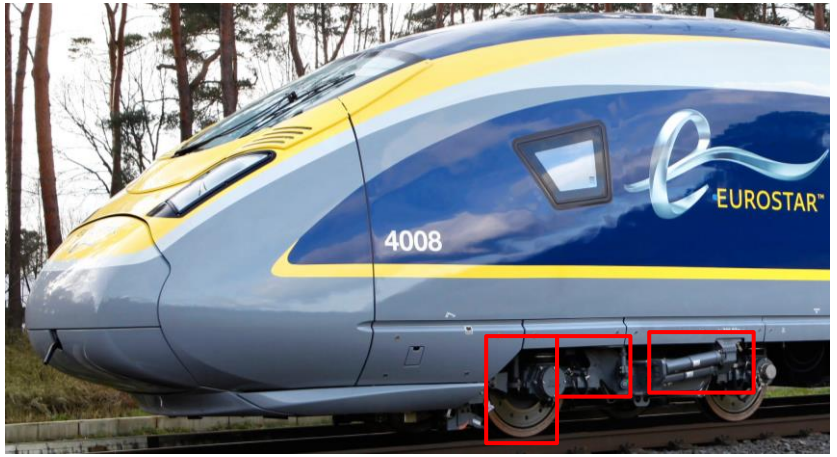
Yaw Damper, Wheel Profile, Wheel Guidance System



Track Irregularities

Conicities

Restrictions:

- **Unstable running behavior** is not only dependent on the track geometry, it is also **influenced from**
  - the **wheel profile**,
  - the **wheel guidance system** and
  - the **yaw damper** functionality
- Therefore **additional bogie diagnostics** is essential to separate:
  - which reaction is coming from the **worn bogie components**
  - Which reaction is coming from the **track irregularities**
- **Different vehicles** might show **different reactions** on certain track defects (when should track maintenance efforts be started?)
- The **SIEMENS Vehicle-Track-Interaction Monitoring System** is not able to measure **lateral track defects** or **track profiles** but it measures the **reactions of the vehicle** on such defects which is **essential for a save operation**

Dr. Thomas Moshammer: Vehicle-Track-Interaction-System Summary

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Summary:

- SIEMENS has developed a **Bogie Diagnostics System** in order to **analyze** the **behavior of the bogie** over its lifetime in order to **optimize bogie maintenance efforts**.
- The **same System** is used to analyze the **vehicle track interaction**.
- Some characteristic parameters of the track such as **longitudinal track levels** are determined.
- In addition track faults e.g. **corrugations** are discovered.
- The difference of the vehicle track interaction system from track recording cars is that the **vehicle reactions induced by the track are measured and rated**.
- Analyzing the vehicle reactions over time in combination with the exact track position might lead to track **maintenance works** where the **vehicle reactions are unfavourable** (high forces and accelerations, instabilities, corrugations, worn switches).
- **The main goal** of the **vehicle-track-interaction monitoring system** is **not to replace track recording cars** but to give additional information about track sections where unfavourable vehicle reactions occur and thus might help to optimize track maintenance efforts.

Contact!

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