

Real life examples of early warnings in railways

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4 September 2018

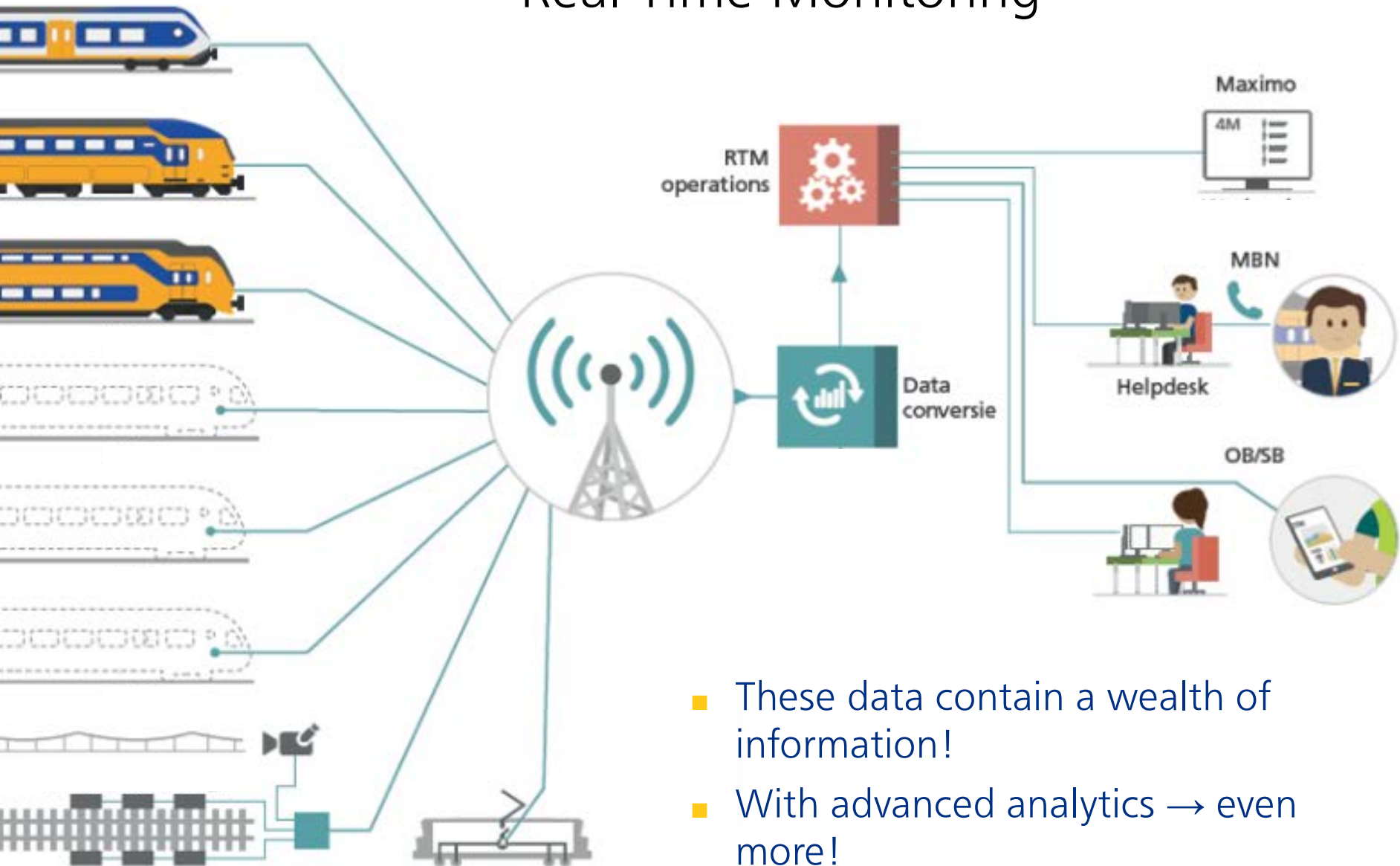


Treasure hunting

- Trend: extra sensors for detection and diagnosis
 - However: already many available sensors
-
- 10^7 weighing in motion records per year
 - 10^6 axle bearing temperatures per year
 - 10^5 maintenance records per year
 - 10^{10} train records per year
-
- A wealth of information is hidden in it!

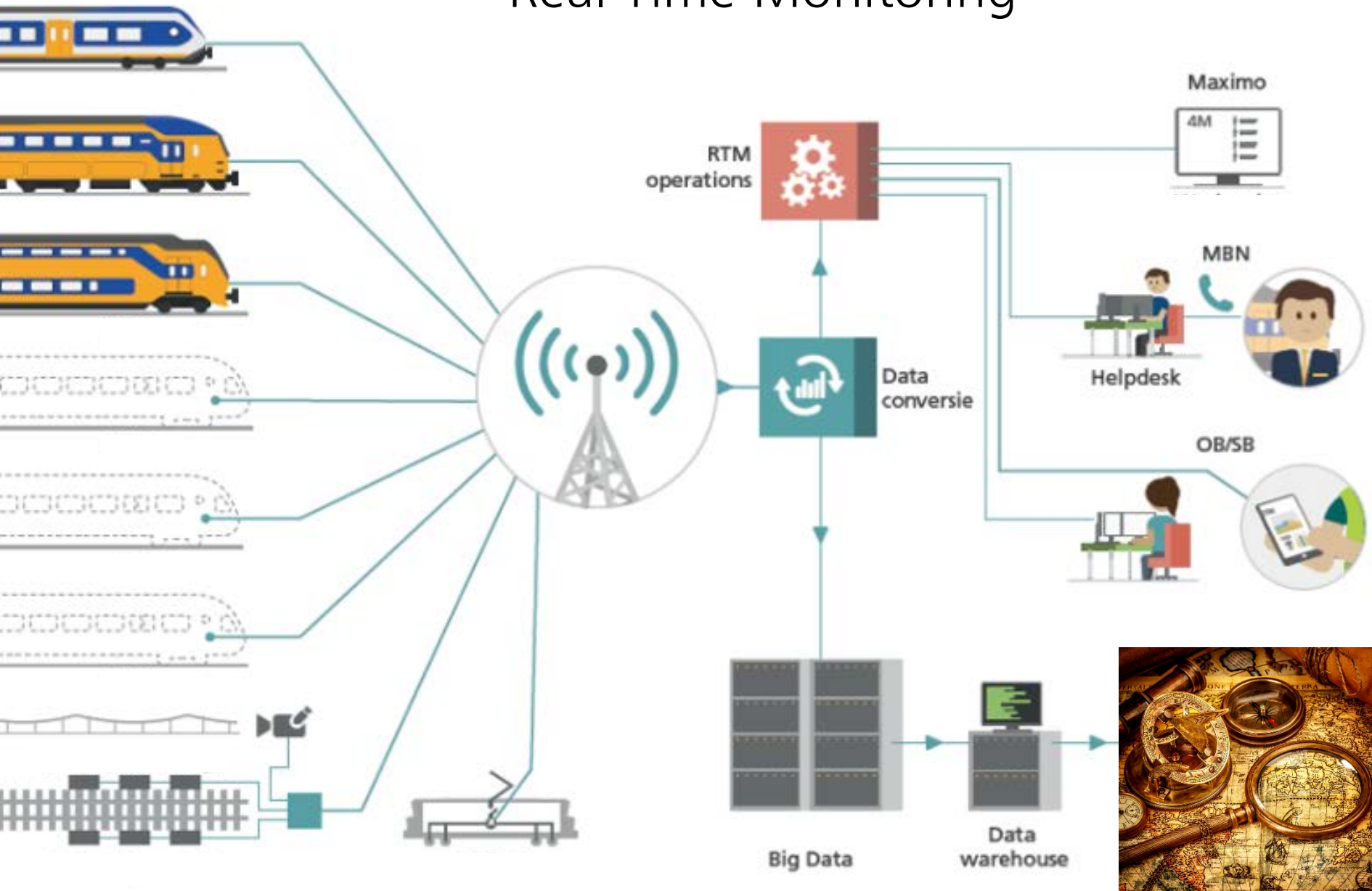


Real Time Monitoring



- These data contain a wealth of information!
- With advanced analytics → even more!

Real Time Monitoring



Overview

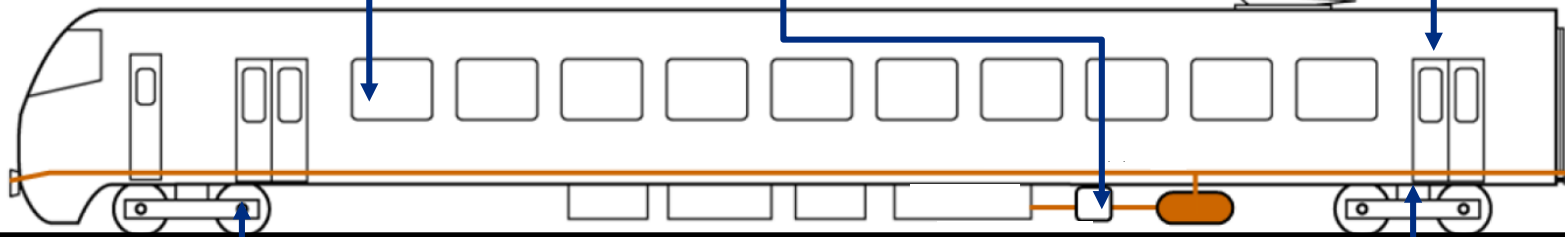
Health meter
Train diagnosis

Low adhesion
Traction, braking,
velocity, GPS

Toilet
Water reservoir
sensors

Air supply
Compressor switch
on and switch off
times

Door problems
Notifications of door
obstruction



Location dependent
disturbances
Train diagnosis, GPS

Axle bearings
Hotbox

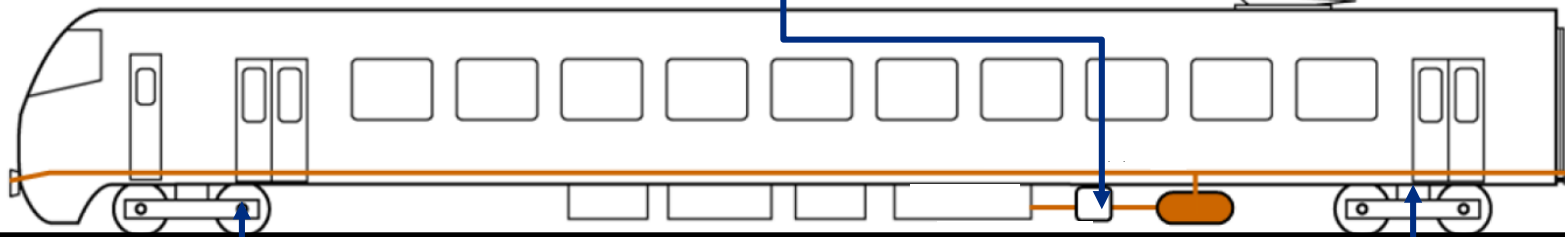
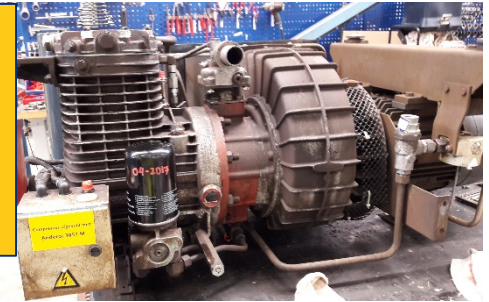
Train imbalance
Gotcha: wheel
imbalance and load
detection

Bogie springs
Gotcha



Overview

Air supply
Compressor switch
on and switch off
times



Axle bearings
Hotbox



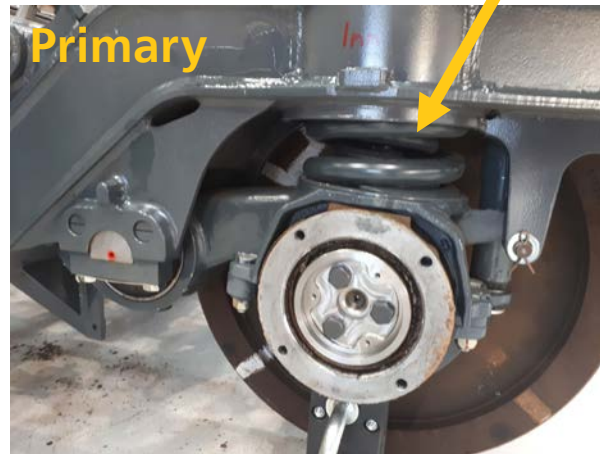
Bogie springs
Gotcha

Example 1: Springs in bogie



Nick Oosterhof, Margot Peters

Proceedings of the
European Conference of the
PHM society, Vol 4 No 1
(2018)



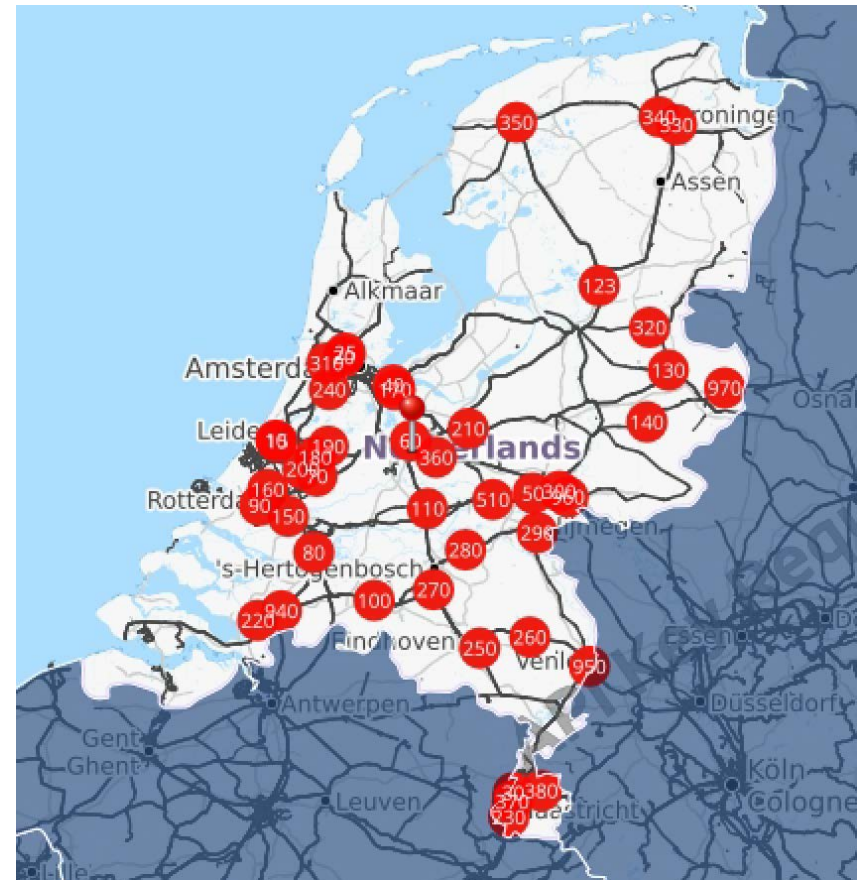
Springs in bogie: Question

- Damage to springs
 - unbalanced train
 - higher derailment probability
- Currently visual inspection
- Sometimes difficult to see
- Can we see it from data?

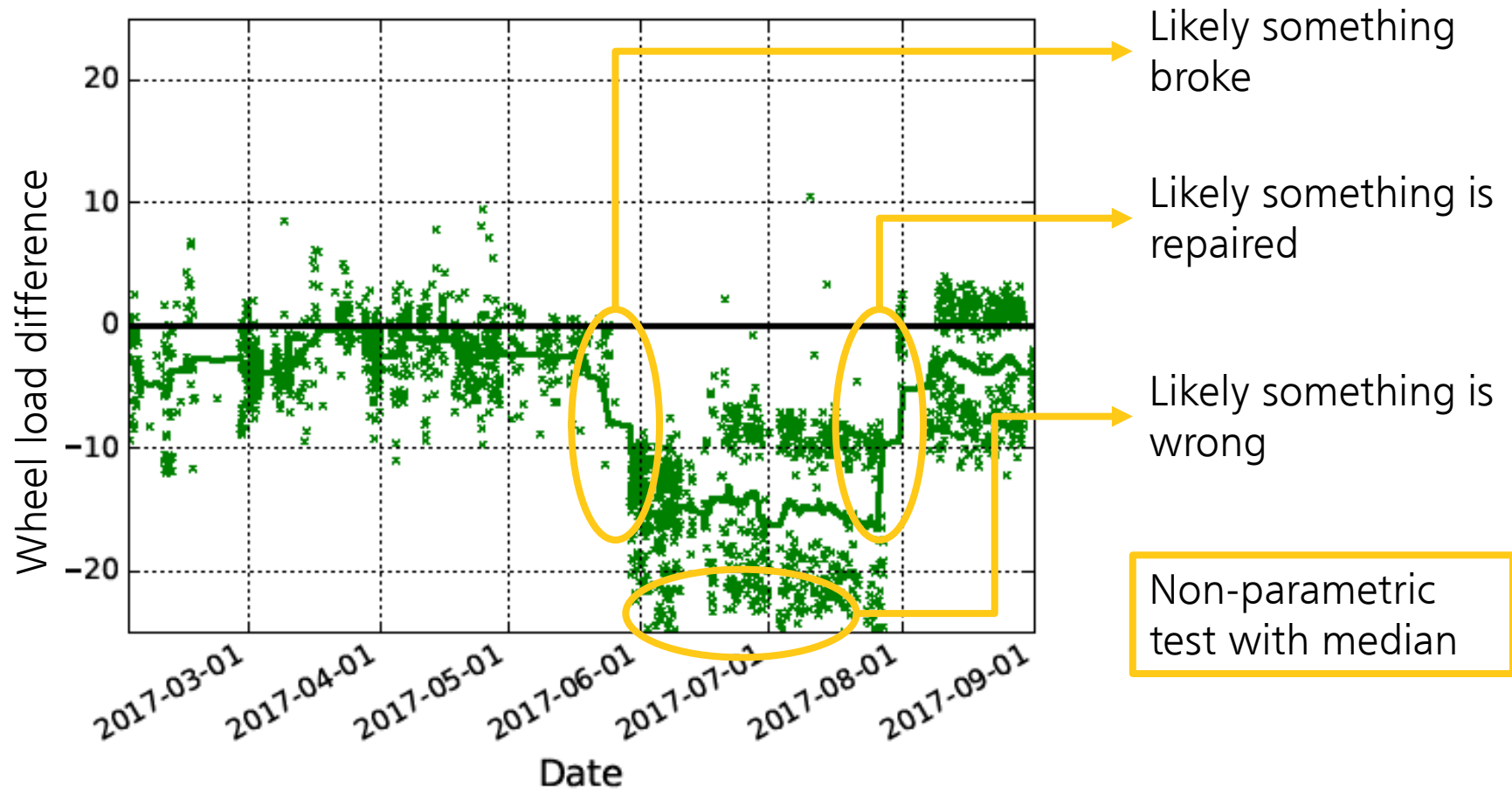


Springs in bogie: Available data

- Possible to use existing data?
- Weighing in motion
 - Cumulative load infra
 - Wheel flatness
 - Wheel load measurements
 - Wheel load differences
- Physics:
 - Damage causes imbalance
 - Damage occurs suddenly



Springs in a bogie: Method



Springs in a bogie:

Detect and *diagnose* suspension defects

- Three types of suspension imbalance:
 - Single axle imbalance → diagnosis unknown
 - Bogie diagonal imbalance. → likely primary suspension issue
 - Coach diagonal imbalance. → likely secondary suspension issue

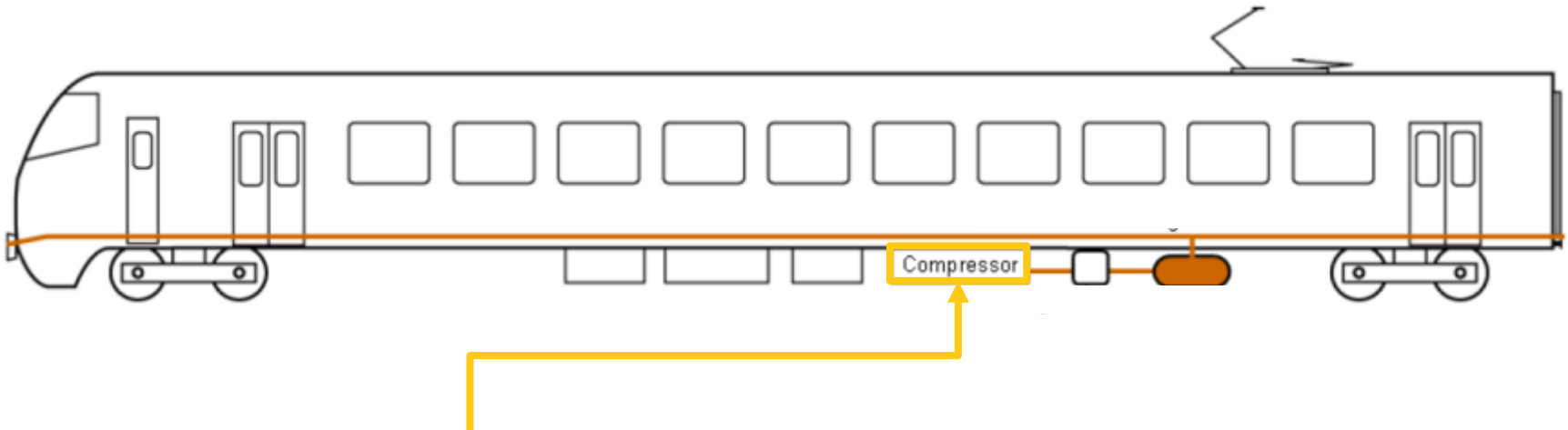
Springs in a bogie: Results

- 8 maintenance records
- All detected by algorithm
 - 2 incorrect diagnosis

Case	True		Model		
	Type of issue	Suspension	Anomalous event	Suspension	
1	defect	primary	yes	secondary ¹	Wrong type of defect
2	defect	secondary	yes	secondary	OK
3	defect	secondary	yes	secondary	OK
4	defect	primary	yes	primary ²	Wrong axle
5	defect	secondary	yes	secondary	OK
6	setting	secondary	yes	secondary	OK
7	setting	secondary	yes	secondary	OK
8	setting	primary	yes	primary	OK

N. Oosterhof and M. Peters, Proceedings of the European Conference of the PHM society, Vol 4 No 1 (2018)

Example 2: Air leakage detection



Wan-Jui Lee

International Journal of
Prognostics and Health
management
Vol 8, No 020 (2017)

Inge Kalsbeek
Implementation

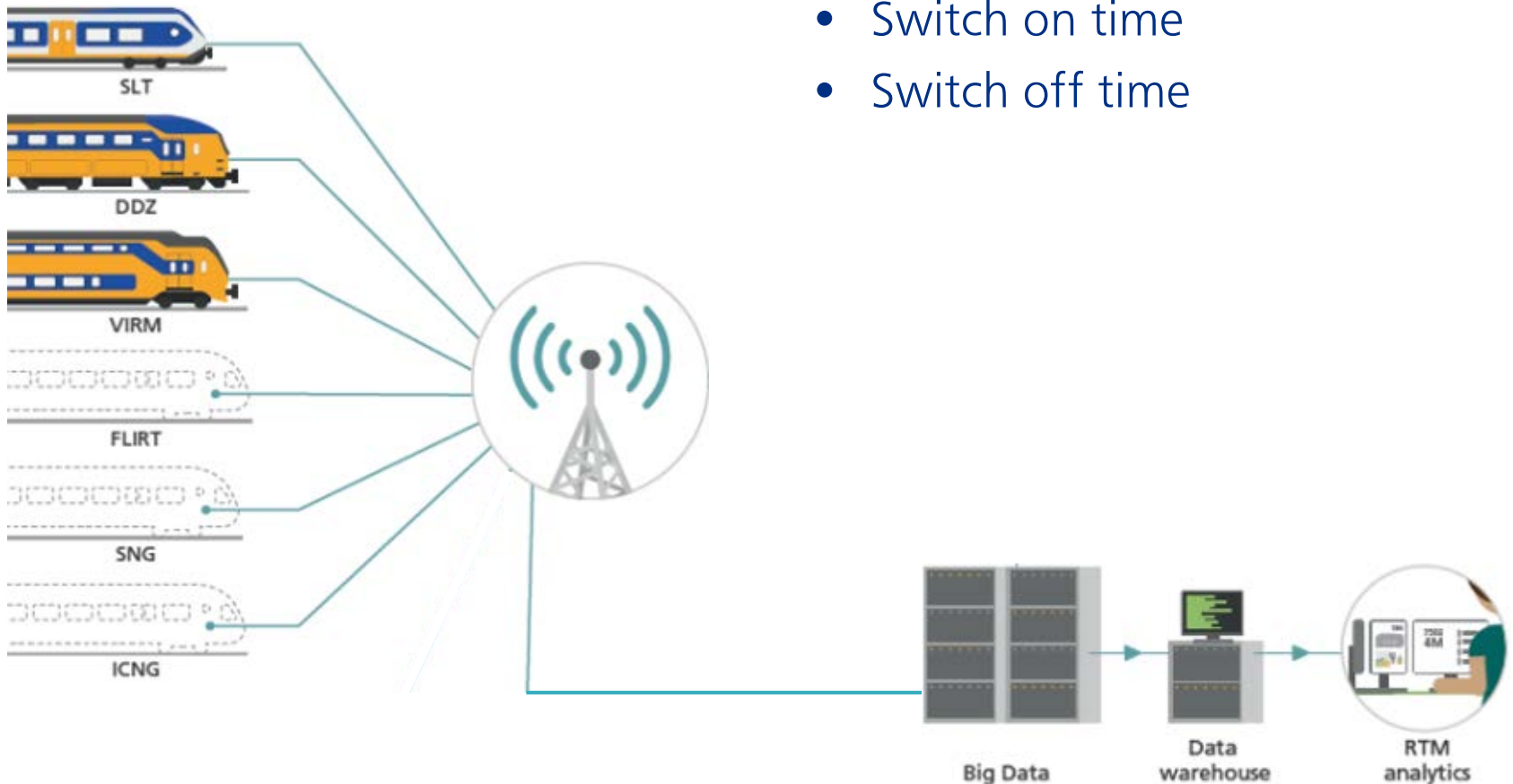
Air leakage detection: Question



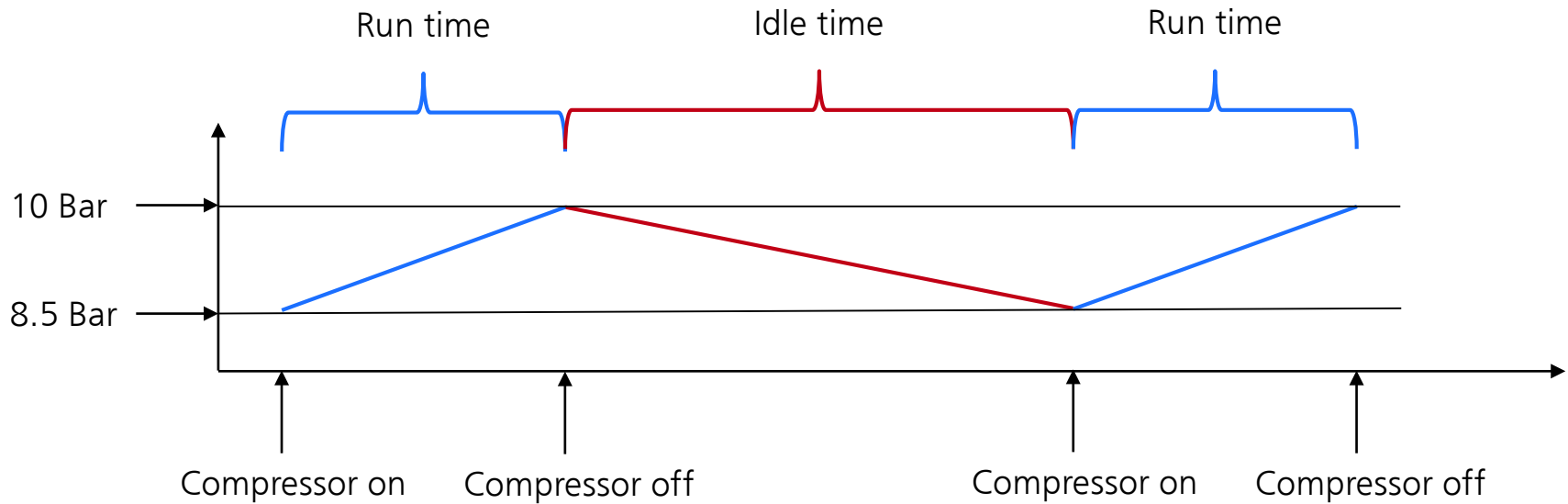
- 1½ leakage / train / year
- Every year:
 - 1/30 trains strand due to air
 - 1/10 trains have delays due to air
- Auditory inspection
- Can we see it from data?

Air leakage detection: Available data

- Real Time Monitoring
 - Switch on time
 - Switch off time

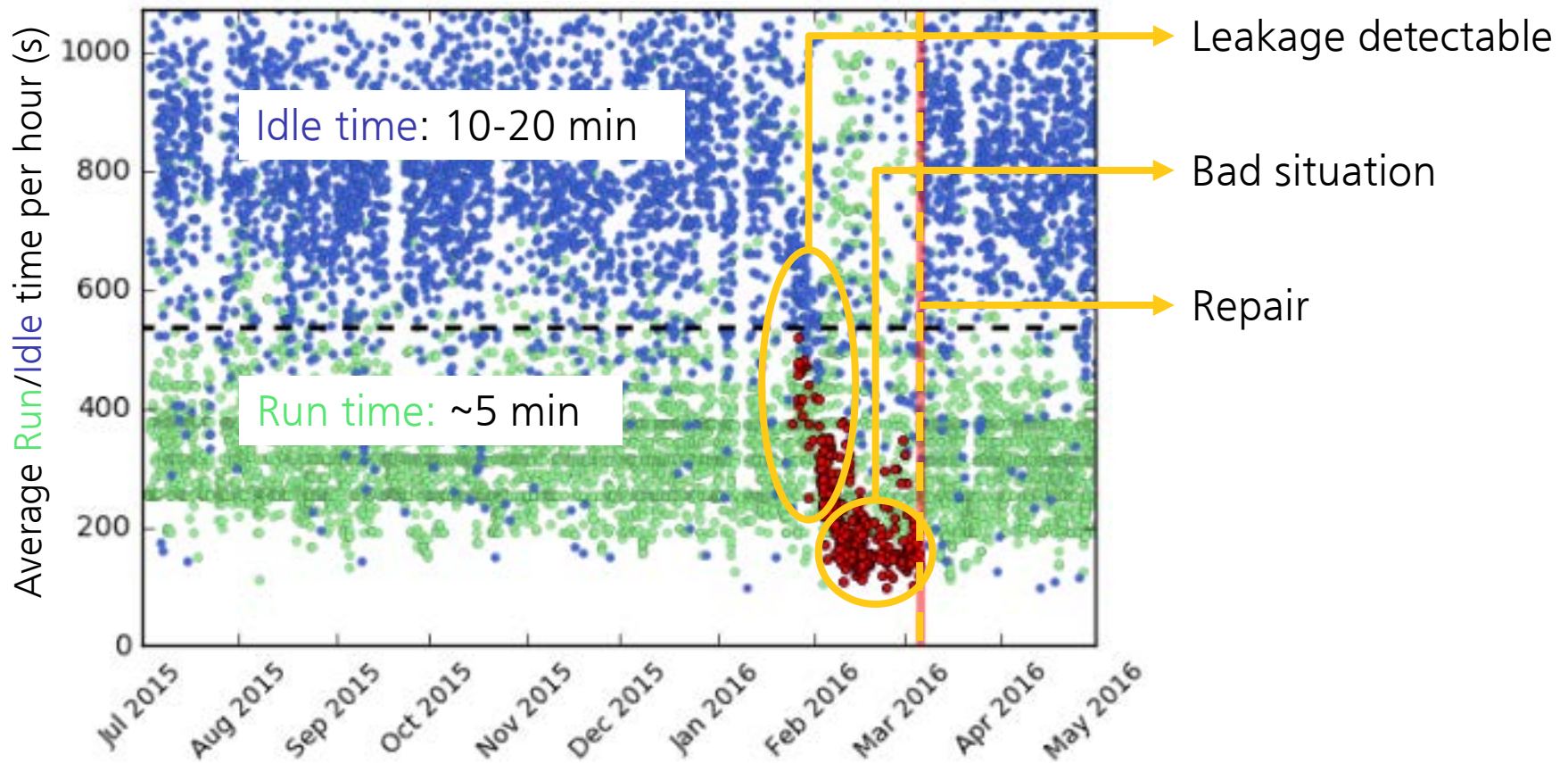


Air leakage detection

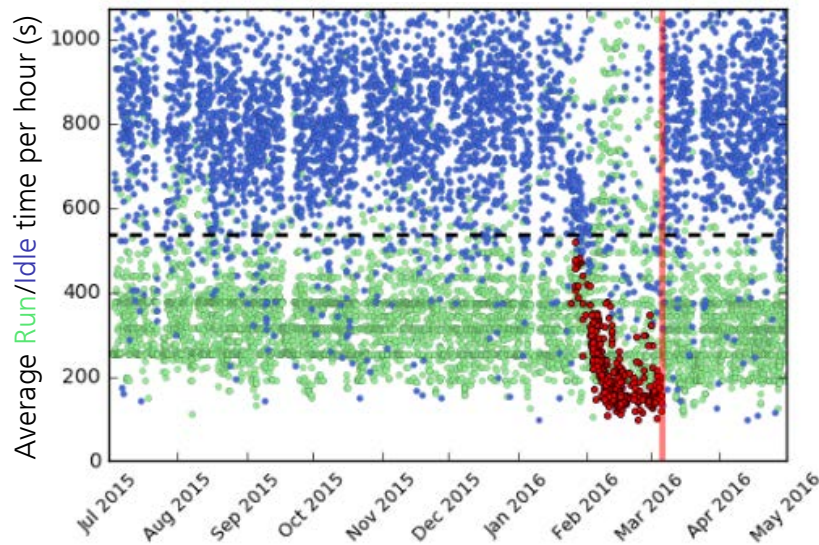


- Physics of leakage
 - Air is consumed faster
 - Decrease in idle time
 - Gradual change

Air leakage detection: Method



Air leakage detection



- Calculation of threshold
 - Automatic
 - Train specific
 - Classification
- Detection of leakage
 - Automatic
 - Clustering

Air leakage detection: Results

- Algorithm testing historic data:
 - > 1 year, >250 work orders
 - 66% clearly detected
 - 17% possible detected
 - 27% not detected
- Since implemented in February:
 - 6 trains taken out of service
 - All had air leakage

W. Lee, International Journal of Prognostics and Health Management, Vol 8, No 020 (2017)



Example 3: Axle bearings



Margot Peters

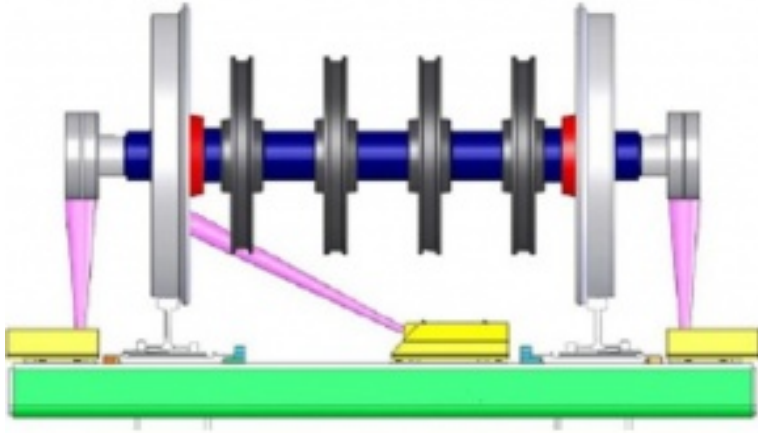
Annual Conference of the
prognostics and Health
Management Society Vol 17
No 041 (2017)

Axle bearings: Question



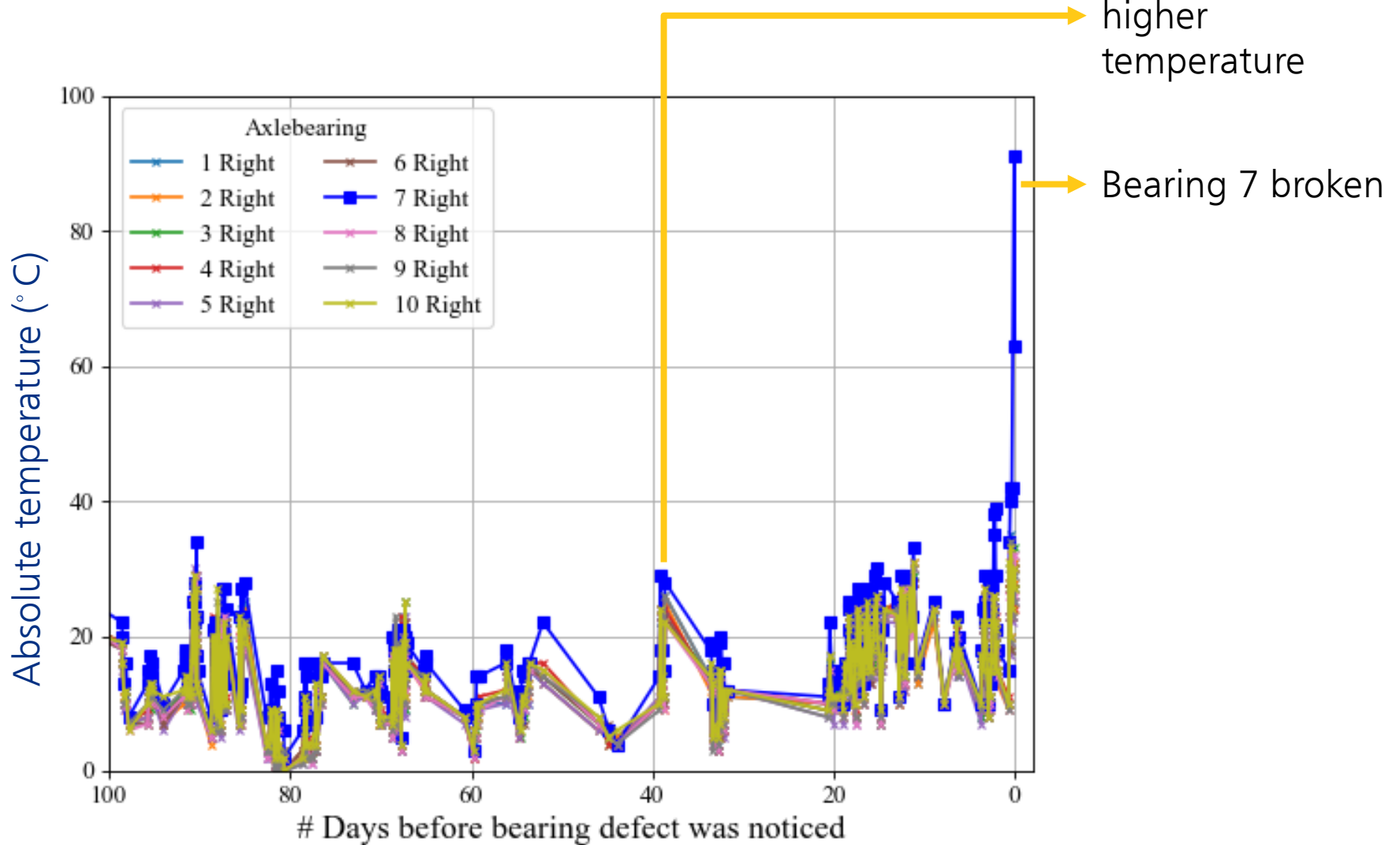
- Axle bearings safety critical
- Many safety nets:
 - Inspection
 - Temperature stickers
 - Hotbox: $T > 115^{\circ}\text{C}$ → train **immediately** out of service
- Very disturbing for timetable
- Can we get an early warning from the data?

Axle bearings: Data

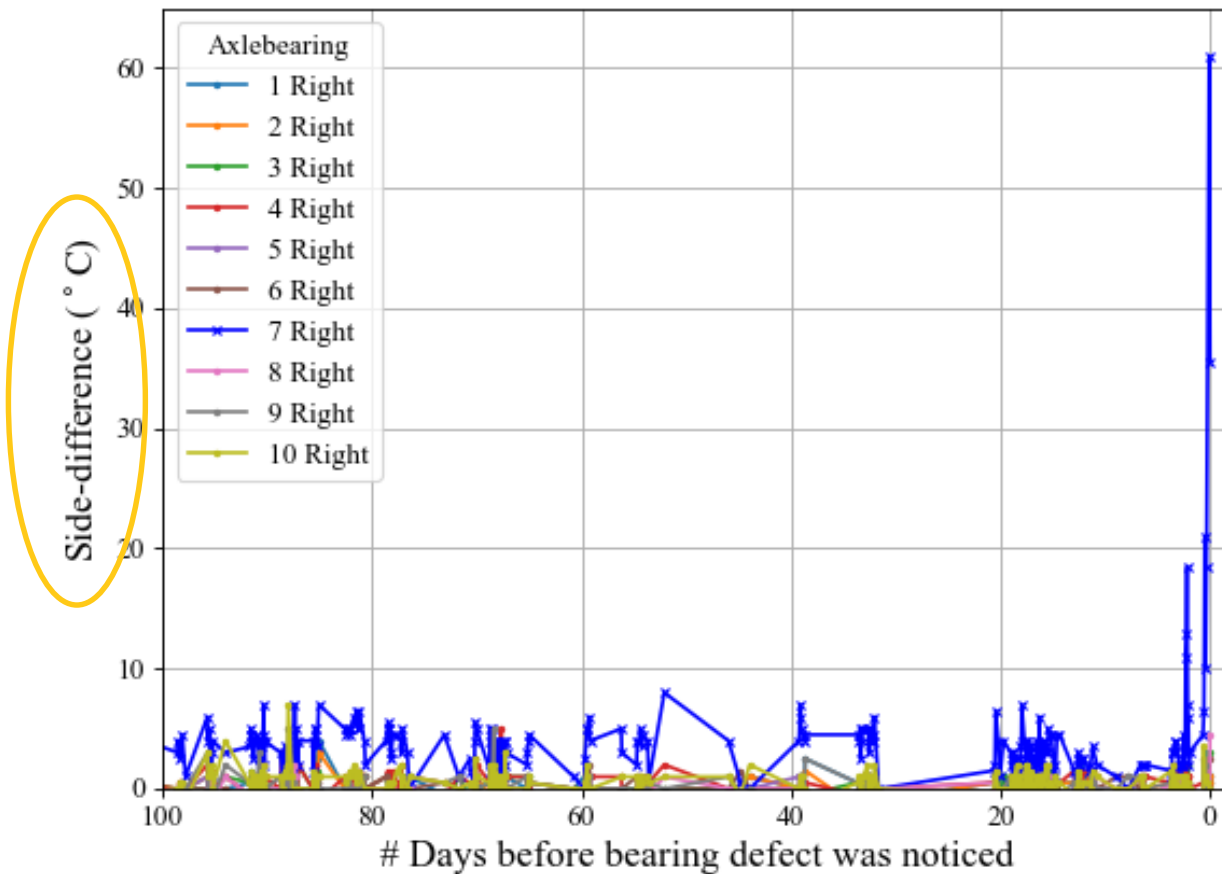


- 24 measuring sites
- Temperature axle bearings

Axle bearings: Method



Axle bearings



Side difference of temperature:
good feature → early warnings

Decision tree:
Severity of warning

Axle bearings: Results

Algorithm	True label	
	Failure	No failure
	Alarm	Correct result: 6x False positive: 1x
No alarm	False negative: 5x	Correct result

Lack of data

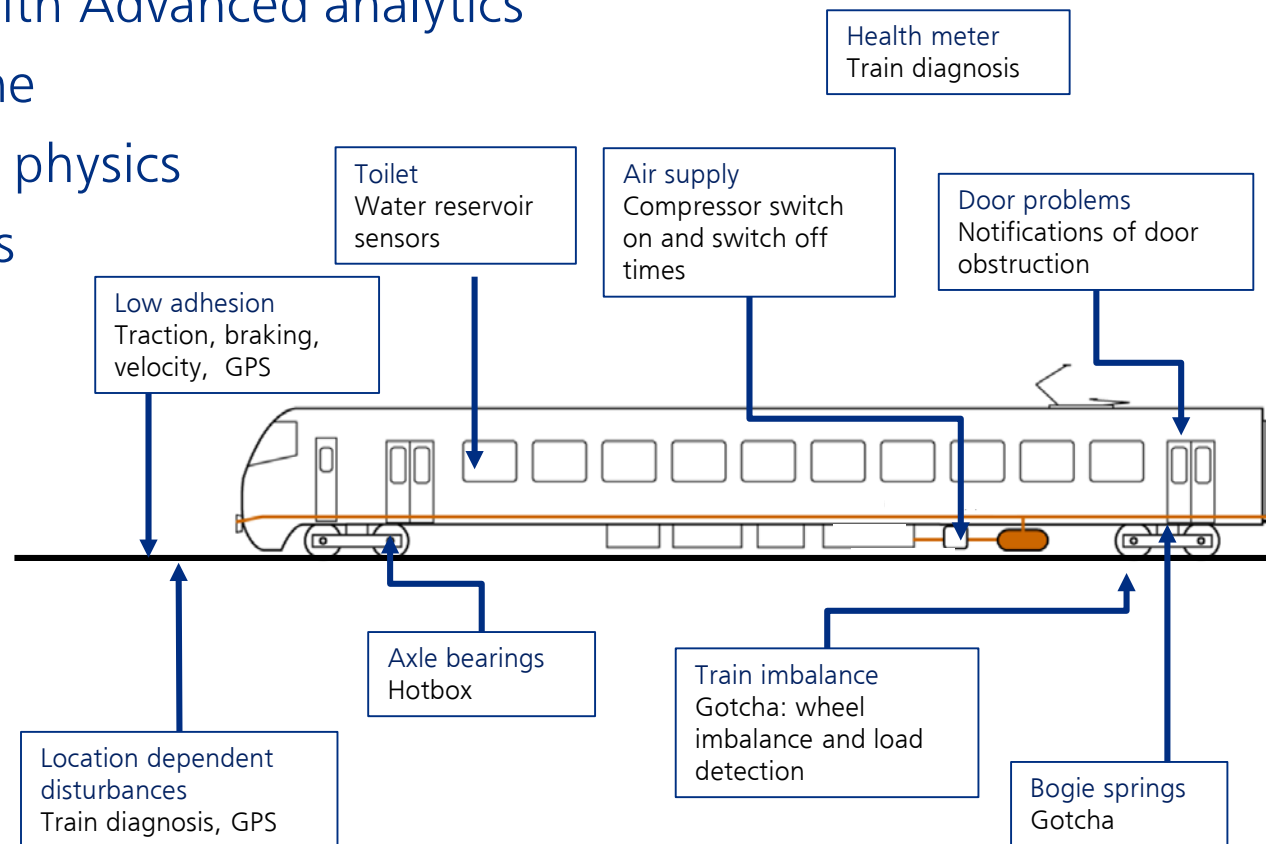
Margot Peters, Annual Conference of the prognostics and Health Management Society Vol 17 No 041 (2017)

Challenges

- Available data
 - Not meant for the new purpose
 - Not always well calibrated
 - Not always complete
- Clear maintenance records
- Rare failures
- Feedback from maintenance depot
- Company Culture

Conclusion

- Available data (train, way side) contain a wealth of information
- Treasure hunting with Advanced analytics
- Philosophy: combine
 - knowledge from physics
 - Smart algorithms



Thank you!



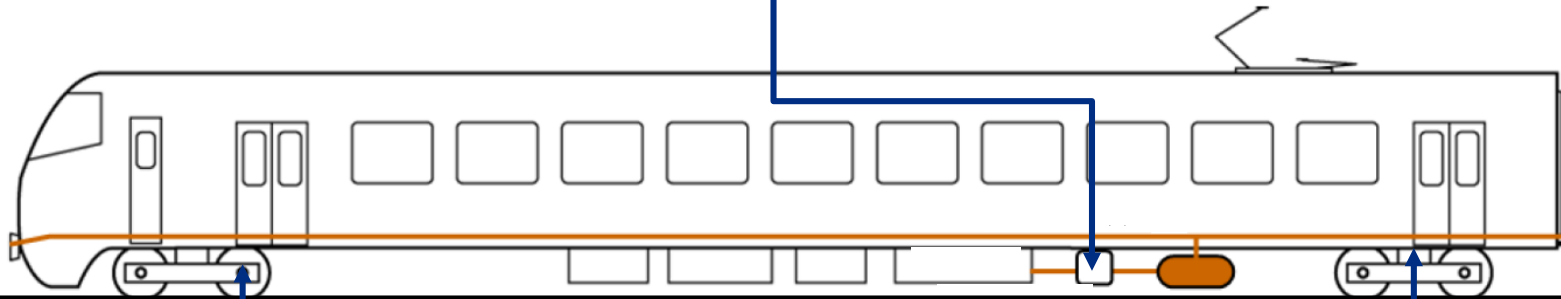
Wan-Jui Lee



Air supply
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Inge Kalsbeek



Axle bearings
Hotbox



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Bogie springs
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