



THE ARCTIC TEST ARENA

Welcome to the Arctic Test Arena

Arctic Test Arena seminar 5. november 2025, UIT Narvik

the Arctic test Arena film:

[Arctic Test Arena – Ofotbanen and Malmbanan - versjon2 on Vimeo](#)

Agenda

09:00 – 09:10 – Welcome to Arctic Test Arena Seminar and UiT

09:10 – 10:00 – Derailment on Malmbanan 2023 – Lessons for Safety & Resilience

10:15 – 11:15 – Research and test activities – ongoing and potential

11:30 – 12:00 – Arctic Test Arena: Ambition and collaboration

12:00 – 12:30 – Lab Visit – UiT Rail Technology Labs

12:30 – 13:00 Lunch UiT

Program launch and seminar

Arctic **test** Arena



Derailment on Malmbanan 2023

– Lessons for Safety & Resilience

Veronica Jägare – Director JVTC, Luleå University of Technology

The Ore line when it works as it should



Derailment Vassijaure december 2023

- o A fully loaded ore train derailed in Vassijaure
- o No personal injury
- o 11 damaged wagons
- o Damages on 15 km railway
- o Repairs took 65 days
- o Major impact for all railway companies
- o Huge impact on LKAB

LKAB building stock



Derailment no2 Vassijaure february 2024

- o An empty ore train derailed in Vassijaure
- o No personal injury
- o 7 damaged wagons
- o Damages on 1,5 km railway
- o Repairs took 11 days
- o Major impact on LKAB and other railway companies



Investigations Derailments

Derailment Dec 17 2023

- ✓ The accident Investigation (SHK) is complete.
- ✓ The direct cause of the derailment was that a wheel moved on its axle due to a crack that had occurred in the wheel.
- ✓ Several factors interacting in a negative way caused the crack.
- ✓ No deficiencies regarding maintenance and checks of vehicles have been identified.
- ✓ It has not been possible to determine how long the fatigue crack has existed and grown in extent. It is also unclear if and under what conditions the crack could have been detected visually.
- ✓ Overall, operational procedures, wheel damage detectors and analyses of detector data could not predict the wheel damage.
- ✓ All in all, all the measures taken by LKAB Malmtrafik AB and Chalmers University of Technology mean that SHK does not see a need to make any safety recommendations.

Derailment Feb 24 2024

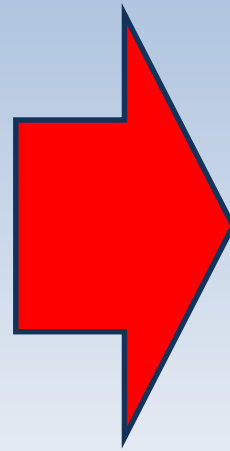
- ✓ The accident investigation (SHK) is complete.
- ✓ The direct cause was that wheel axles were lifted up by packed snow and that lateral forces caused flanges to climb over the rails and derail.
- ✓ The contributing factors was strong winds in combination with the temperature differences in air and ground that formed snow drifts of hard and packed snow in the track. A further contributing factor was that the hole in the wall of snow gallery 14 made it easier for snow to drift onto the track and under the wagons. The train's long stop meant that more snow drifted under the carriages.
- ✓ SHK recommends that the Swedish Transport Administration review rules and procedures for the construction and maintenance of snow galleries and, together with railway companies, assess how procedures/measures can be developed to reduce the risk of derailment in connection with snow drifts.

How To Prevent Derailment by Innovation

Dan Larsson
CEO - Damill AB

Damill is on a Roll

2002



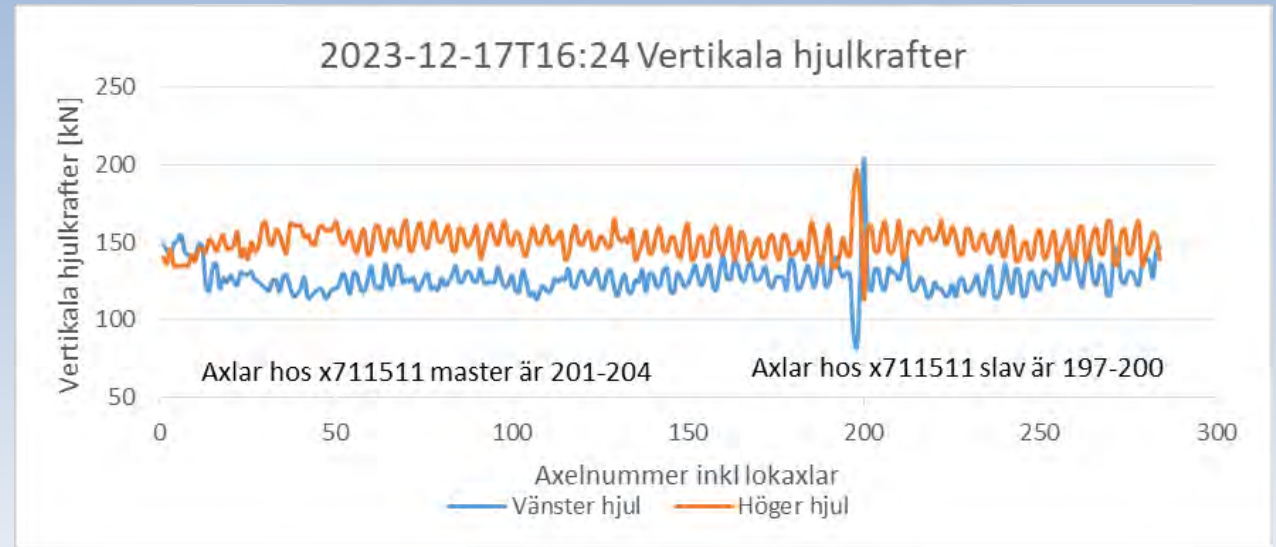
2025

More than 20
year
experience of
railway
monitoring



We Recorded the Derailing Train

- In December 2023 Damill had a monitoring station active in Tornehamn.
- In afternoon Dec 17, an LKAB train started to derail with station only 1000m ahead.
- The station was able to record the full train passage.
- Data was sent to Swedish Accident Investigation Authority



When passing station, only the right side wheel on axle 200 had derailed!

Cause of the Derailment

Data from Tornehamn:

- We have analyzed historical data from the derailed wagon for period from June 2022 up to the derailment day.
- Special attention was paid to the axle 200 in the train set.
- Data showed no or small anomalies regarding vertical forces, lateral forces and AoA.

Swedish Accident Investigation Authority report said:

- The cause of the wheel moving was a ... fatigue crack in the flange...caused by a combination of unfavourable and interacting factors....
- Measures will be taken by LKAB Malmtrafik AB and Chalmers University of Technology ... SHK refrains from issuing any safety recommendations.

Cracks Must be Expected

- Axle load is increased to carry heavier loads.



- Higher amplitude in load cycles decreases time to first crack and increases crack propagation rate.

- There has been a trend towards harder steel to get better wear resistance and longer operation.



- Harder steel often increases crack propagation rate.

- Longer operation of wheels before disposal is searched for to reduce replacement cost.



- Longer operation increases probability that a crack will actually start.

Current Routines to Detect Cracks

- Ultrasonic testing of wheels after (lathe) turning them.
- Visual inspection and magnetic penetrant/particle testing in workshop when doing preventive overhaul (every 2-10 months).
- Visual inspection in yard before departure (daily).

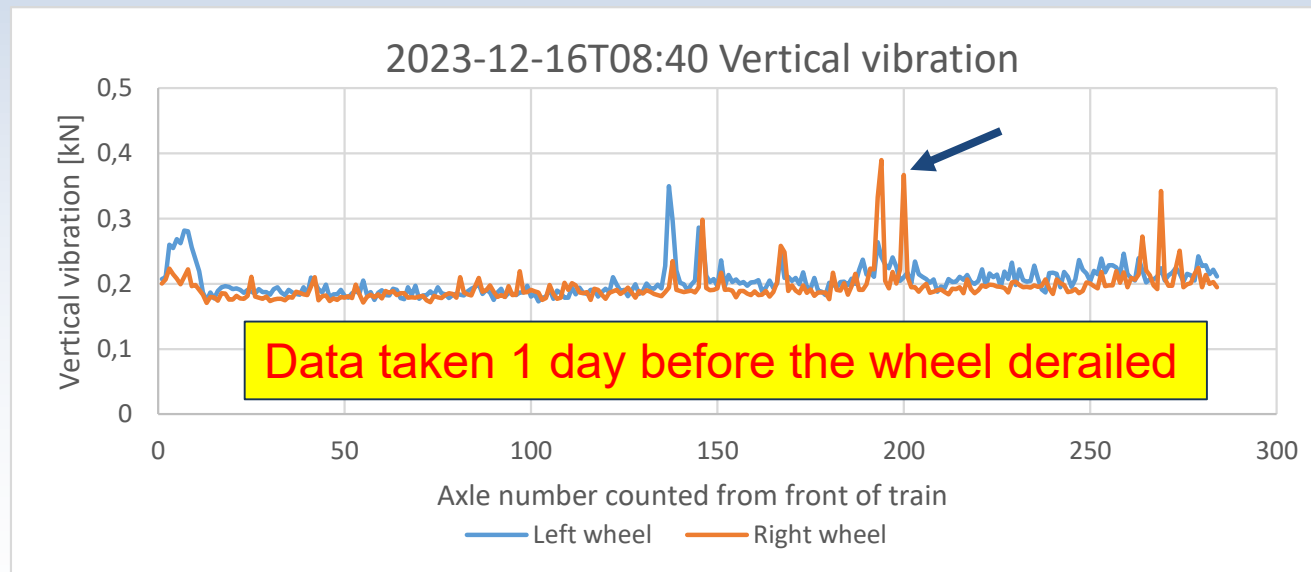
There are quite few changes compared to routines before the 2023 derailment.

Open Questions

- What has been done after 2023 to prevent further derailments due to wheel cracks ?
- What is the probability of a new derailment like the one 2023?
- If probability has not been strongly reduced, is it OK to accept a new derailment due to cracked wheels within 5-10 year and maybe another cost of 6-7 Billion SEK ?

Conclusion and Proposal

- There is a strong need to add redundancy in wheel crack detection.
- We should search/develop and evaluate methods that can check wheels for cracks on daily basis. The Arctic Test Arena is perfect for evaluation.
- Damill has, by own means, already started some work on this topic.



How do we Prevent & Detect Derailment through Innovation

Derailment on Malmbanan 2023 - Lessons for Safety & Resilience
Artic Test Arena - 05NOV25

RMD - Railway Metrics and Dynamics Sweden AB

peter.melander@railwaymetrics.com

+46 73 030 1410

<https://railwaymetrics.com/>



FRA - Federal Rail Administration

Test Track - TTC - Transportation Technology Center, Pueblo, CO.

RMD invited

- Interested in digitalization of trains and Derailment Detection & Prevention
- Full scale derailment and demo (3 MSEK)
- Slow speed – still detectable and preventable.

The image is a promotional banner for the ENSICO 3rd Annual TTC Conference & Tour. The background is a photograph of a train derailment at a test track, with a locomotive and a tank car involved. In the foreground, a group of people wearing hard hats and safety vests are taking photos with their smartphones. The banner includes the ENSICO logo in the top left, navigation links (HOME, ABOUT, TTC AT A GLANCE) in the top right, and two green callout boxes with the text 'DPF: Derailment Prevention Function' and 'DDF: Derailment Detection Function'. The main text in the center reads '3rd Annual TTC Conference & Tour' and 'October 7-8, 2025'. A red button with the text 'REGISTER NOW' is located at the bottom left. An RMD logo is in the bottom right corner.

ENSICO

HOME ABOUT TTC AT A GLANCE

DPF: Derailment Prevention Function

DDF: Derailment Detection Function

3rd Annual TTC Conference & Tour

October 7-8, 2025

REGISTER NOW

RMD

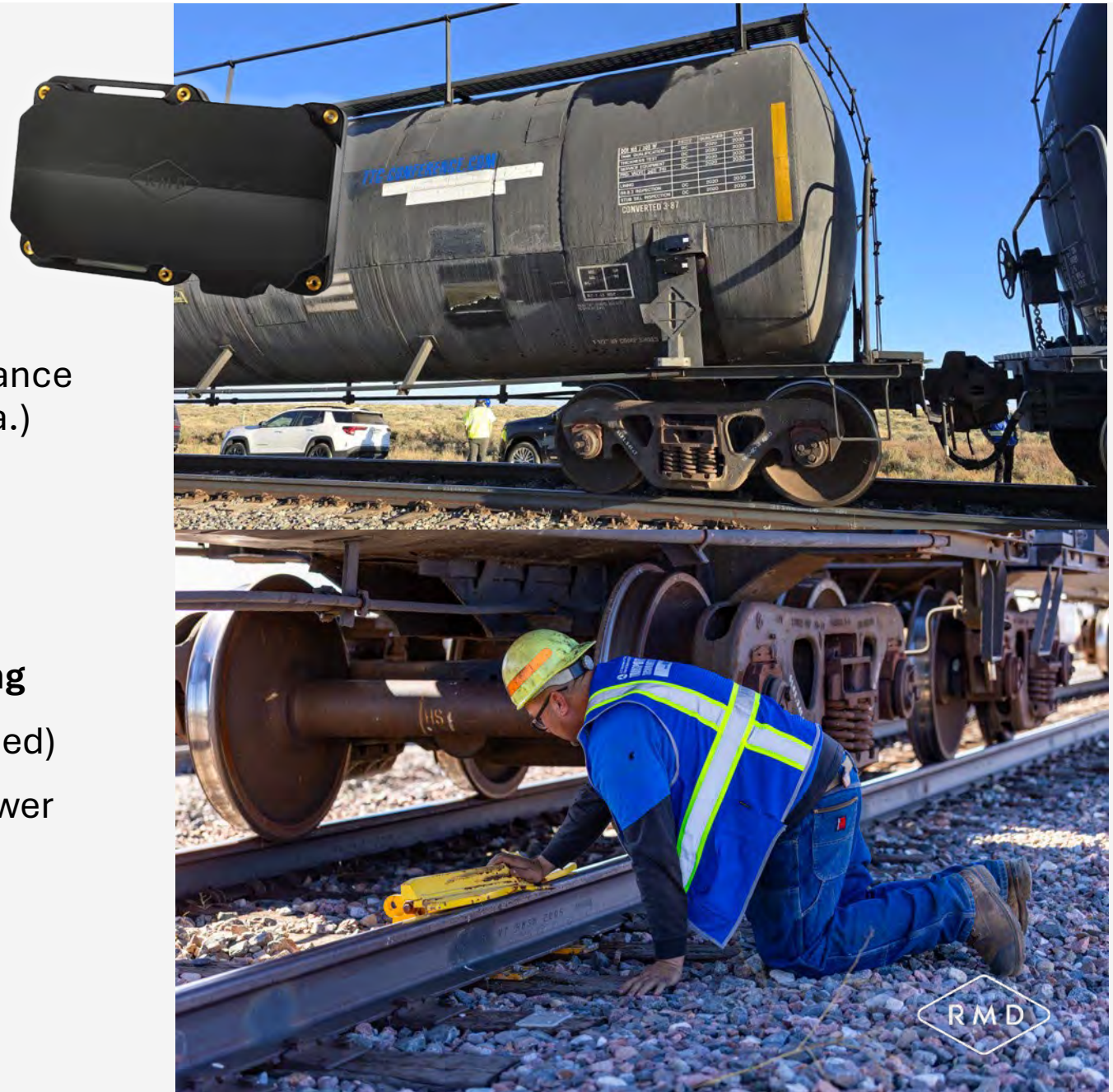
Demo Preparations

Prevention - causes of derailment

- Wheel flats & track defects - RMD Performance Monitoring Units - one on each bogie (15 ea.)
- *Based on vehicle simulation and M/L*
 - o *Heat variations – smart bolt on Axle Box*

Detection - rapid alarm & precise positioning

- Wireless reporting - RMD PMU (only 1 needed)
- Alert in Drivers MyTrain app & in Control Tower Dash-Board

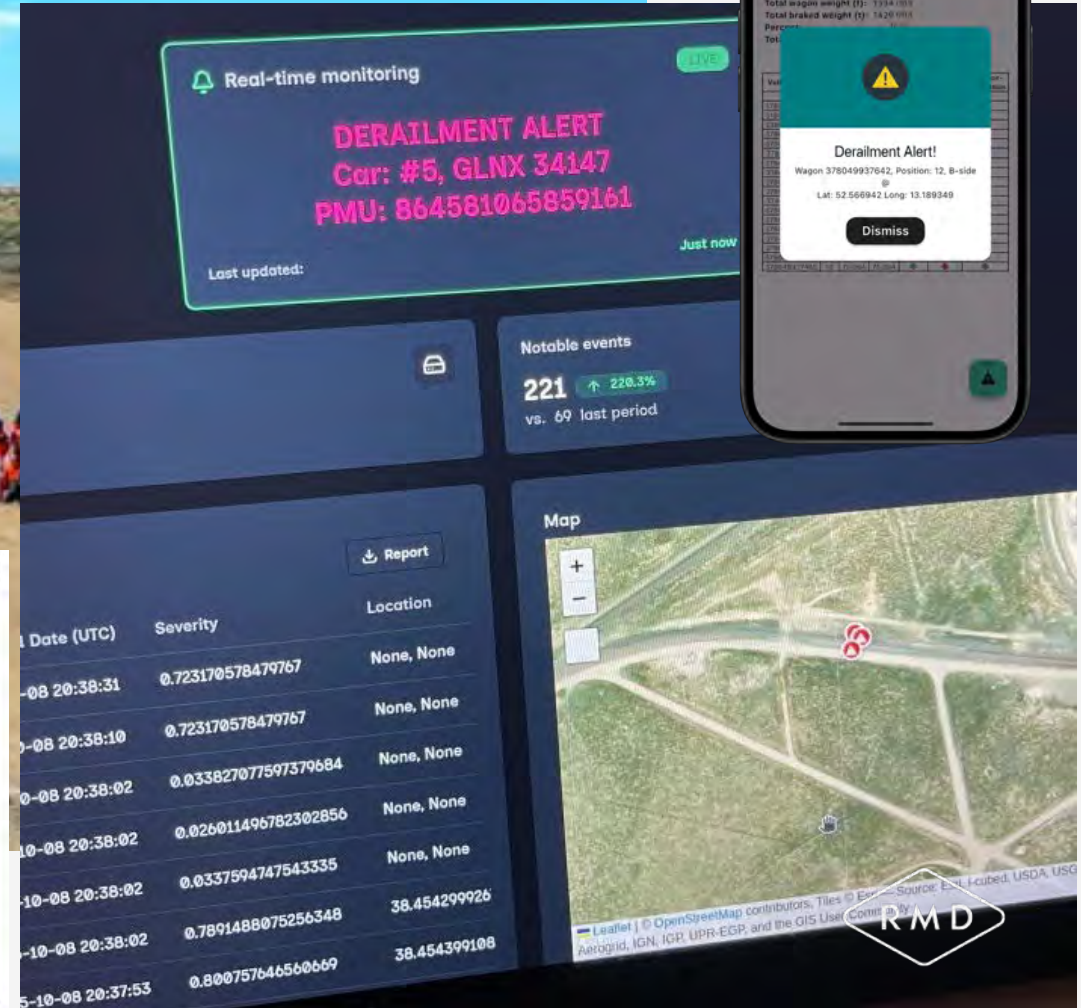
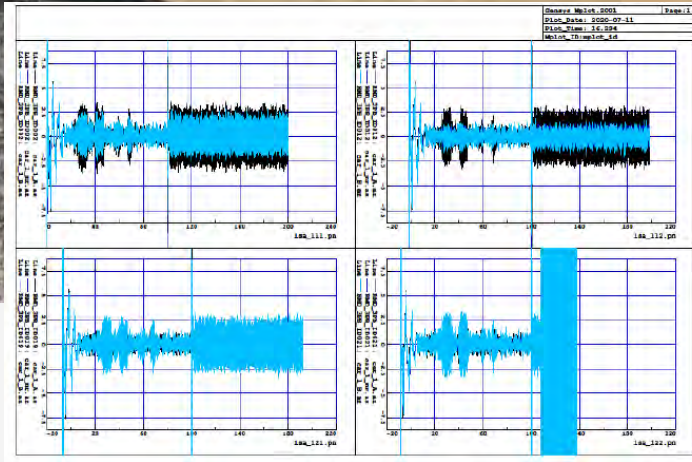
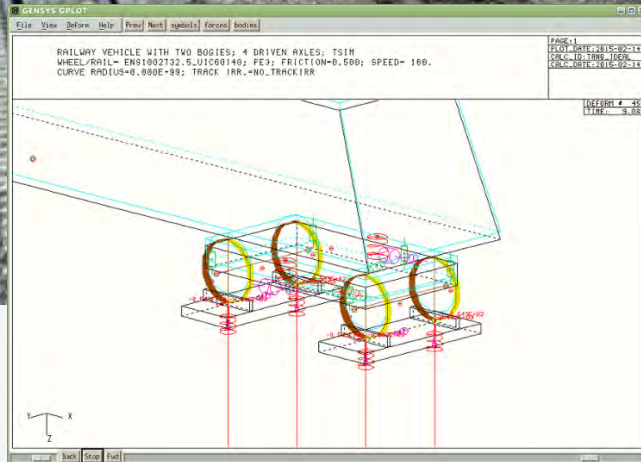




Demo Success

DPF: Derailment Prevention Function

DDF: Derailment Detection Function



<https://enscorail.sharefile.com/share/view/s886565fe598646f79a900a47c10c3dee/fo09131b-3c5a-4e3c-9205-94e93d584a9f>

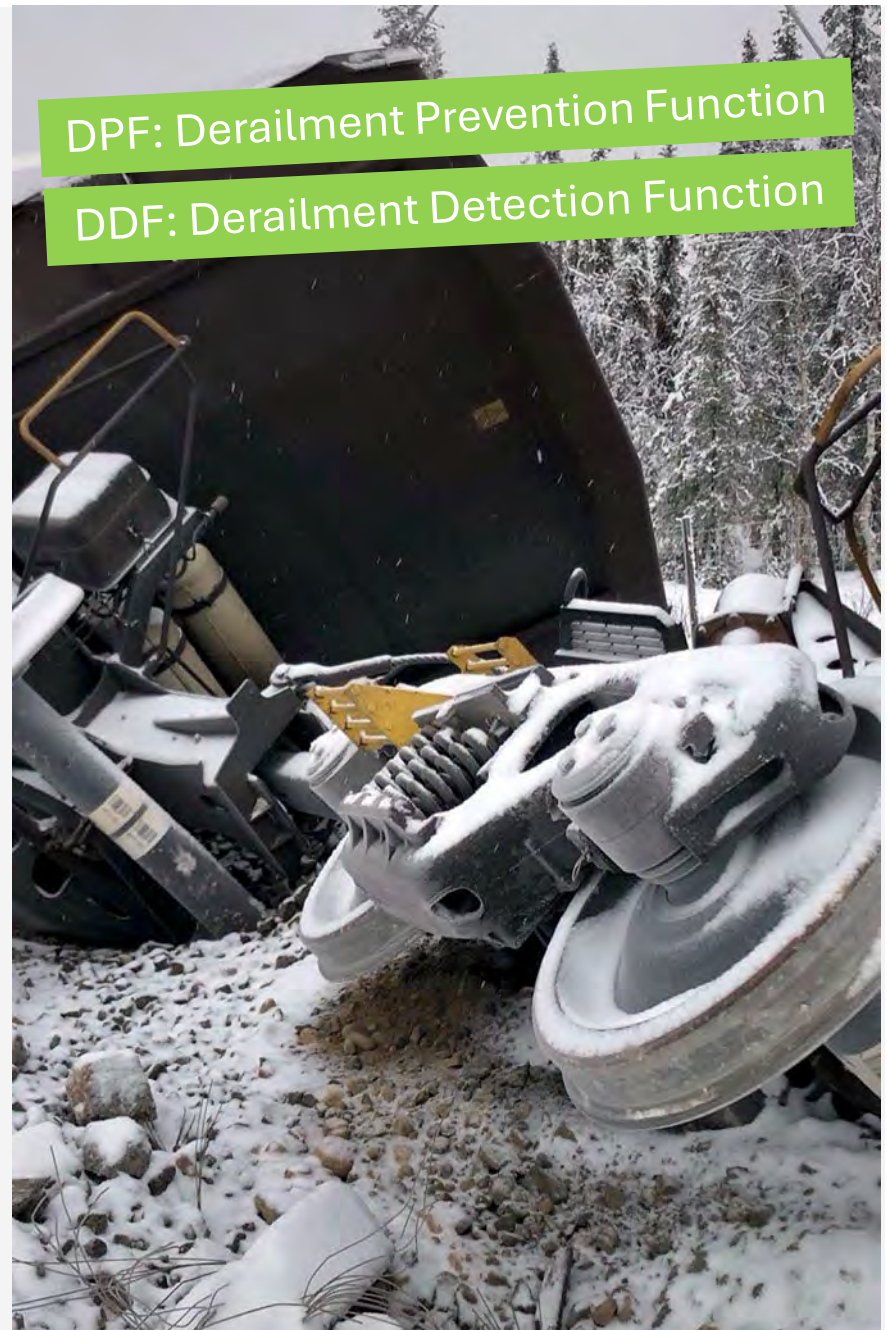
Benefits to Society

Detection - rapid alarm & precise positioning

- Driver can aim at “destroying 250 sleepers next time, not 25.000”
- Everyone receives Precise Positions and Time-Stamped, deploys the most efficient resources
- Quicker restoration of rail capacity

Prevention - wheel flats, track defects & bearing heat

- Focus on most common causes of derailment
- ✓ Just Do It! (US) – Don't overcomplicate (EU)
- Increased Gross National Product (GNP)



DPF: Derailment Prevention Function

DDF: Derailment Detection Function

Summary

- RMD innovation already tested and rolled out – *RMD results from Pueblo. And the innovations are **scalable!***
- DPF & DDF part of RMD Systems of System - *digital and smart train management, supporting the operators & partners. Cost efficient and Scalable!*
- Buy-in from those paying for digitalisation of trains: the operators – *towards crowd-sourcing. Scalable!*
- Includes precise positioning: GNSS / “GPS i lok” - *RMD awarded Trafikverket contract. Scalable!*
- Supported by lower insurance & risk cost - *Initiative with Tågföretagen, S&P and RMD. Scalable!*
- Aligned with TSI LOC PASS / WAG, TSI Telematics & TAF/TAP - *Scalable! RMD helps Graham Bell meet Steve Jobs 😊*
- Start using RMD to Detect & Prevent – NOW! - *Detect: prepare for next derailment (Spring -26), Prevent: pilot for increase to 32,5 tons.*





"Risk Managers" - System of Systems

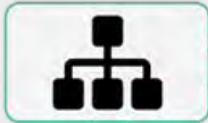
MAINTENANCE + ECM



INFRASTRUCTURE
MANAGER (IM)



RAILWAY
UNDERTAKING (RU)



DASHBOARD & MyTrain



DIGITAL, SMART
TRAIN
OPERATION &
MANAGEMENT!

Business
Intelligence

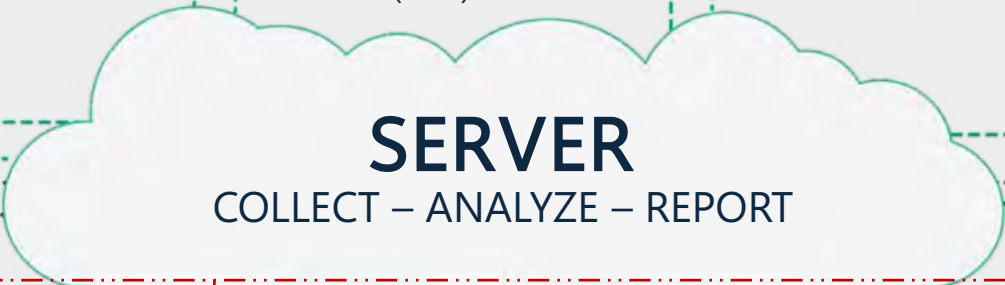
Train Consist

Train Position

Train delay,
departure,
arrival

Train Consist

Common
Interface (RNE)



Dashboard

Train Management System

Infrastructure

Rolling stock,

Wagon location etc.

Driver behavior energy index

Ride Index

WARNING!
DERAILMENT!

MY
TRAIN
APP

BODY DYNAMICS
(PMU)

GPS
RTK

RAILWAY
CAMERA
SAFETY
EFFICIENCY

END-OF-
TRAIN-
DEVICE
BRAKE
STATUS

WHEEL BOX
TEMP.
SENSING
W. SMART
BOLTS

KINGPIN LOCK
SENSOR
VERIFY
CARGO
LOCKED

WEIGHT
SENSOR
CARGO
WEIGHT

PERFORMANCE
MONITORING UNIT (PMU)
WHEEL FLAT DETECTION
TRUCK HUNTING
TRACK FAULTS, IMPACT
DERAILMENT, ROUGH LOADING

WHEEL
SENSOR
WHEEL
PROFILE

PANTOGRAPH
SENSOR (PMU)
PANTOGRAPH
AND CATENARY
CONDITION

PERFORMANCE
MONITORING UNIT (PMU)
WHEEL FLAT DETECTION
TRUCK HUNTING
TRACK FAULTS, IMPACT
DERAILMENT, ROUGH LOADING

FRONT
SENSOR

DPF: Derailment Prevention Function

DDF: Derailment Detection Function

Summary

- RMD innovation already tested and rolled out – *films and RMD results from Pueblo. And the innovations are scalable!*
- DPF & DDF part of RMD Systems of System - *digital and smart train management, supporting the operators & partners - Scalable!*
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- Includes precise positioning: GNSS / “GPS i lok” - *RMD awarded Trafikverket contract - Scalable!*
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- Aligned with TSI LOC PASS / WAG, TSI Telematics & TAF/TAP - *Scalable! Graham Bell meets Steve Jobs 😊*
- How to start using RMD to Detect & Prevent - NOW! - **Detect:** *prepare for next derailment (Spring -26?),* **Prevent:** *pilot for increase to 32,5 tons - monitor trains & tracks.*



Predge and Derailments

Safety & Reliability

Predge contributes to increased safety and reduced risk for derailments



Credit :Network rail

Predge actively supports customers in their work towards increased safety, reliability, and reduced risk for derailments.

We provide a sophisticated decision support, facilitating collaborative work between various data/service providers and our customers .

Content:

- What causes a derailment?
- How do Predge Rolling Stock target these failure modes?

Derailment – Not a single root cause problem

- Derailments can be caused by a variety of factors and combination of those factors
- Typical factors are human errors, weather conditions, track defects, operational issues and poor maintenance.
- In the D-Rail project the 8 most common failure modes in the technical system leading to derailments on main lines are listed [1]
- A single root cause is rare situation [1]. A combination is the common situation.
- Example: Flange climb due to worn flange + poor track geometry.

Priorities of derailment causes, according to [1].

1. Axle Failure
2. Incorrect track gauge
3. Wheel failure
4. Skewed load
5. Skew errors in tracks
6. Incorrect cant and/or track geometry
7. Broken Rail
8. Broken suspension system

Combine data to combine factors

- Monitoring technologies contribute to essential data but should not be kept in silos.
- Combining is enabled by sharing and integrating
- Analytics and Prognostics need to consider all data

Example of Predge feature mapping towards prioritized causes:

1. WDP / WPP / BFP
2. *Track Geometry Prediction*
3. WDP/WPP
4. BP / ORLOS
5. Track Geometry Prediction
6. Track Geometry Prediction
7. WDP / BP / BFP / WPP + Track Geometry Prediction
8. BP

Priorities of derailment causes, according to [1].

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Abbreviations

WDP	Wheel Damage Prediction
WPP	Wheel Profile Prediction
BFP	Bearing Failure Prediction
BP	Boogie Performance
TGP	Track geometry Prediction
ORLOS	On Route Load Shifting

Customer stories

Concrete examples

on how Predge Rolling Stock
has been used in different
customer stories

CargoNet AS – Bergen and Bergseng

Predge BFP were developed jointly with CargoNet after an incident which caused a derailment. Predge is mentioned in the report by Havarikommisjonen as an action to prevent this from happening again.

VTG Rail UK – Petteril Bridge, Carlisle 19th of October 2022

Predge Rolling Stock was used by VTG Rail UK to quickly investigate if any deviations in data could be seen relating to the derailed train. They could quickly conclude that no deviations were seen in data and that incident must have happened after last detector.

Kaunis Iron – Narvik 2021

Kaunis incident caused by material build-up in wagons over time causing a extreme load distribution in left-right ratio. Deviation could have been identified weeks in advance by Predge but feature were not activated.

Today Kaunis subscribes to the Bogie Performance / ORLOS feature.

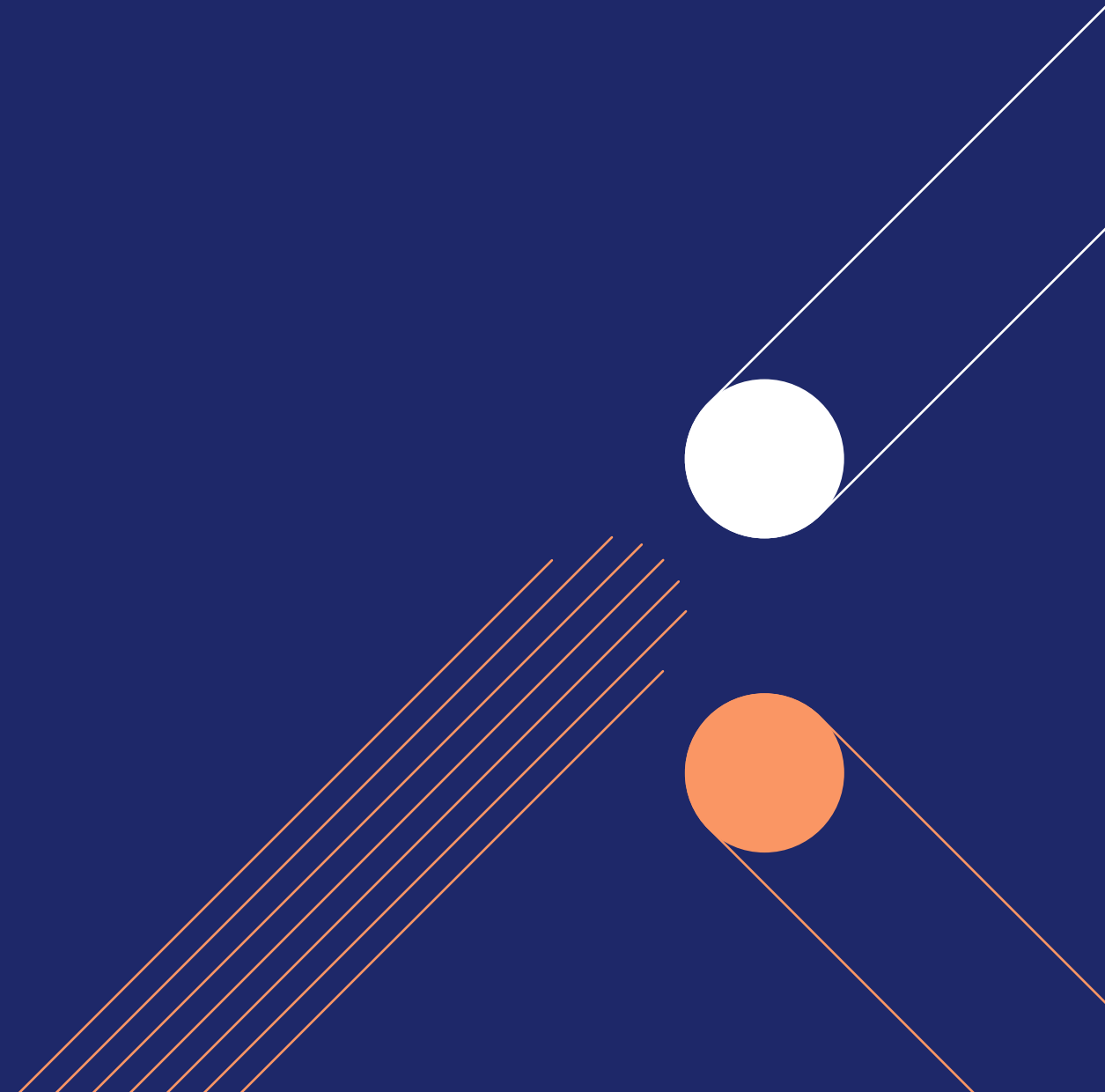
Research and test activities

- ongoing and potential

Testing on Ofotbanen

Svetlana Lorentzen

5. November 2025



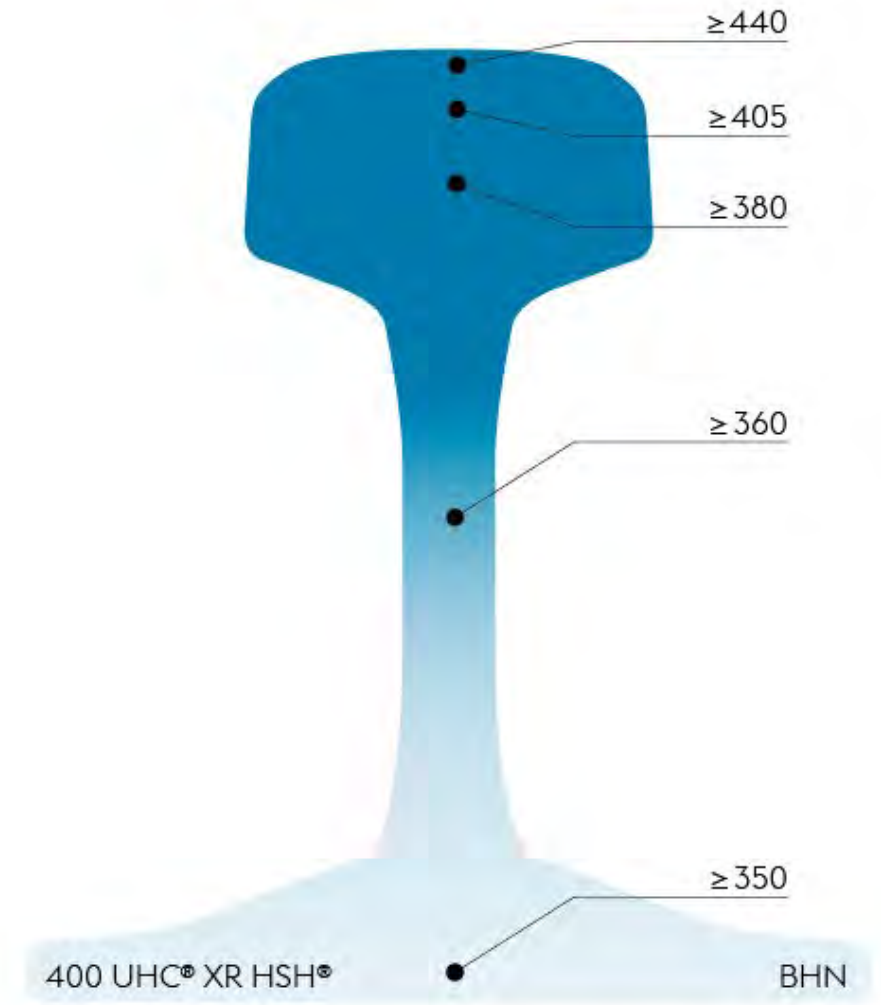
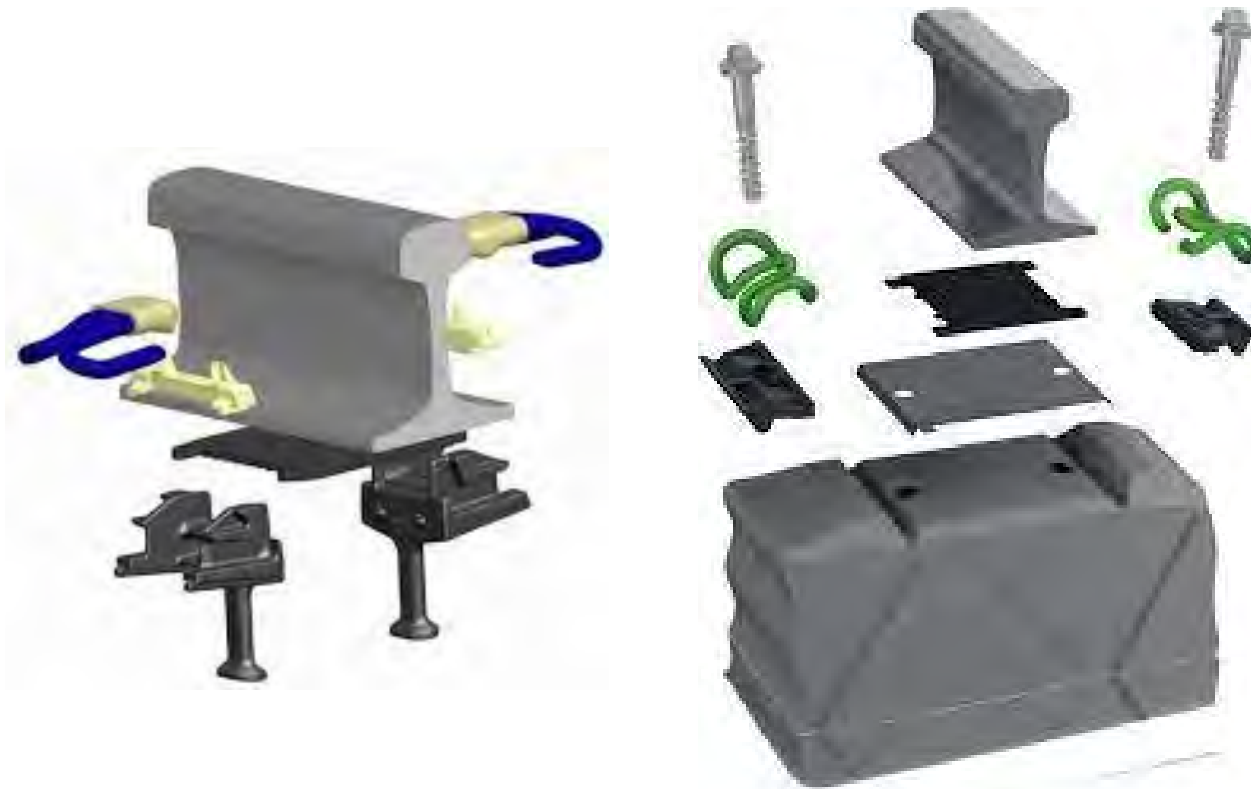
Ototbanen

- ❖ Iron ore line: the Norwegian Ofoten line
- ❖ Axle load: 31 tonnes
- ❖ Annual traffic: 32-35 MGT
- ❖ Only 20 % of track is tangent
- ❖ 50 % of track is curves with $R \leq 500$ m
- ❖ Loaded trains: 50 km/h
- ❖ Longitudinal falling gradient: 10-21 mm/m
- ❖ Rail profile: 54E4
- ❖ Sleeper: creosoting impregnated beech with Pandrol e-clip and fast-clip fastening



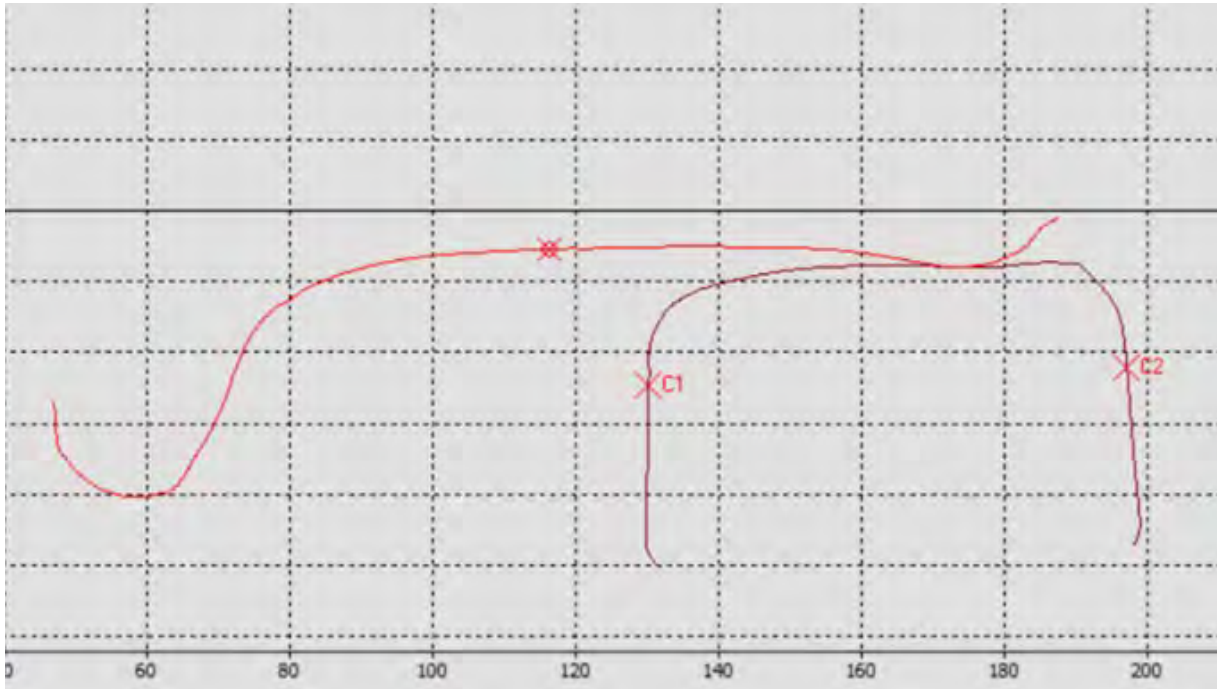
Why and what do we test?

- Rails
- Sleepers and fastening systems



Testing on Ofotbanen

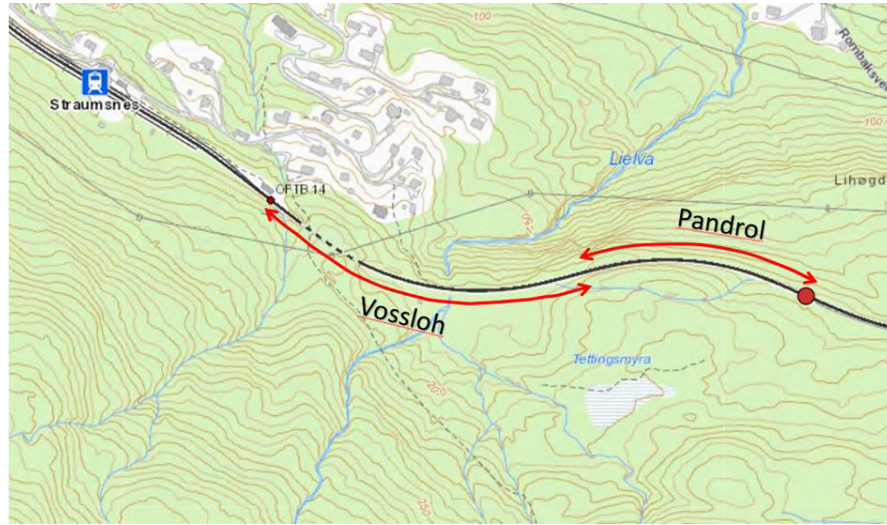
The combination of tight curves, wide gauge and hollow-worn wheels causes damage on rails.



It is important for us to have control over the gauge in the tight curves.



Test section designed for 35-ton axle load (2022)



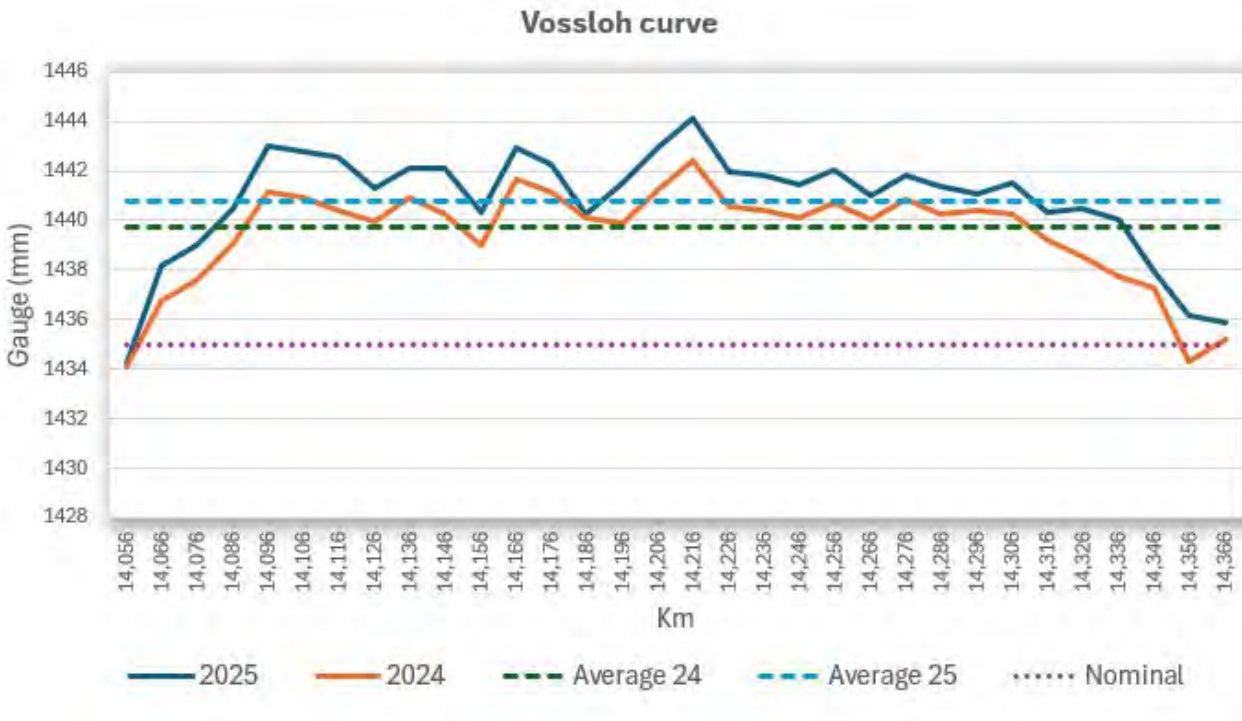
Km 14,014-14,374:

- Rail: 60E2 R400HT
- Concrete sleeper RailOne HHS 18 W60-20 with Vossloh fastening W30HH
- Rail inclination: 1:20
- Under sleeper pad (USP): Getzner and Paul Müller 3007 with stiffness $C_{stat} = 0,30 \text{ N/mm}^3$
- Sleeper distance: 600 mm
- Ballast fraction: 31,5/63 mm.
- Curve R=300 m

Km 14,374 – 14,640:

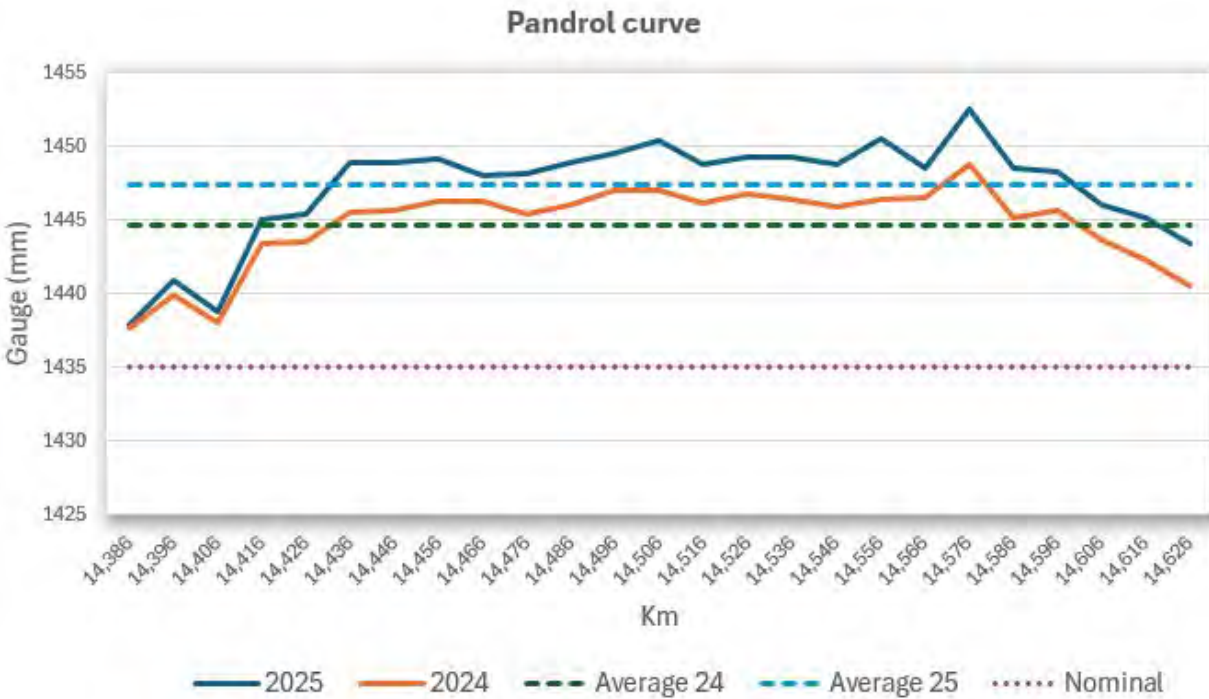
- Rail: 60E2 R400HT
- Concrete sleeper OB35 HAL with Pandrol Fastclip fastening FC1604
- Rail inclination: 1:30
- Under sleeper pad (USP): Getzner with stiffness $C_{stat} = 0,30 \text{ N/mm}^3$
- Sleeper distance : 600 mm
- Ballast fraction: 31,5/63 mm.
- Curve R=300 m

Measuring development of gauge (unloaded track)



Vossloh curve

Average 24 = 1439 mm
Average 25 = 1441 mm
Max 24 = 1442 mm
Max 25 = 1444 mm



Pandrol curve

Average 24 = 1445 mm
Average 25 = 1447 mm
Max 24 = 1449 mm
Max 25 = 1452,5 mm

Railprofile comparison (Spring 2025)

Pandrol curve

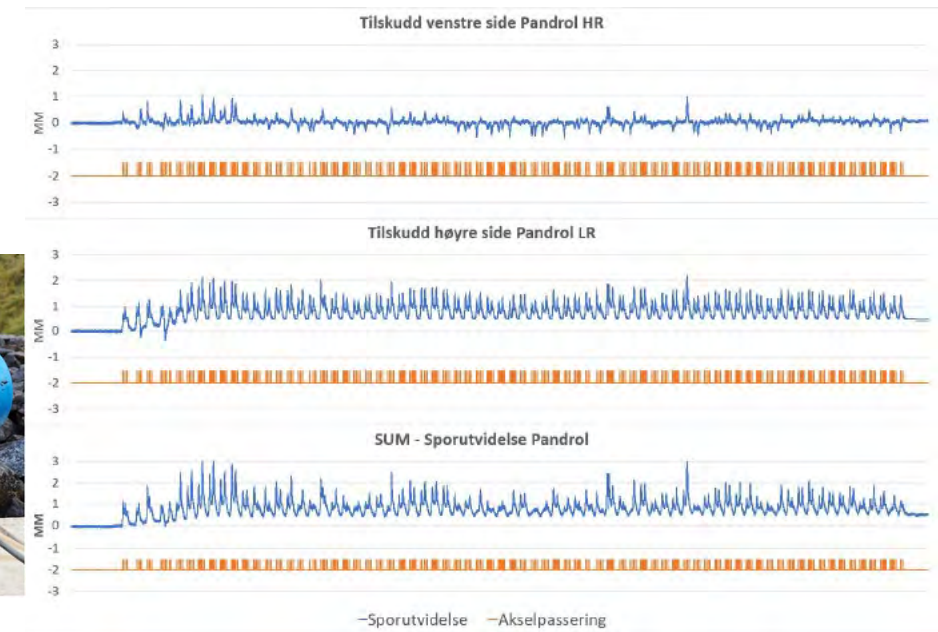


Vossloh curve

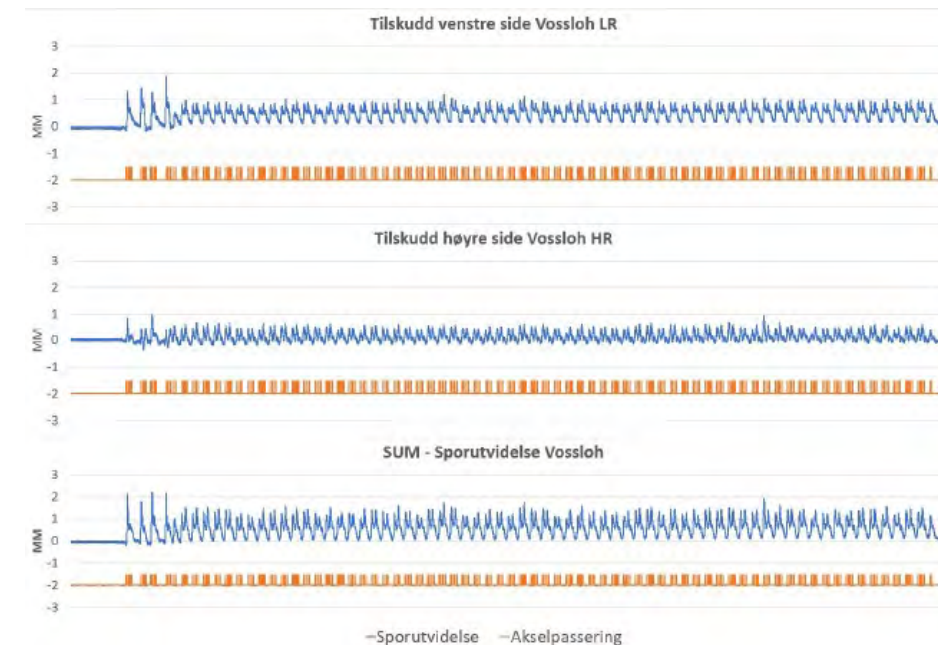


Measurements

Gauge measurement on loaded track



Longitudinal movement (rail creep)



Visual observations

HR Pandrol curve



HR Vossloh curve



Pandrol curve km 14,556 - 14,576 HR (60E2 R400HT) Spring 2025

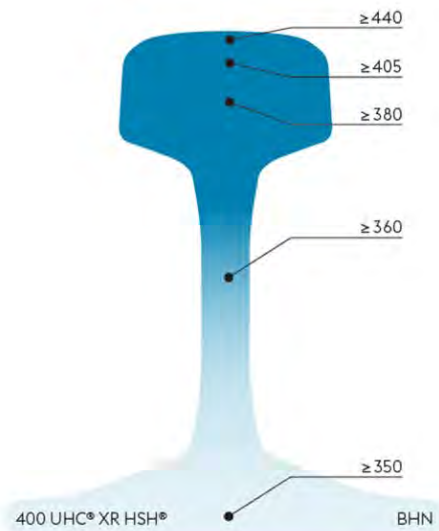
- Local large side wear $W2=8,7$ mm
- Gauge 1452,5 mm
- Last grinding october 2024



More potential test section

- ❖ Evaluate the effect of USP, Under Sleepers Pad on HH Sleepers. Ofoten line have installed HH Concrete sleepers with two types of USP and without USP
- ❖ Installing fastening components to increase lateral stability of track structure
- ❖ Evaluate installation of Concrete HH sleepers with USP in tunnel with low ballast depth (10-25 cm of ballast under sleepers)

Testing of rail grades R400HT and 400UHC® XR HSH®



400 UHC® XR HSH®

❖ Steel Design

- Deep head hardened pearlitic rail steel with grain refinement (toughness) and strengthened lamellar structure (wear and RCF performance)

❖ Best Performance

- Hardness >440BHN, Tensile Strength > 1350MPa
- Highest resistance against RCF and Wear

❖ Maximum Safety

- Maximum notch impact strength
- Soft web and soft foot ensure highest safety in track



Ofoten line in-service testing of rail grades R400HT and 400 UHC® XR HSH® in small radius curves

S. Lorentzen
Bane NOR, Narvik, Norway

R. Hochfellner
Voestalpine Rail Technology GmbH, Leoben, Austria

Name of curve	B1 (R400HT)	P1 (400 UHC® XR HSH®)
Radius, [m]	403	417
Direction	Right	Right
Superelevation, [mm]	74	70
Longitudinal falling gradient, [mm/m]	16	16
Length of circular curve, [m]	280	187
Amount of measurement points	23	14

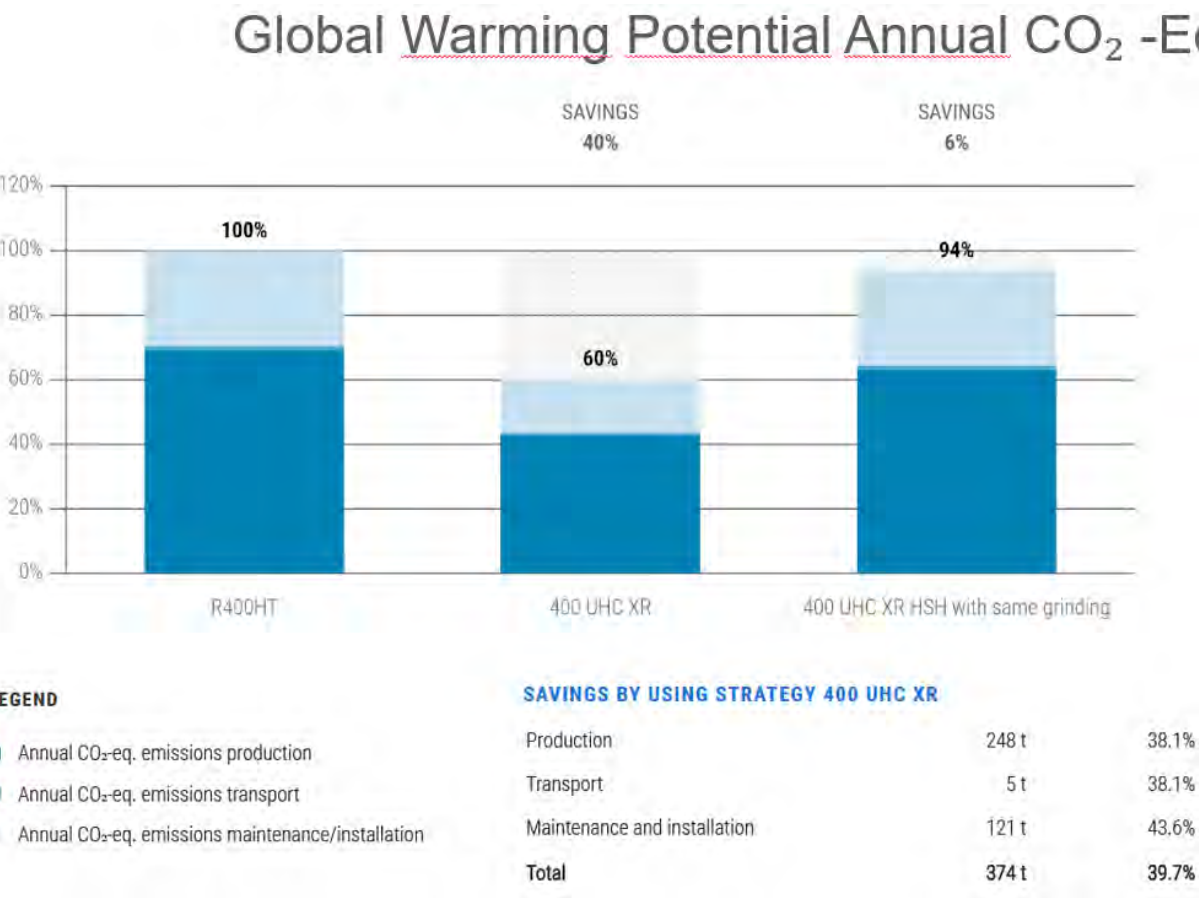
Progression of natural and artificial wear in curves



❖ Material loss due to grinding: 63 % of total wear in curve B1 (R400HT)

❖ Material loss due to grinding: 74 % of total wear in curve P1 (400 UHC® XR HSH®)

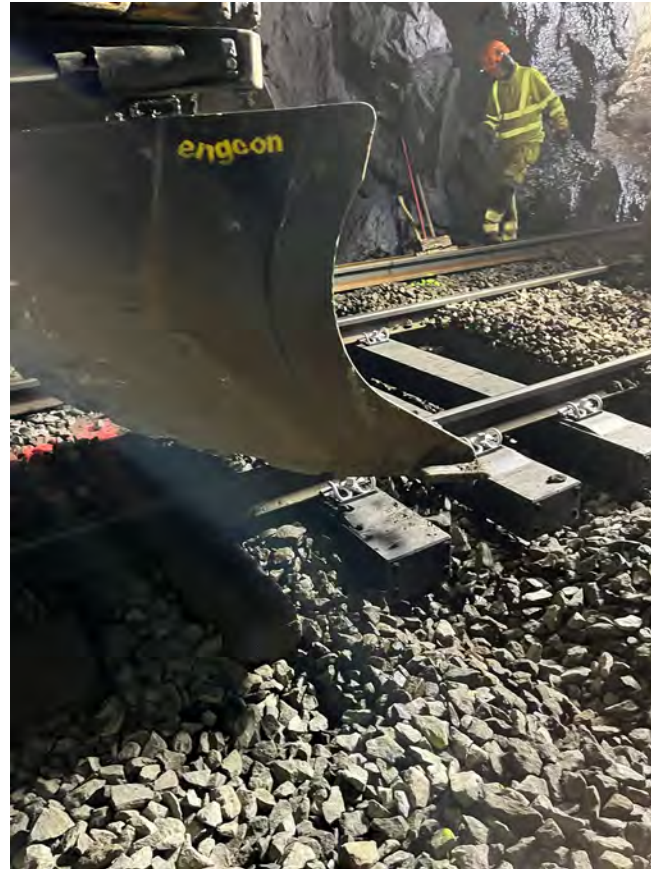
Life Cycle Cost Assessment



❖ By using the 400 UHC® XR HSH® grade with optimized grinding, the analysis reveals a potential reduction of 374 tons of CO₂-equivalent emissions.

Testing of composite sleepers in tunnel (2024)

- ❖ Direct fastening system
- ❖ Dual rail 54E4-60E2
- ❖ Low ballast depth



The measurement station at Haugfjell

- Established in 2010 as a research project
- Km 37.0 in a curve with $R = 300$ m
- We measure:
 - o Lateral track forces
 - o Vertical track forces
 - o Change in longitudinal track forces
 - o Wheel angle of attack (AOA)
 - o Temperature in rail and air
 - o Air humidity



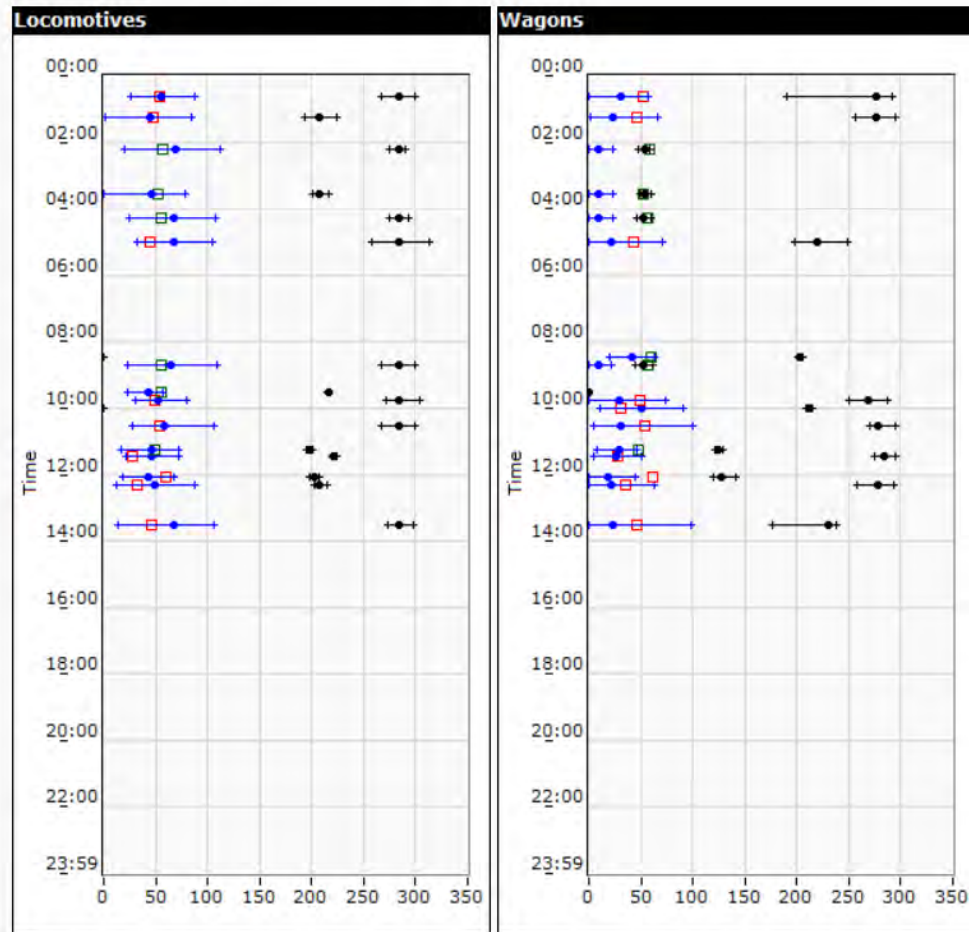
The measurement station at Haugfjell

Stratoforce - Haugfjell MP1

Today

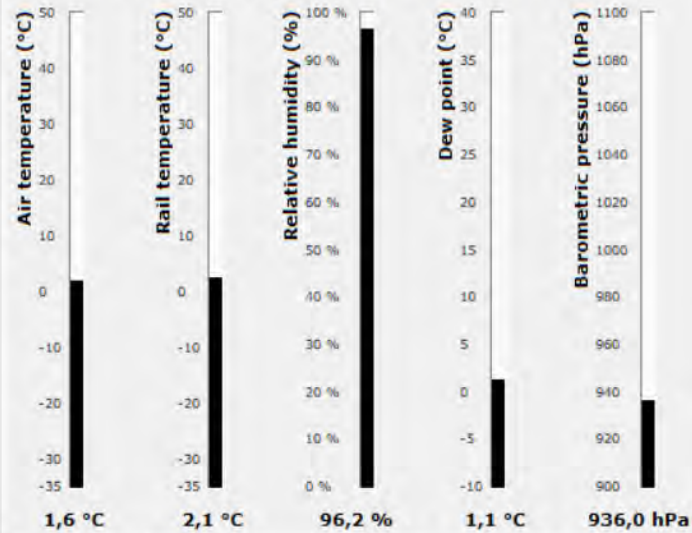
Vehicle users

Limit axle lists



Force [kN] (blue for lateral, black for vertical) / speed [km/h] (square, green=+dir/red=-dir)

Environment info (2025-10-27 13:31:59)



Passage summary

Date	2025-10-27
Total weight (T)	51717,92
Axle passages	2856
Train passages	17
Highest speed (km/h)	62,75
Lowest speed (km/h)	27,51
Average speed (km/h)	50,50
Vertical maximum (kN)	312,72
Lateral maximum (kN)	111,64

Environment summary

Air temp. deg.C (Max)	1,90
Air temp. deg.C (Min)	0,30
Rail temp. deg.C (Max)	3,20
Rail temp. deg.C (Min)	-0,50
Relative humidity % (Max)	98,80
Relative humidity % (Min)	94,80

The measurement station at Haugfjell

Stratoforce - Haugfjell MP1

[Today](#)

[Vehicle users](#)

[Limit axle lists](#)

Locomotives

Time	Operator	Direction	Speed	Vertical (tonnes)								Lateral (kN)								Total weight (T)
				Max	Min	Mean	# < 30,0	# 30,0 - 31,0	# 31,0 - 32,5	# > 32,5	Max	Min	Mean	# < 50,0	# 50,0 - 100,0	# 100,0 - 150,0	# > 150,0			
2025-10-31 00:23:27	-??-	0	58,5	21,5	20,9	21,2	4	0	0	0	79,8	11,2	46,7	2	2	0	0	84,7		
2025-10-31 00:41:12	MTAB	0	48,9	31,3	27,0	28,9	9	2	1	0	87,6	35,4	65,1	3	9	0	0	347,3		
2025-10-31 01:00:11	-??-	1	61,3	22,0	19,2	20,7	8	0	0	0	83,6	1,1	46,6	4	4	0	0	165,8		
2025-10-31 01:15:54	-??-	0	45,2	22,9	20,0	21,3	12	0	0	0	81,0	7,0	44,2	6	6	0	0	255,9		
2025-10-31 01:34:43	-??-	1	49,2	22,7	19,3	21,1	4	0	0	0	87,6	23,8	52,1	2	2	0	0	84,3		
2025-10-31 01:47:13	MTAB	0	49,6	30,4	27,8	28,9	10	2	0	0	96,8	14,5	52,3	7	5	0	0	347,3		
2025-10-31 03:13:02	MTAB	1	57,7	29,9	27,8	29,0	12	0	0	0	114,4	20,7	58,2	8	1	3	0	347,5		
2025-10-31 03:38:09	-??-	1	50,0	22,0	21,0	21,4	12	0	0	0	85,2	2,0	49,6	6	6	0	0	256,4		
2025-10-31 04:50:58	MTAB	1	53,4	29,8	28,4	28,9	12	0	0	0	103,7	20,3	72,5	3	7	2	0	347,2		
2025-10-31 05:07:25	MTAB	0	53,2	30,1	28,0	28,9	11	1	0	0	103,7	14,7	63,1	5	5	2	0	347,2		
2025-10-31 08:43:33	MTAB	1	56,8	29,6	28,3	28,9	12	0	0	0	102,3	4,6	43,4	8	3	1	0	347,2		

Wagons

			Vertical (tonnes)								Lateral (kN)								
Time	Operator	Direction	Speed	Max	Min	Mean	# < 30,0	# 30,0 - 31,0	# 31,0 - 32,5	# > 32,5	Max	Min	Mean	# < 50,0	# 50,0 - 100,0	# 100,0 - 150,0	# > 150,0	Total weight (T)	
2025-10-31 00:23:27	-??-	0	62,6	19,1	5,7	10,9	82	0	0	0	39,7	0,2	15,5	82	0	0	0	896,1	
2025-10-31 00:41:12	MTAB	0	51,0	23,8	20,9	22,2	272	0	0	0	76,1	8,7	22,3	270	2	0	0	6032,7	
2025-10-31 01:00:11	-??-	1	60,6	21,8	7,8	13,9	90	0	0	0	57,0	0,4	23,4	88	2	0	0	1248,2	
2025-10-31 01:15:54	KAUN	0	49,4	30,1	25,0	28,1	156	4	0	0	81,7	5,8	26,0	150	10	0	0	4502,2	
2025-10-31 01:34:43	-??-	1	49,2	18,0	5,6	13,7	72	0	0	0	52,9	0,2	19,5	69	3	0	0	985,7	
2025-10-31 01:47:13	MTAB	0	46,8	29,5	26,4	28,3	272	0	0	0	52,7	5,1	27,0	269	3	0	0	7687,8	
2025-10-31 03:13:02	MTAB	1	57,5	6,2	4,9	5,5	272	0	0	0	22,2	0,1	10,2	272	0	0	0	1489,9	
2025-10-31 03:38:09	KAUN	1	49,9	6,2	5,0	5,6	160	0	0	0	23,4	0,0	10,7	160	0	0	0	893,6	
2025-10-31 04:50:58	MTAB	1	54,3	6,6	4,7	5,5	272	0	0	0	24,4	0,1	10,9	272	0	0	0	1506,9	
2025-10-31 05:07:25	MTAB	0	52,0	29,4	26,6	27,8	272	0	0	0	111,3	0,4	28,9	264	7	1	0	7557,7	
2025-10-31 08:43:33	MTAB	1	57,0	6,1	4,7	5,5	272	0	0	0	17,9	0,0	9,1	272	0	0	0	1492,2	



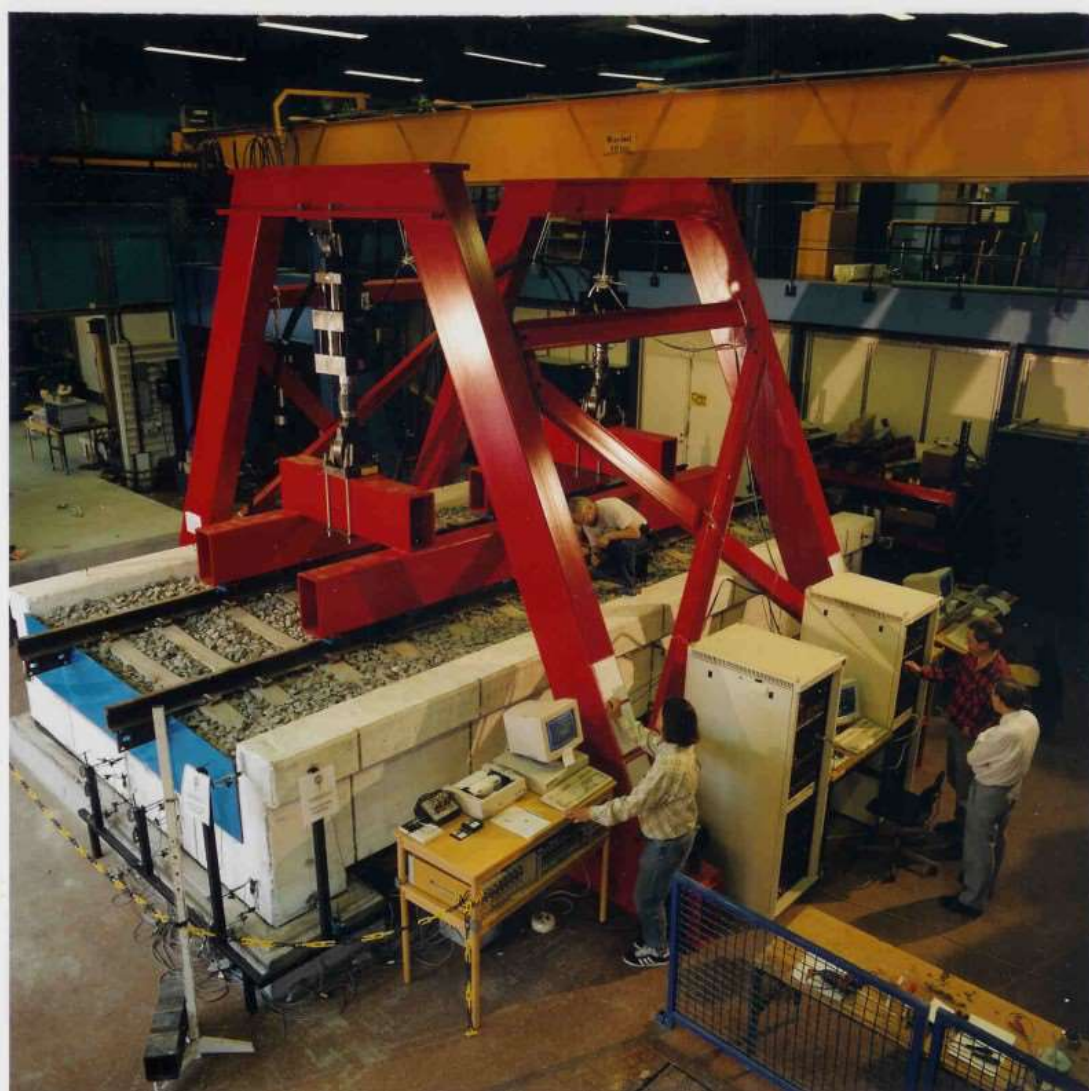
THANK YOU!

MCE-Lab and Bridge Research

Mining and Civil Engineering Laboratory

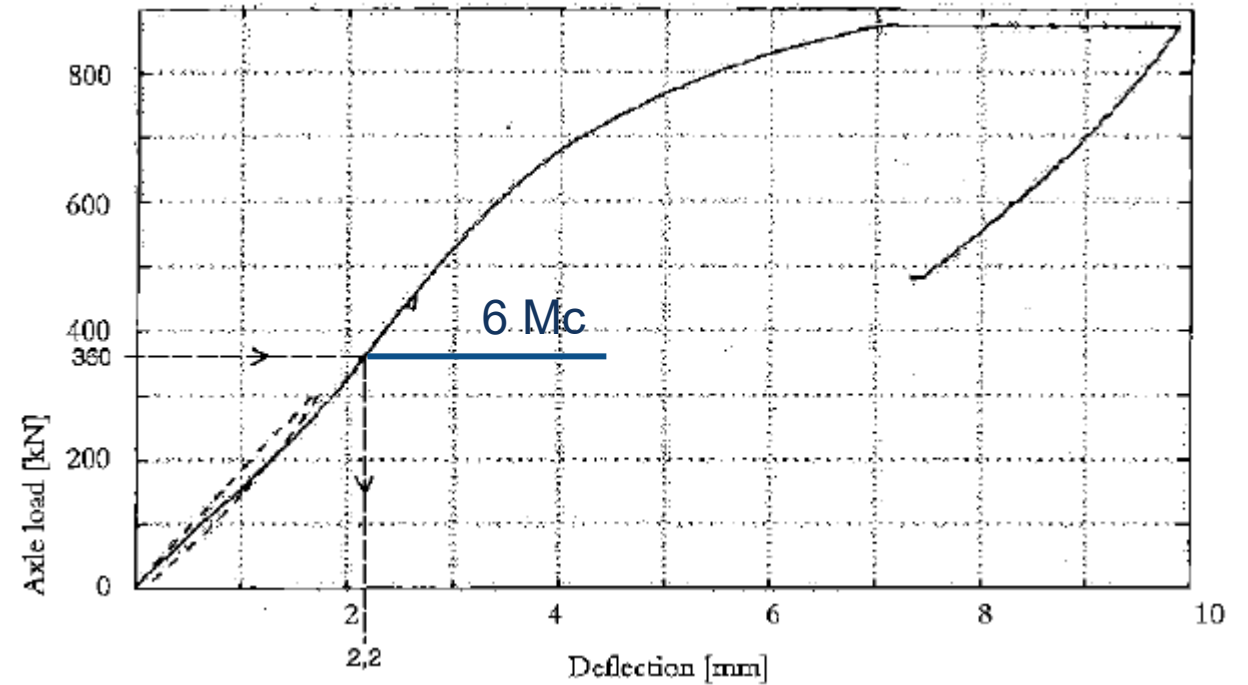
Gabriel Sas, Jaime Gonzalez, Chao Wang, Silvia Sarmiento
Björn Paulsson and Lennart Elfgren

Division of Structural Engineering, Luleå University of Technology



1996 Malmbanan 30 ton

A 29 year old railway bridge was tested in the lab in Luleå



2006 A strengthened bridge tested in Örnsköldsvik

2024-25 A new bridge tested in the lab

2006

**A Railway RC
Trough Bridge
was
Strengthened
with Carbon
Fibre Reinforced
Polymer Bars
and Tested to
Failure in
Bond-Shear-
Bending in
Örnsköldsvik**

**Allowed load
could be
increased
6 times
without
strengthening**

**EC Project
Sustainable
Bridges**





2024-2025
One bridge is
instrumented
and is tested
to fatigue in
our lab

Trough bridge project

Financer: Trafikverket

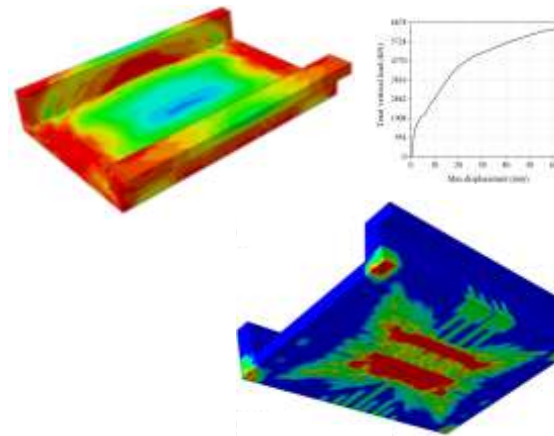
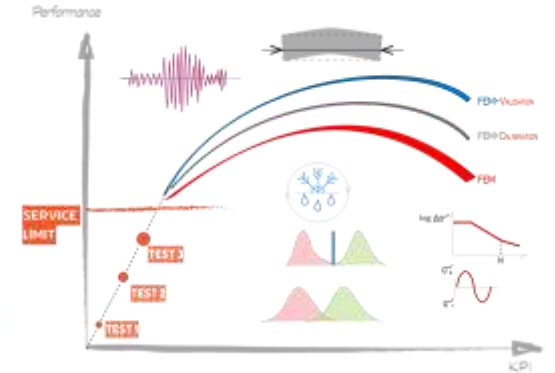
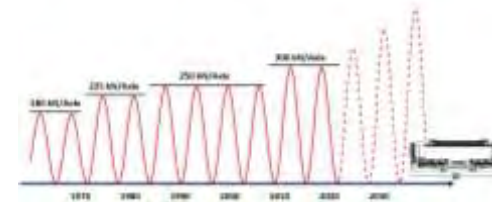
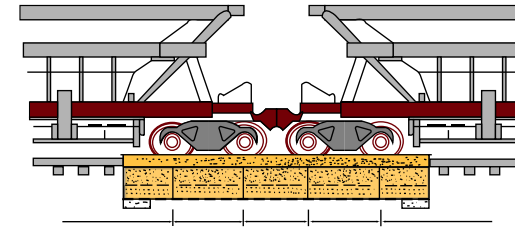
Timeline: Jan 2021 - Dec 2025

PI: Gabriel Sas

Team: Jaime Gonzalez-Libreros
Chao Wang
Silvia Sarmiento
Vedad Coric
Mert Pinar



119 126
7 bridges



The aim of is to increase the transport capacity of the bridges located on the Ore Line (Malmabanen).

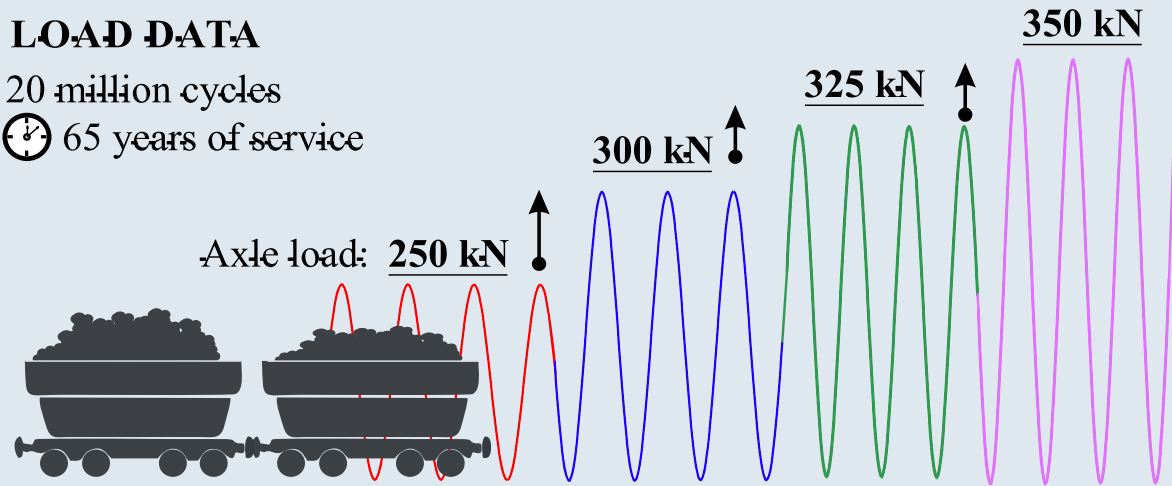
The objectives are to measure the static and dynamic performance of the trough bridges as realistic as possible and to suggest methods to mitigate potential challenges.

Trough bridge project

LOAD DATA

20 million cycles

⌚ 65 years of service

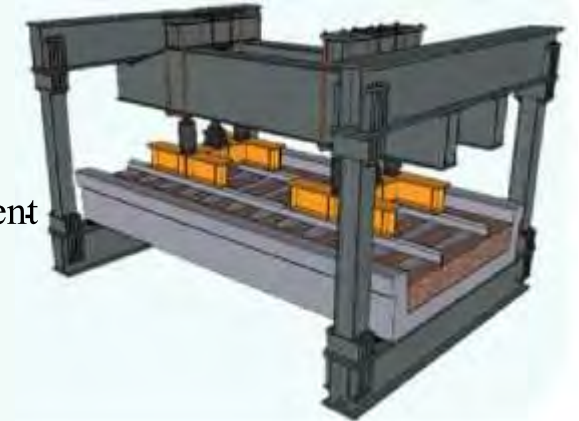


FULL-SCALE TEST

RC trough bridge

Monitoring parameters:

- Displacements
- Strains in reinforcement
- Strains in concrete
- Crack size



RESULTS - after 10 million cycles

1. Test:

Stiffness $\searrow$ 29%

Max. strain reinforcement = 710.0 $\mu\epsilon$

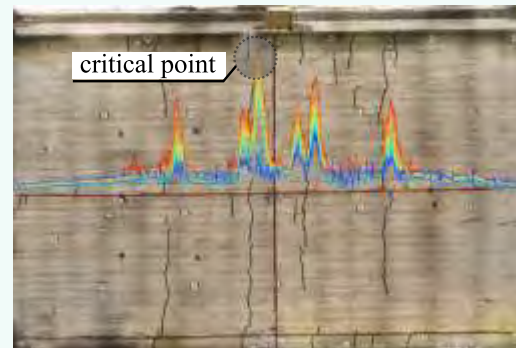
2. Reliability:

$$\beta = 6.8 > \beta_t$$

Remaining service life: 27 years

✓ Overall structural performance maintained

Bottom slab view - strains in reinforcement

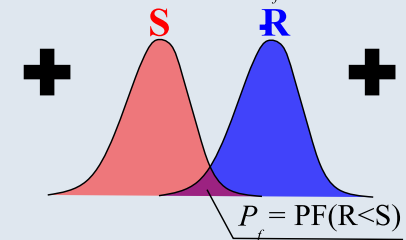


ANALYSES

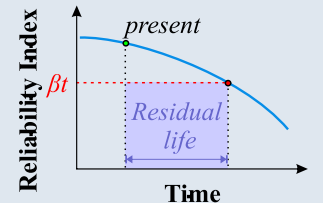
Fatigue verification



Reliability evaluation (β and P)



Remaining Service Life



Haparandabanan



Vitån, km 1192+943

Avafors GC-port, km 1192+989



Degerselet, VP, km 1170+686



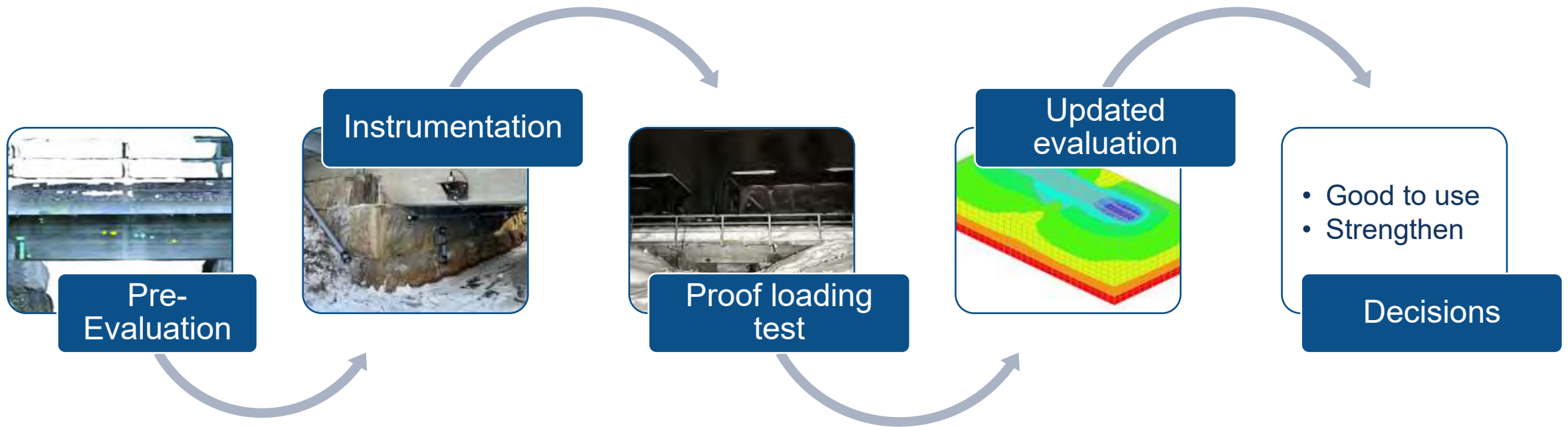
Svartbäcken, km 1151+546



Objectives:

1. Evaluate the capacity of the structures;
2. “Train” the railway line to higher loads;
3. Prescribe actions and recommend solutions for optimum use

Capacity assessment - Proof load methodology

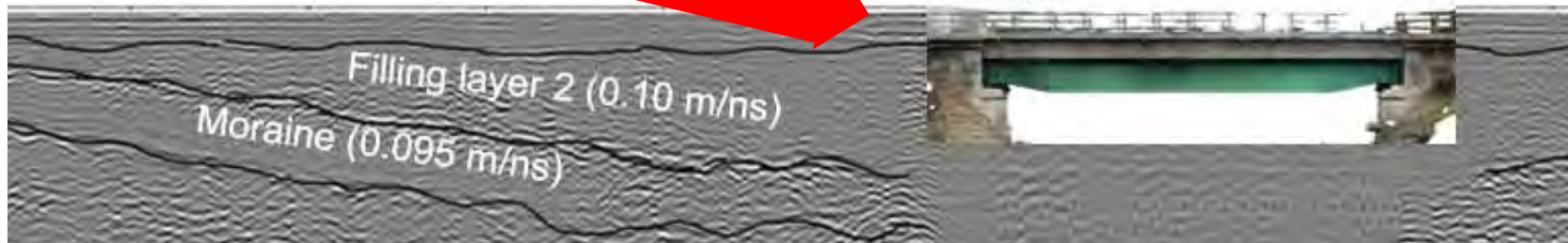
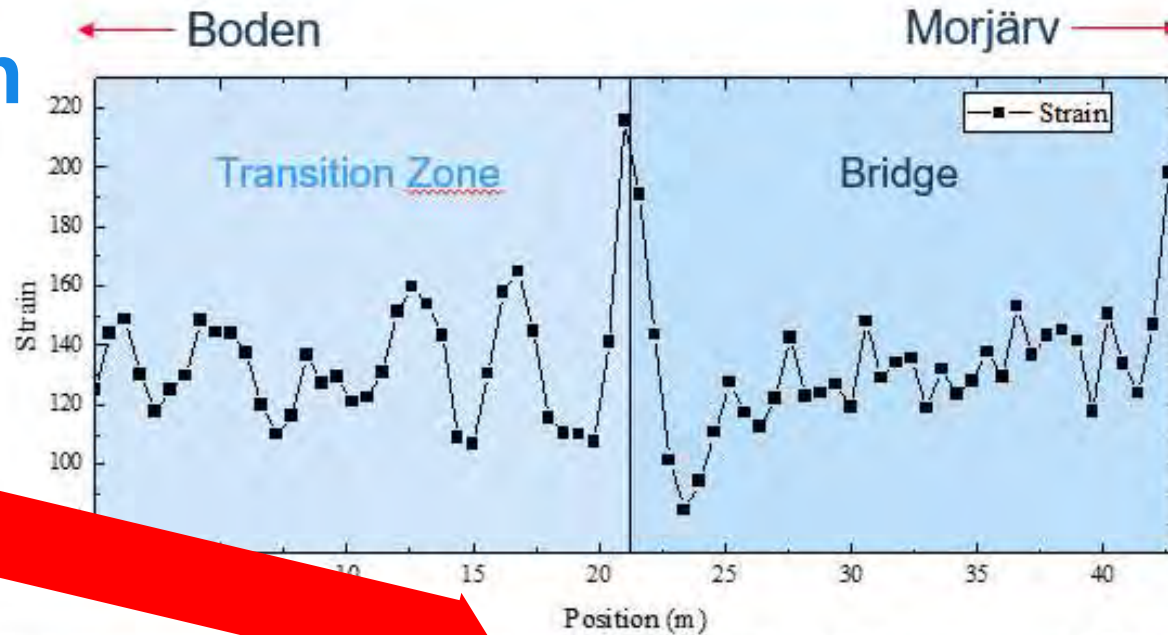


Demolition of Kiruna Mine Bridge over the Ore Railway Line in 2014



Transition zones

Ballast condition
Ballast drainage



Under Sleeper Pads, USP



Under Ballast Mats, UBM

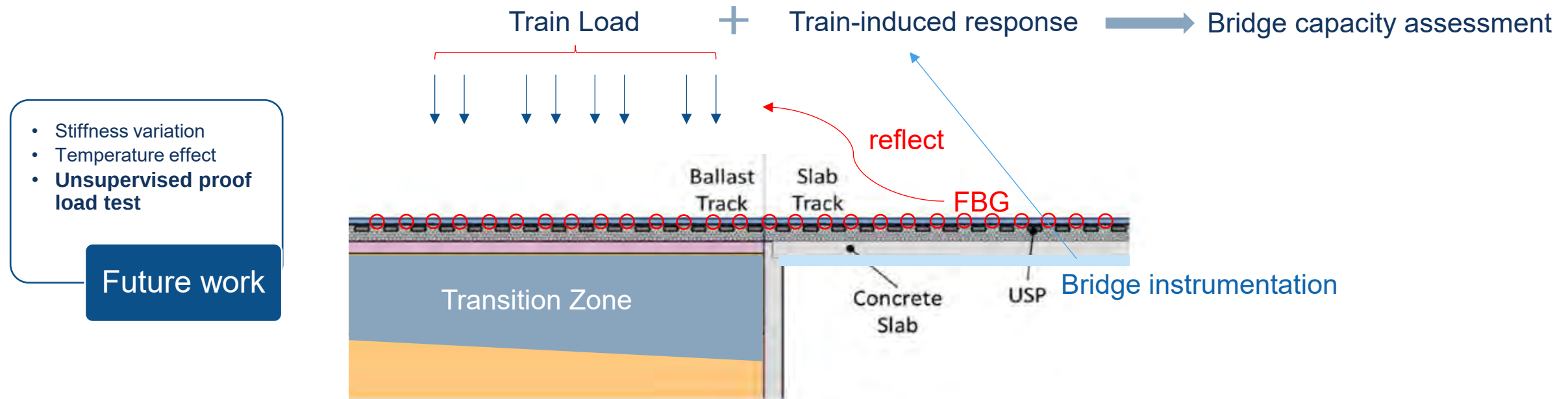


Reduction of rapid variations in track stiffness around e.g. bridges and tunnels

By Björn Paulsson, Jens Nielsen, Eric Berggren & Lennart Elfgren

To be published in Dec 2025

Measurement – Unsupervised proof loading



Conclusions

- **Bridges** have hidden **strengths** (conservative codes & materials) and hidden **faults** (scour, corrosion, fatigue). You should find them.
- **Stiffness variations in track** can be **smoothed out** by better **transition** zones, better **ballast**, better **drainage**, under sleeper pads (**USP**) and under ballast mats (**UBM**).
- **The Railway is a system**. No chain is stronger than its weakest link. But the whole is more than the sum of its parts (Aristotle, ca 350 B.C.). Cooperation is needed. One hand should know what the other is doing.



Acknowledgements to Trafikverket: Lars-Olov Andersson, Tommy Höjsten, Ola Enoksson and to our colleagues at LTU & MCE-Lab: Mats Petersson, Erik Andersson, Vedar Coric, Mert Pinar, Angelica Agredo, Dongyun Liu, Jie Chao & Lei Yan.

Lennart.Elfgren@ltu.se

Many thanks for your kind attention !



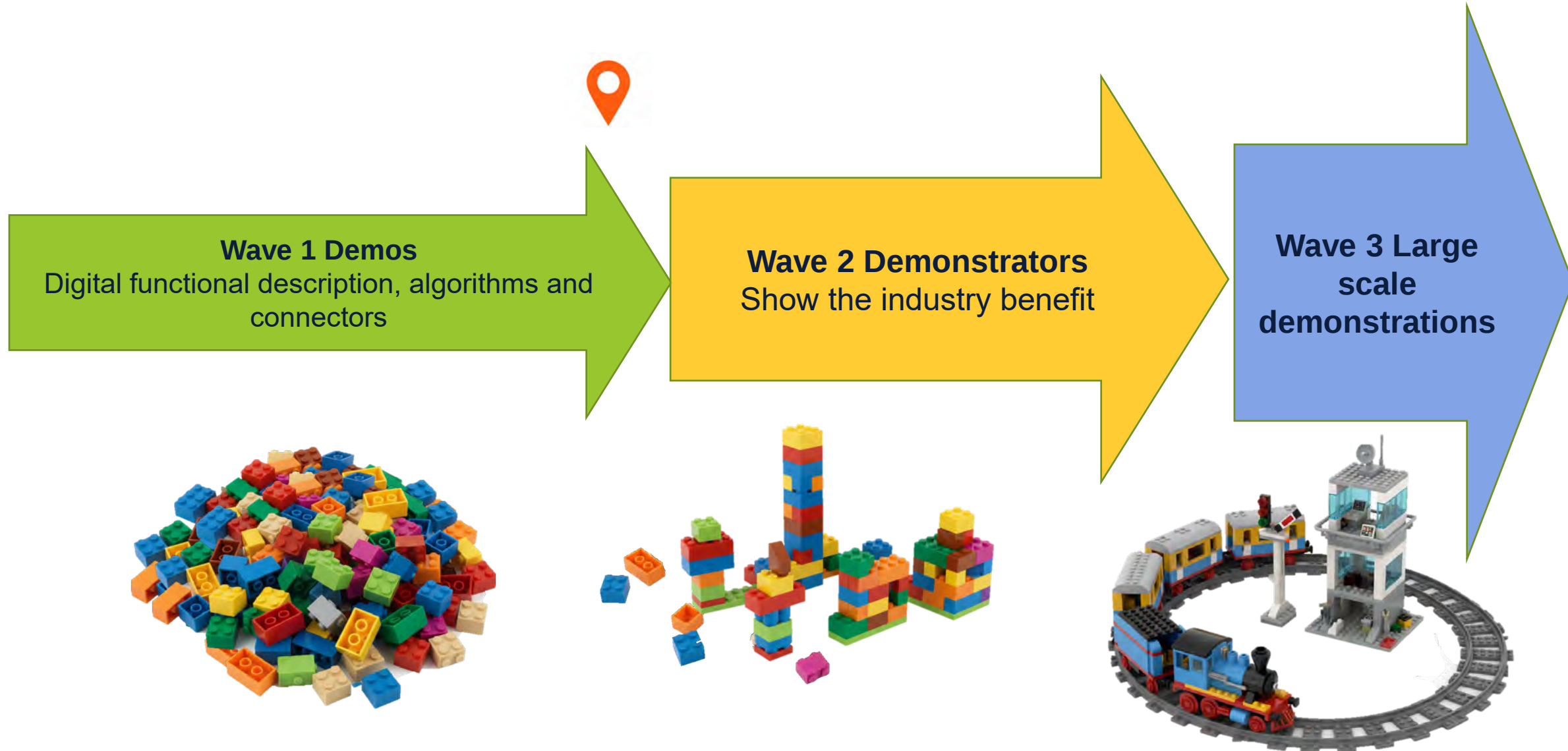
The digital Arctic test arena - BIM, Rail Data Spaces and C-DAS

Isabelle Tardy

Launch and seminar: Arctic Test Arena, Narvik, Nov.5th 2025



Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Europe's Rail Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them. The project “FP1-MOTIONAL” is supported by the Europe's Rail Joint Undertaking and its members.



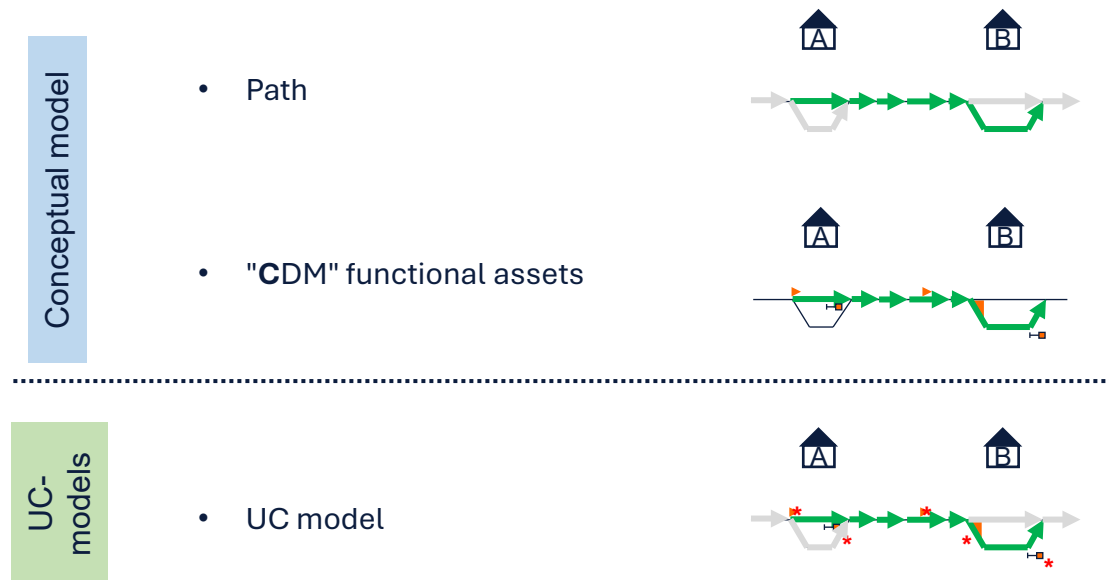
Building blocks



- ➡ • Building unequivocal and ERA-compliant Conceptual Data Model,
- Developing digital twins environments – functional mock-up unit and interfaces
- BIM asset descriptions as input to a digital twin environment,
- ➡ • Developing connectors for federated data spaces used for distributed data sharing
- Developing optimisation algorithms for timetabling (long-term and short-term) as well as dispatching,

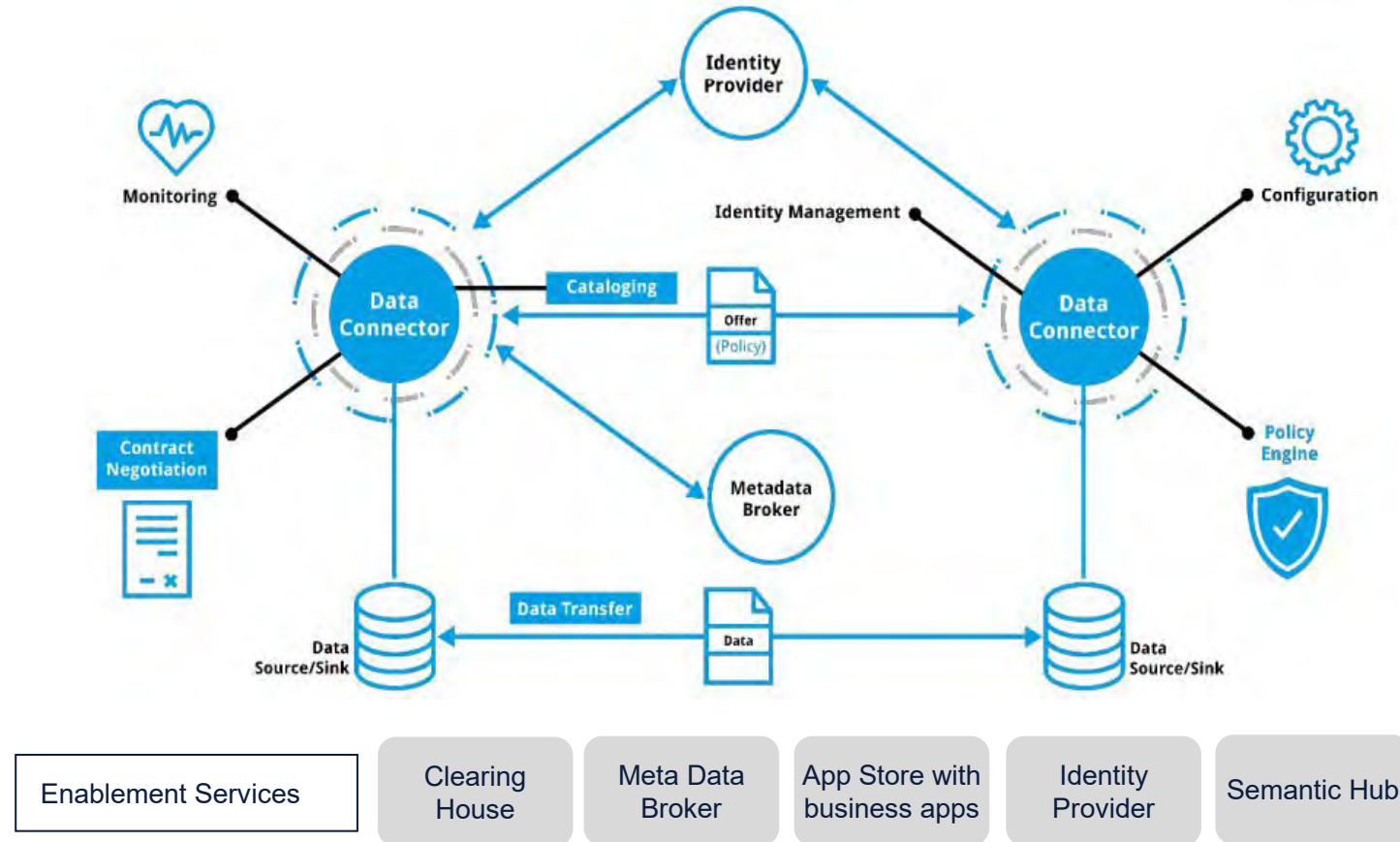
Conceptual data model - Ontology

- One common conceptual basic model that unites railway stakeholders and that is open and can be extended
- Common Malmö-Alnabru description, Ofot/Malm coming soon
- Governance continued at ERA, where support from UIC that guarantees wider knowledge about existing developments from e.g., Eulynx, RNE, railml.org, Transmodel, IFC and others in the rail data domain



Data Sharing via the Rail Data Space

Rail Data Space is an interoperable and secure federated Data Space for Rail that can be trusted by all partners.



Benefits



Compliant with EU legislation including EU Data Act



Maintain data ownership by defining who can access data and under what terms



Full transparency and verification of data transactions



Most efficient way to share data with multiple parties



Shared costs of scalable data space infrastructure

Building a tower: the C-DAS case



- Foundation: Common functional track description. RailML description
- 3D and BIM for bridge modelling (e.g., Søsterbekk) to dynamically report events like temporary capacity restrictions in traffic models
- Rolling stock model as static and dynamic data
- Algorithms optimising traffic robustness
- C-DAS equipment on board, parallel to TMS in a shadow mode operation, possibly from several industrial partners, using above-mentioned data
- Stakeholders IMs, RUs, vendors...retain data sovereignty, ensuring cybersecurity and scalability thanks to Rail Data Spaces.



Improving traffic on single-line tracks

- Challenging Ofot/Malm line: mainly heavy and long iron ore trains combined with freight and passenger trains, single track, topography, climate, roadless country
- ...hence ideal for testing C-DAS impact for:
 - gaining better control of planned distribution of time buffers over the line,
 - improving timing calculations to meet train trajectories and scheduled RTTP,
 - reduce general delays, energy consumption, wear and tear,
 - reduce risk of unplanned traffic stops, ie. when freight train brakes freezes when stopping in harsh winter environment causing major delays.
 - decision support for possible infrastructure changes in the longer run,
 - allowing a safe exchange of quality-verified data between stakeholders for the sake of improving network usage.
- Digital testing goes beyond the sole interest of local stakeholders in Norway and Sweden



AI FACTORY FOR RAILWAY

Ramin Karim, Chair Professor
Operation & Maintenance Engineering
Luleå Railway Research Center – JVTC
05 November 2025, Narvik, Norway

RAMIN KARIM

- PhD, Chair Professor, Head of Subject (Research focus: Industrial AI & Engineering Asset Management)
- Director of the 'Centre of Intelligent Asset Management (CIAM)' at LTU
- Founder of Predge AB
- Scientific leader of 'AI Factory'
- ...

LTU Supervisor
of The Year (2023)



IVA's
100-list (2021)



IVA's
100-list (2020)



Swedish 33-list
Predge (2014)



Swedish 33-list
Predge (2013)







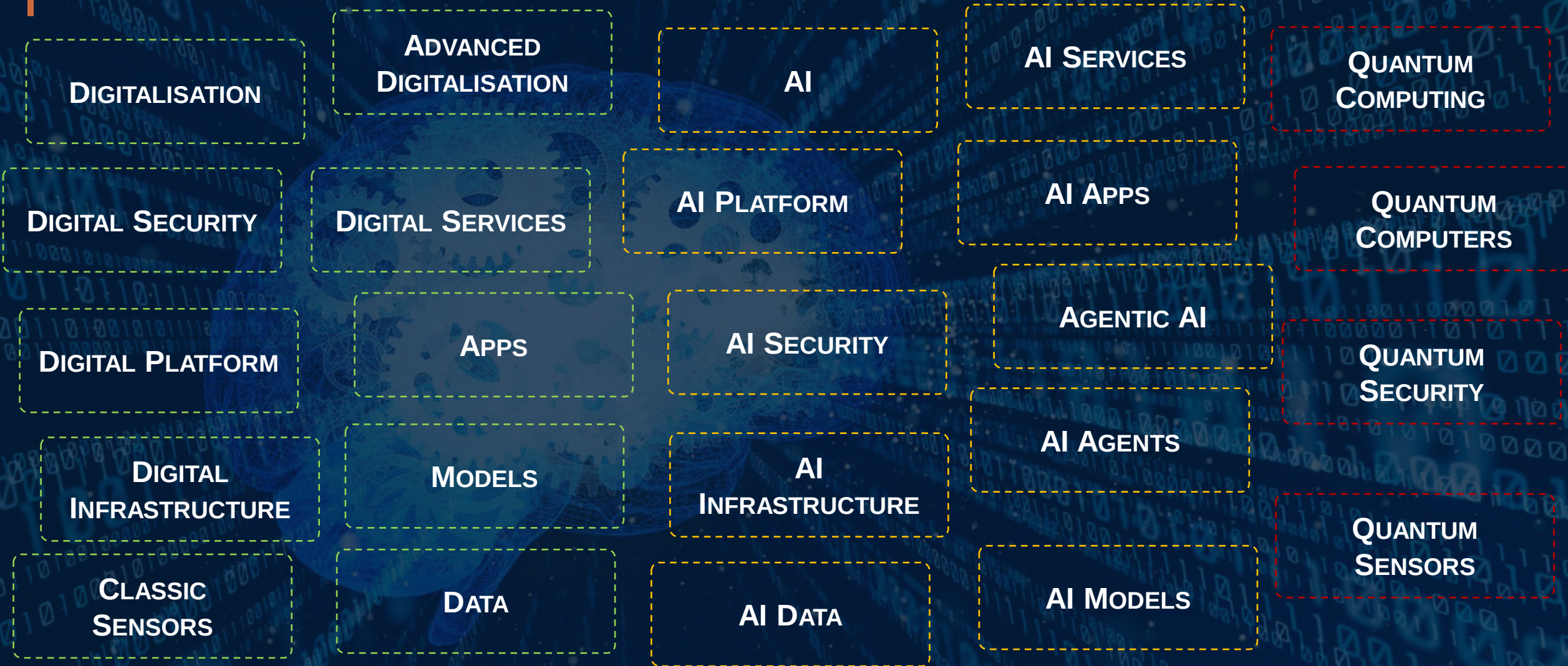
**RAILWAY IS A
DYNAMIC
CYBER-PHYSICAL
SYSTEM-OF-SYSTEMS**

**MANAGING RAILWAY
DURING ITS WHOLE
LIFECYCLE IS
COMPLEX &
COMPLICATED**

SOME FUNDAMENTAL DISCIPLINES IN RAILWAY MANAGEMENT



SOME BASIC TECHNOLOGIES FOR MANAGING RAILWAY



“THIS IS THE WAY”

A JVTC approach

Focus

SCIENCE

helps us to understand real-world phenomena
Example: Physics-of-Failure



TECHNOLOGY

applies science and facilitates engineering
Example: AI & Quantum



**O&M RESEARCH
COMBINES & INTEGRATES
S/T/E/M**



ENGINEERING

helps us to solve problems using technology
Example: Maintenance Engineering

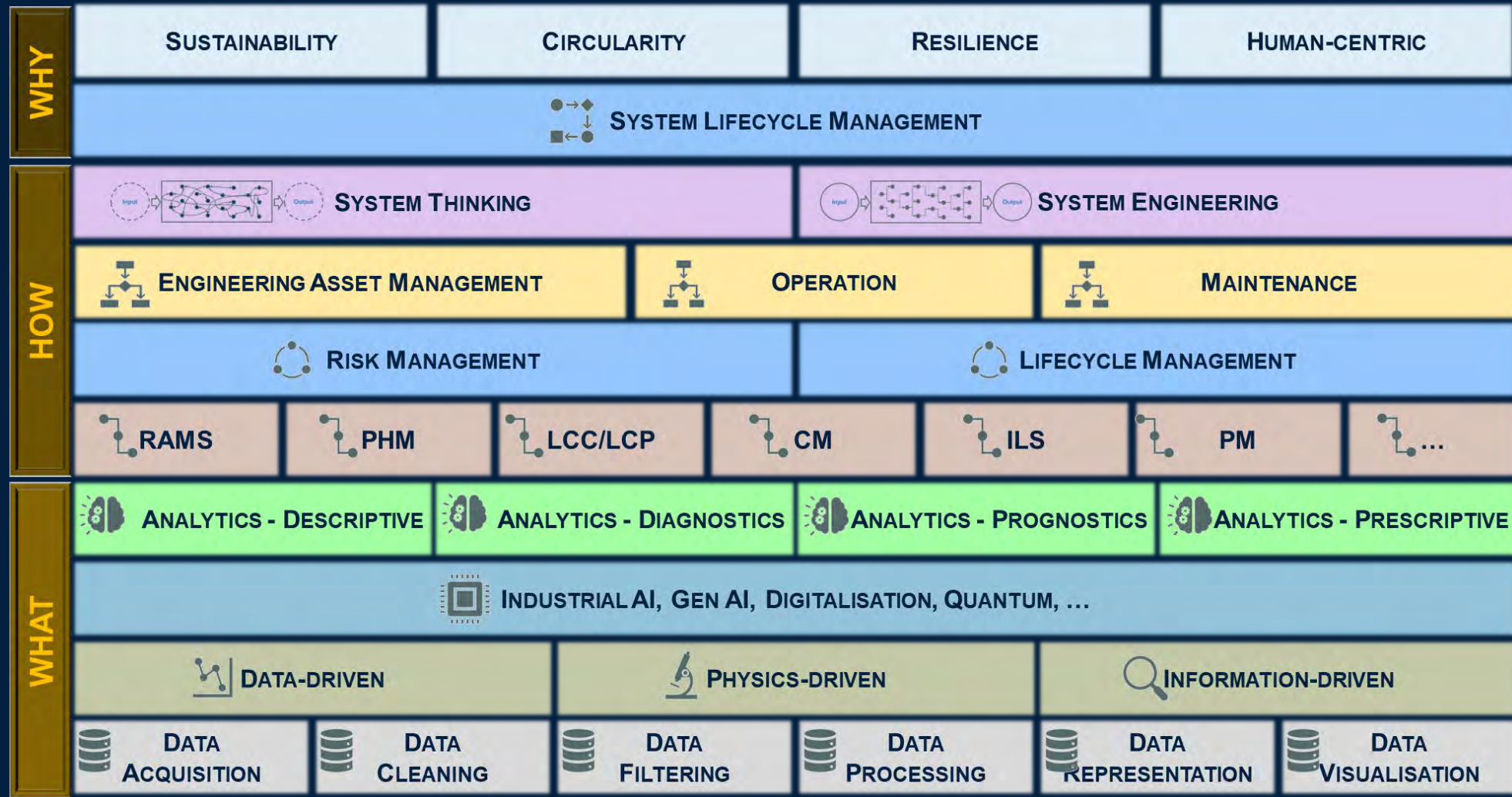


MANAGEMENT

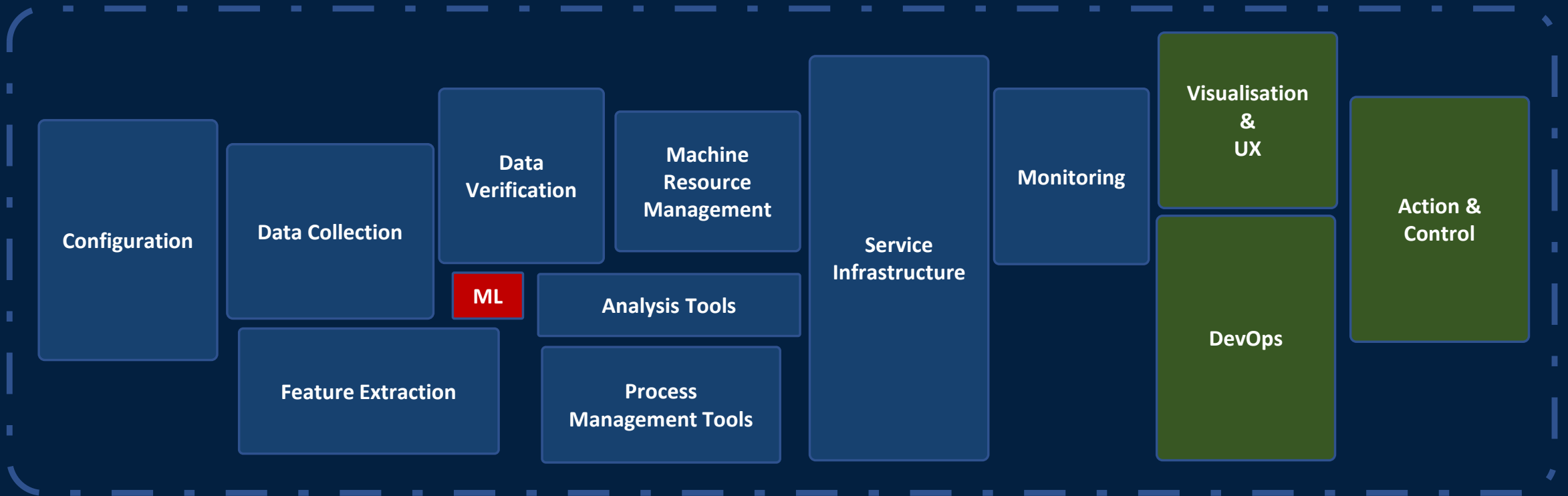
helps us to manage system-of-systems using technology
Example: Asset Maintenance

(Karim, 2020)

O&M - SCIENTIFIC STACK



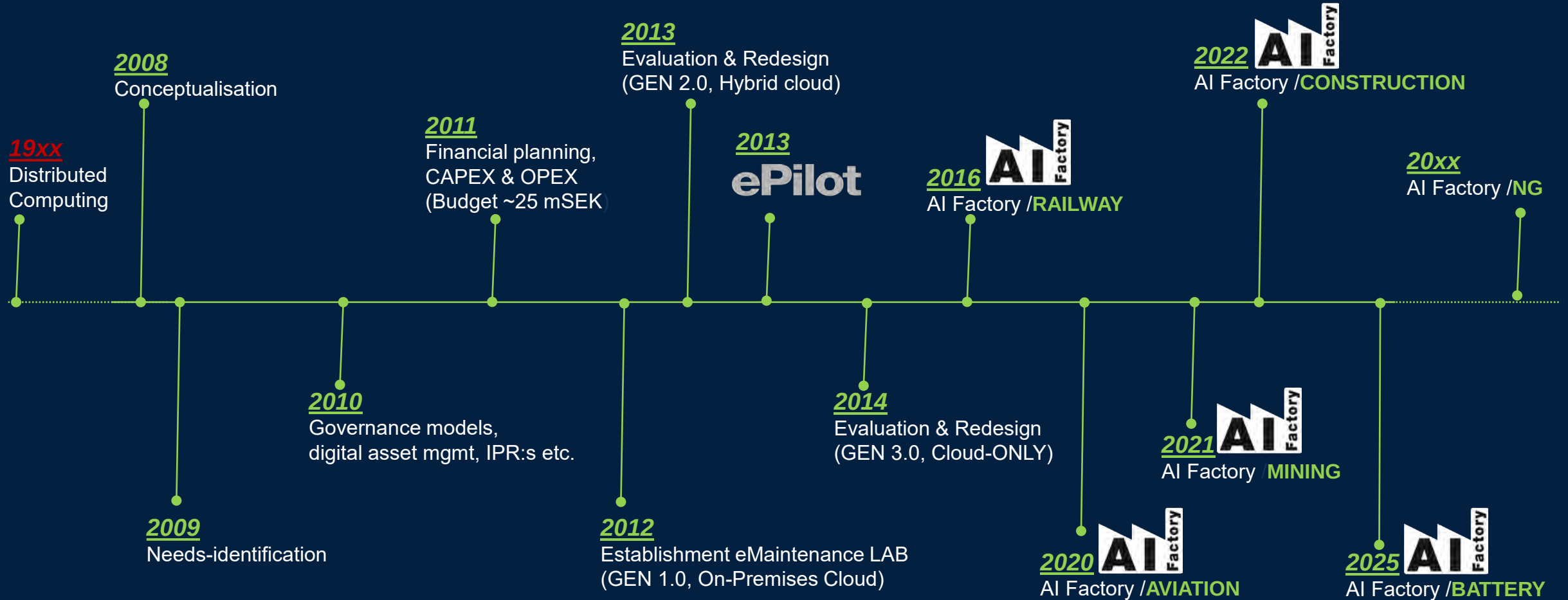
INDUSTRIAL AI – AN ENGINEERING PERSPECTIVE



(Sculley et al., 2015)

TIMELINE

(PAST & FUTURE)





I. A **RESEARCH** CONCEPT

II. A **TECHNOLOGY** PLATFORM

III. AN **ENGINEERING** TOOLBOX

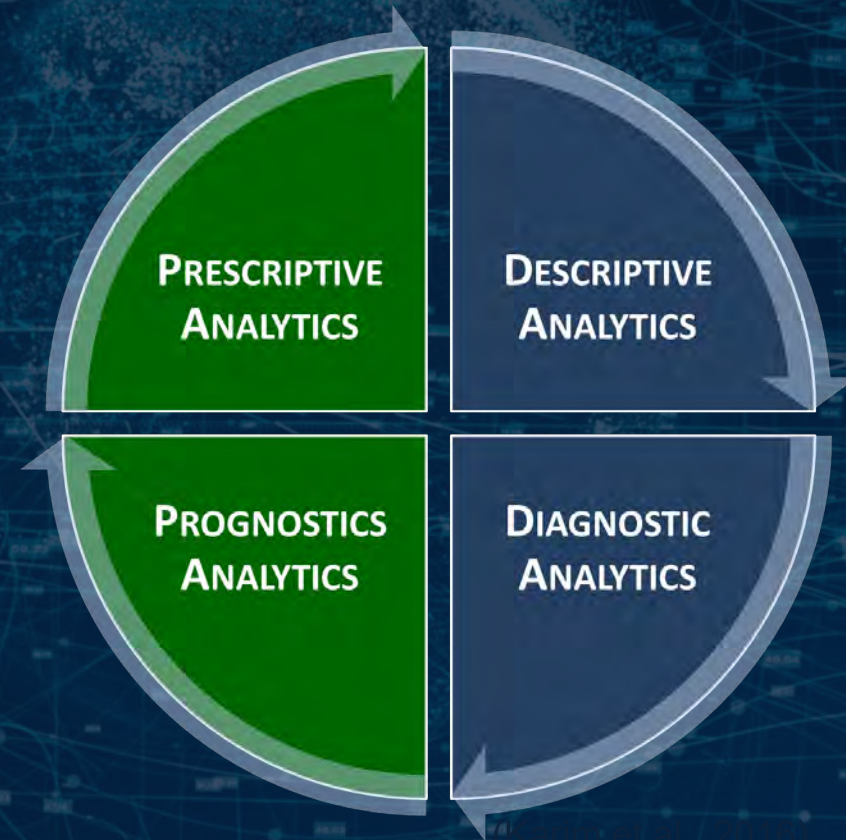
AI FACTORY: SEEING INTO THE FUTURE!

■ Nowcasting

- 1) What happened in the past
 - What is happening now
- 2) Why something happened

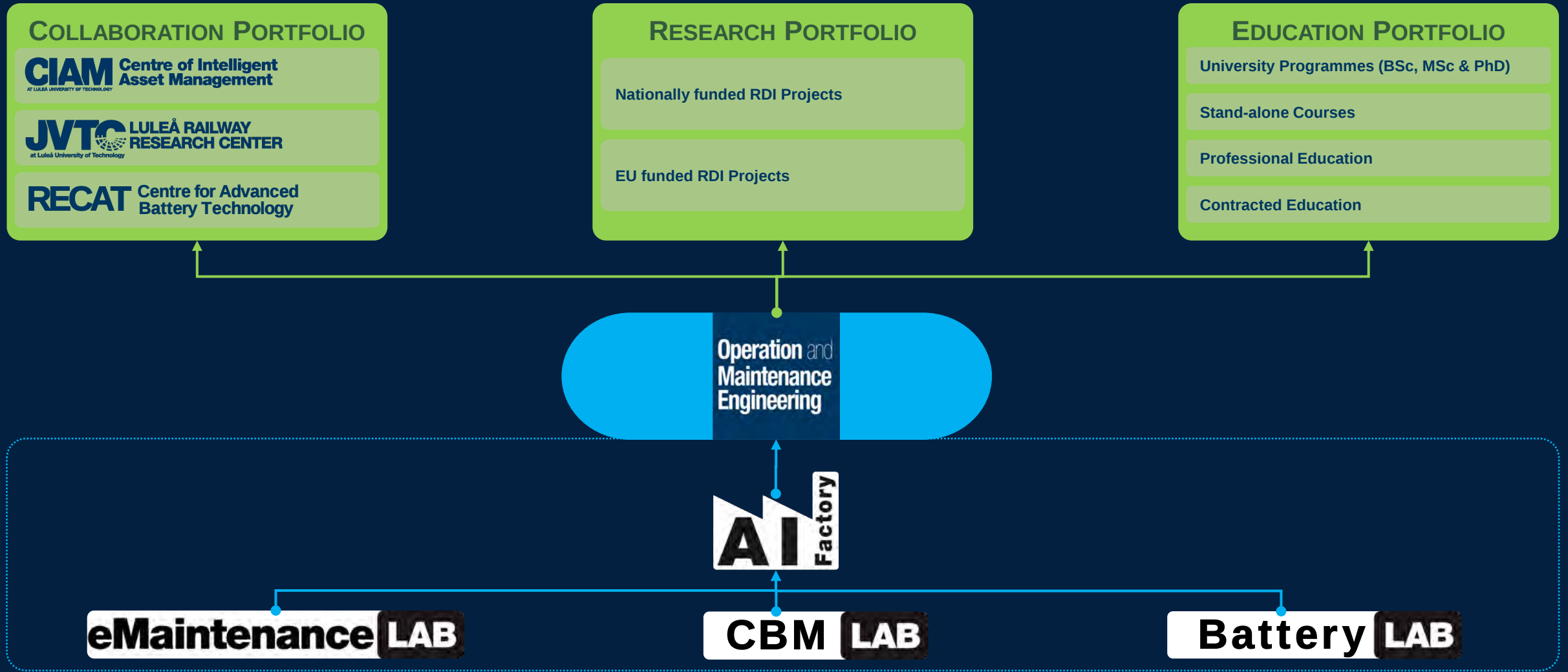
■ Forecasting

- 3) What will happen in the future
- 4) What needs to be done next



(Karim et al., 2016)

O&M – RESEARCH & EDUCATION INFRASTRUCTURE



CONCLUDING REMARKS

- **Vision & goals**
 - Clear & accepted
- **Multi-disciplinary team**
 - Scientists & engineers
- **Physical infrastructures**
 - Physical test arena
- **Technology infrastructure**
 - Digital, AI & Q – AI Factroy
- **Resources**
 - Financial, physical, virtual & human assets
- **Business Models**
 - Scalable
- **Regulatory**
 - Frameworks & sandboxes
- **Persistence**
 - Learning & improving

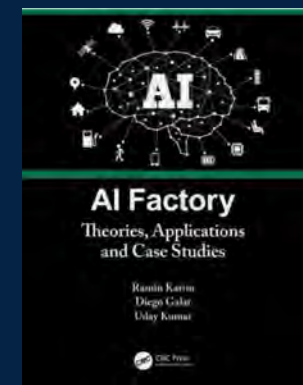


“FIRST, YOU MUST UNLEARN
WHAT YOU HAVE LEARNED!”

Thank You for Your Attention!



(Jedi Master Yoda)



Concrete Innovation Cluster

Rune Nilsen





SINTEF

ONE OF EUROPE'S LARGEST **INDEPENDENT**
RESEARCH ORGANISATIONS

4,4 billion NOK
turnover

2200
employees

6300
projects

3300
customers

INTERNATIONAL

934 million NOK

NATIONALITIES

80

PUBLICATIONS (INCL. DISSEMINATION)

5900

Vision: Technology for a better society



Research infrastructure

- Financing to research/research institutes
- Funding 2-200 MNOK (special reason > 60 MNOK)
- Purpose:
 - provide Norwegian research communities and the business sector **access to relevant and up-to-date infrastructure, which supports high-quality research and innovation** and helps to provide the knowledge needed to address societal challenges

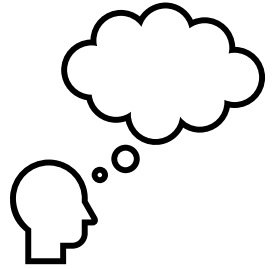


Not a research project



Build infrastructure to facilitate research!

Why do we need railway research infrastructure?



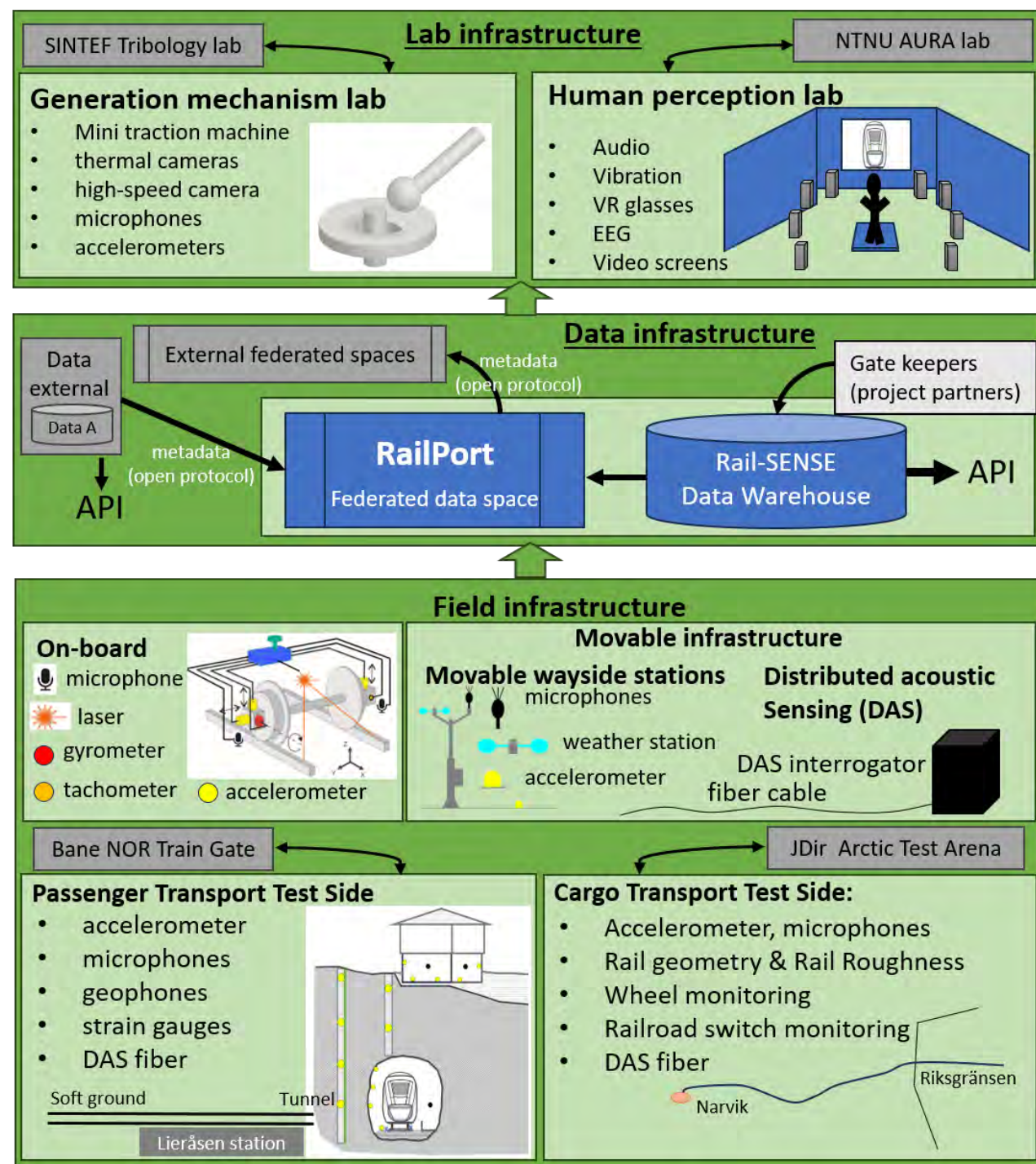
- Railway research infrastructure is essential for advancing our understanding of the mechanisms that cause wear and degradation of wheels and rails. This degradation leads to reduced service life, increased maintenance needs, operational disruptions, and elevated levels of noise and vibration.
- The research infrastructure will be used to develop new solutions and to document the effects of implemented measures.
- It will support the development of standards and best practices
- Moreover, railway research infrastructure can also attract international research projects and partners, strengthening European collaboration and knowledge exchange.

Rail-Sence Consortium

- **SINTEF Digital (Lead/ coordinator):** acoustics, measurement & modelling noise, CNOSSOS-EU, non-destructive testing, sensors
- **SINTEF Narvik:** Railway technical challenges on infrastructure, maintenance, structural health monitoring, field measurements, load impact analysis
- **SINTEF Industry:** tribology, cross-disciplinary knowledge, advanced laboratories, develop new materials & technologies
- **NGI:** national digital transformation(NGI Live), geotechnical engineering, soil & rock dynamics, railway vibration, high speed railways, critical speed, mitigation measures, effects of vibration on humans
- **NORSAR:** seismological data processing & analysis, seismic instrumentation, technical laboratory equipment, data transmission & storage, fibre optic sensing
- **NTNU:** Acoustics research & teaching, 3D sound, sound perception, noise annoyance, environmental acoustics (transportation noise emissions, outdoor sound propagation), **AuraLab**
- **Bane NOR:** Methodology for daily maintenance, development of new methods; Problem owner
- **Norske tog:** Owns and manages rolling stock services, CMB of train & Infra

Rail-Sense

- Data Infrastructure
- Sound generation infrastructure
- On-board measurement
- Freight train transport site (Ofotbanen)
- Passenger transport field site (Lieråsen)
- Movable stations
- Human perception infrastructure





SINTEF

— 75 år —

Rail-Sense After project period

**Project
Build
infrastructure**

**After project
Use Infrastructure**

- Infrastructure for everyone to use
 - rental fee to ensure maintenance
- Research projects
 - national (NFR)
 - international (EU)
- Direct projects with/for industry partners
- Test activities

The challenge of harsh environments - film:

- [The challenge of harsh environments - Ofotbanen and Malmbanan on Vimeo](#)

(DAS) Interrogator Nordlandsbanen/Ofotbanen

05.11.2025

Rune Brannfjell

Tracking rockfall, landslide and Avalanche along the railway track



24.10.2024 Bjerka and Finneidfjord

Triggering Point for The Project, rockfall Bjerka and Finneidfjord 24.10.24



→ Overview of DAS (Distributed Acoustic Sensing) Project



Purpose and Background

Landslide Risks on Railways

Landslides on railway tracks cause serious safety hazards

Limitations of Traditional Systems

Mechanical warning systems are costly and provide limited coverage, unsuitable for large-scale use.

DAS Technology Solution

DAS uses fiber optic cables to detect vibrations, offering real-time, scalable landslide monitoring.

Safety and Efficiency Benefits

DAS deliver broader coverage at lower costs, improving railway safety and operational efficiency.



What is DAS for Bane NOR?

Fiber Optic Acoustic Monitoring

DAS uses fiber optic cables to detect acoustic signals and vibrations by analyzing backscattered laser light.

Real-Time Environmental Sensing

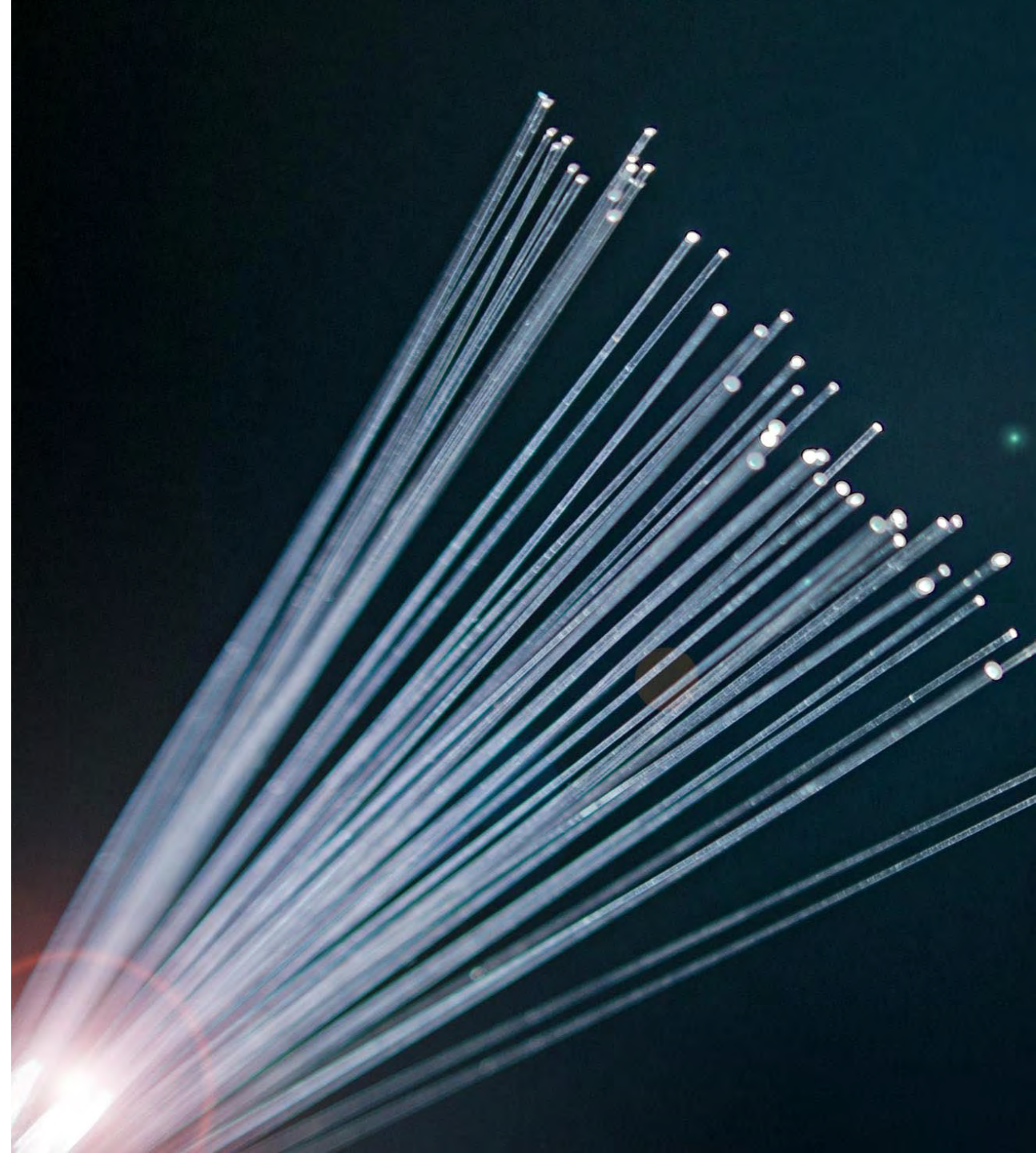
DAS continuously monitors environmental changes in real time.

Railway Safety Applications

DAS detects train movements and landslides, enhancing safety and operational efficiency on railways.

Infrastructure Benefits

DAS using existing fiber optic infrastructure, reducing installation costs and enabling efficient data collection.



Milestones

Initial Operation

The first DAS interrogator was put into operation in December 2024, marking the project's launch phase.

Pilot Phase Completion

By July 2025, the pilot phase demonstrated DAS feasibility for detecting landslides along railway routes.

Technology Readiness Level 7

In September 2025, DAS reached TRL 7 with monitoring on Nordlandsbanen and Ofotbanen railways.

Future Expansion

In 2026, research will expand to railroad crossing and train positioning to enhance railway safety.



Ofotbanen 02.09.2025

Tests and Simulations





Bane ⓘ

Nordlandsbanen B05 (0.8 - 728....) ⬇

Banestrekning ⓘ

Lønsdal - Fauske (601.76 - 675.26) ⬇

Delstrekning ⓘ

Rognan - Fauske (648.11 - 673.44) ⬇

Kilometer ⓘ

658,51

Km-retning ⓘ

→ Fra km-retn

Tests and Simulations

Train Movement Monitoring

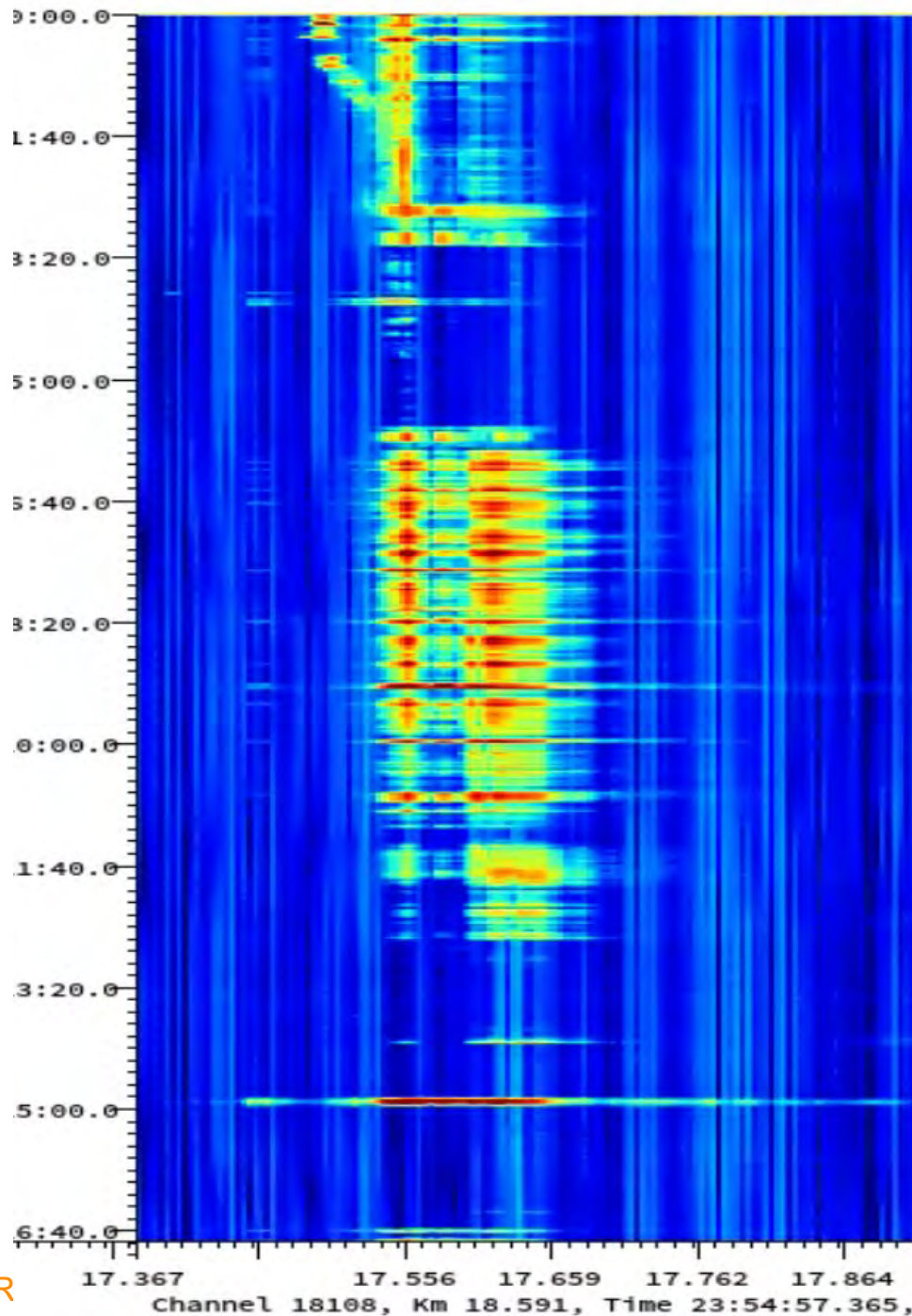
The system monitored train movements over a 100 km railway stretch, enhancing operational awareness.

Rock fall and Snow Avalanche Simulations

Simulations of rock fall and snow avalanches inside and outside tunnels showed clear signal patterns.

RMS Vibration Analysis

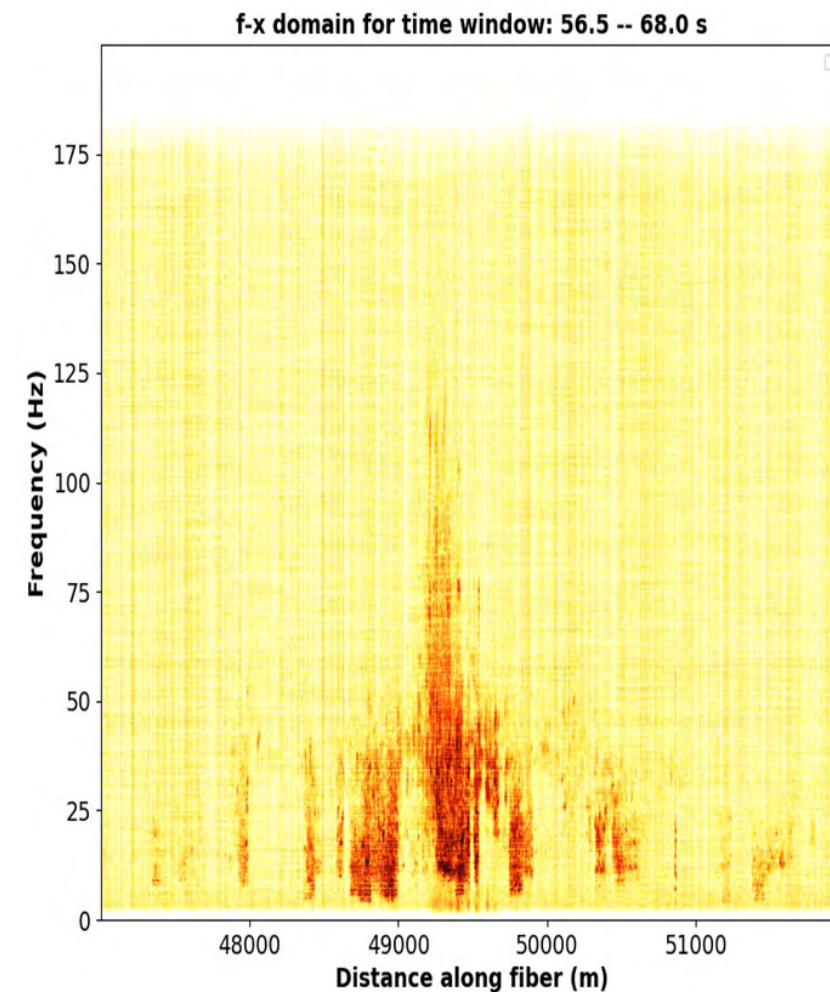
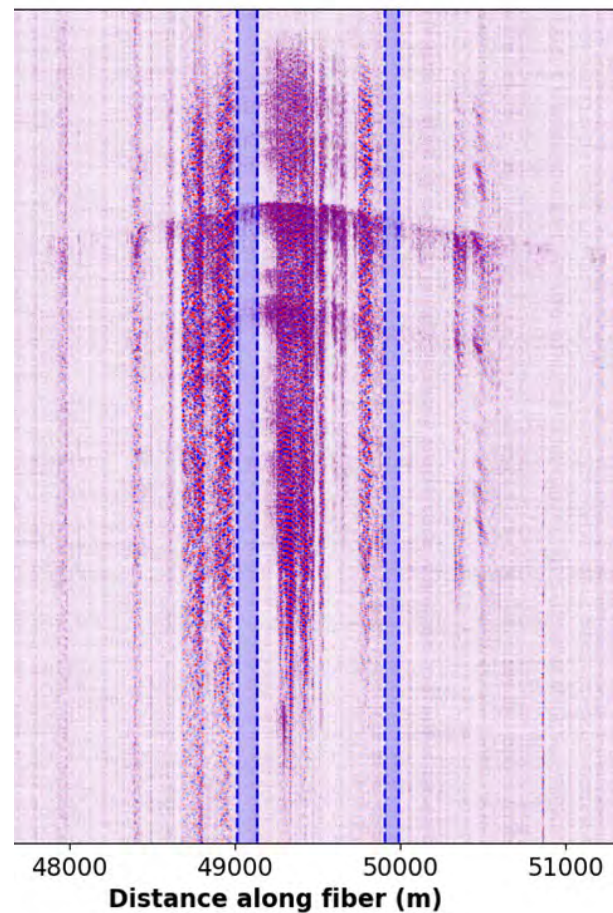
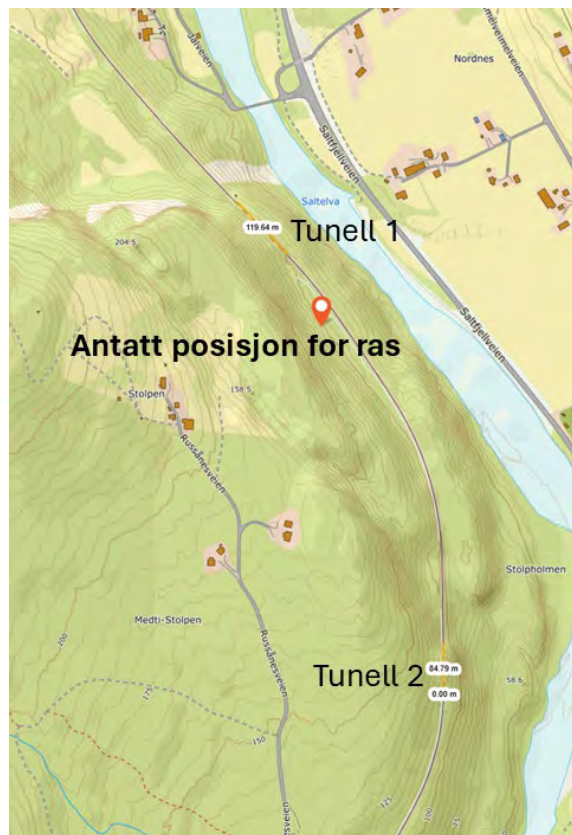
RMS levels were plotted to visualize vibration intensity and duration, confirming system accuracy.



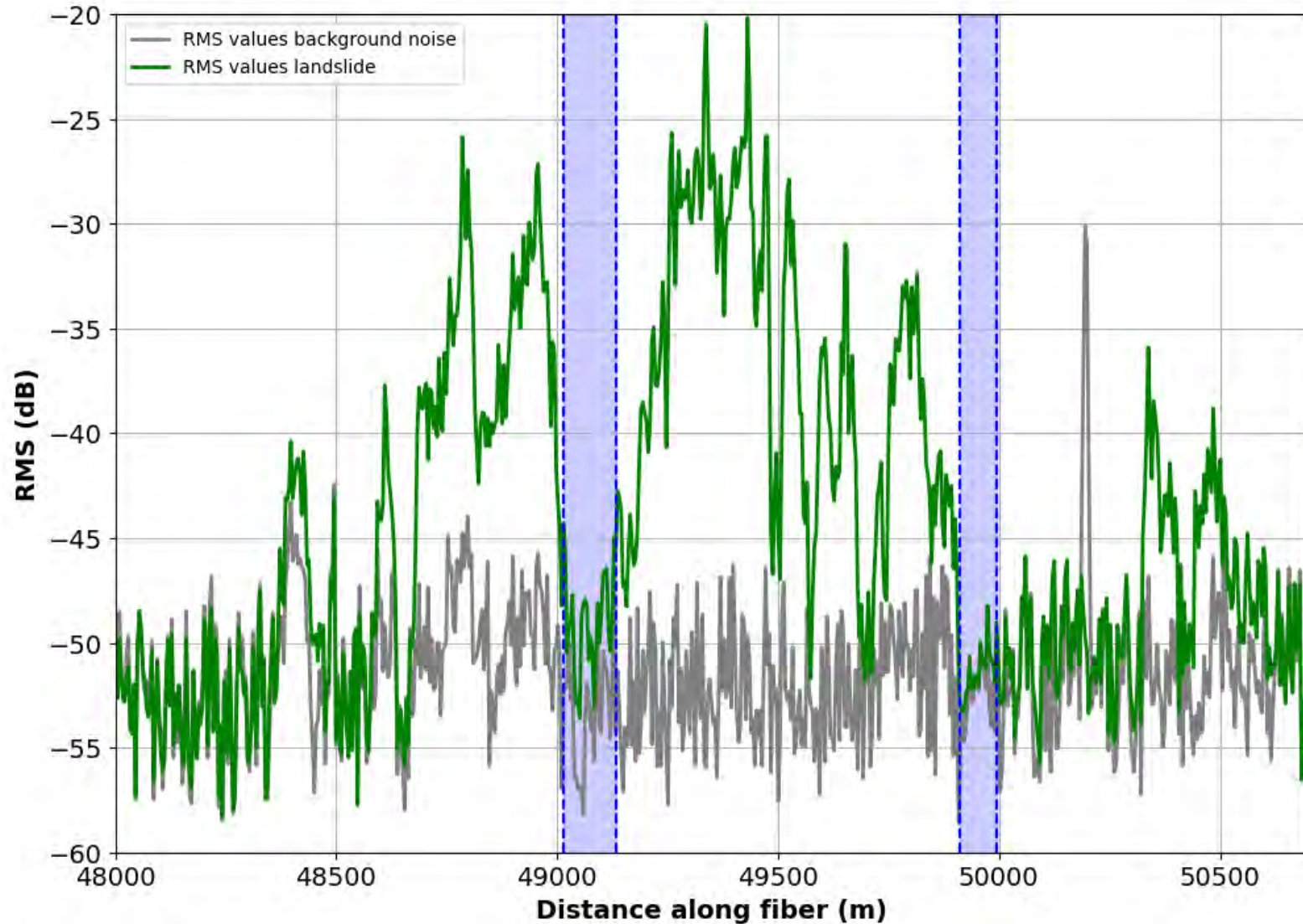
km 629.0



Rockfall – Nordlandsbanen 14 mai 2025, stopped 10m from Railway



→ RMS for landslide (green) and background noise (grey) – tunnels in light blue



→ 3 steps for 2026

1. Start with the detection of rockfall in tunnels.

Here, we have simulated rockfall in a tunnel, as well as signals from a person walking in the tunnel

2. The next step will be to select areas on the Nordland Line and Ofotbanen that have little or no noise.

3. The final step will be to include the entire railway section and develop algorithms that eliminate false positives caused by cars and trucks.

Arctic Test Arena

- **Ambition and collaboration**

Ann Kristin Bjerknes, Project Leader Arctic Test Arena



AMBITION

Develop Ofotbanen and
Malmbanan into an international
Arctic Test Arena for Railway
Technology

If it **works** here,
it **works** anywhere



Why

- Heavy Loads and Infrastructure Wear
- Extreme Arctic Conditions
- Safety Challenges
- Cross-Border Transport Complexity

Strategic Importance

- Key export route for iron ore and raw materials
- Critical link in a shifting security and logistics context
- Supports regional growth and low-emission transport
- Part of major ongoing investments to strengthen capacity and resilience



Goals

- Improve operational reliability
- Develop climate-resilient solutions
- Promote innovation and enable research and testing activities





Areas of Focus

- Testing of infrastructure and rolling stock
- Develop solutions for cold climate and heavy freight
- Research on maintenance and operational reliability
- Share data and drive digital collaboration
- Build skills through education and events
- Promote the test arena internationally

Test Activities

- Bridge monitoring with sensors
- Digital condition monitoring from trains in regular operation
- Wheel profile detectors – testing and expansion of the detector network
- Detection of ground movement, landslides, and rail defects
- Infrastructure monitoring using optical fiber
- Measurement of track geometry, forces, and wear
- Testing of rails and sleepers using trains loaded up to 32.5 tonnes axle load



A Joint Nordic Initiative with Global Ambitions



Partners and Collaboration Model

Partnership Structure

- Main Partners
- Associated Partners
- Strategic Partnerships

Memorandum of Understanding (MoU)

Organization

- Steering Group
- Working Group
- Arctic Test Team
- Test & Research Portfolio

What's Next

- Partner access will expand through test projects and joint funding applications
- Broader deployment expected within 3–5 years



How to Test and Conduct Research

- Start by submitting a digital request form
- Requests are reviewed by the Arctic Test Team
- Evaluated for safety, innovation relevance, and project links
- Testing is fully financed through research projects, joint funding, or participating companies

The screenshot shows the website of the Norwegian Railway Directorate (Jernbane-direktoratet). The page title is 'How to Test and Conduct Research at the Arctic Test Arena'. The content includes an introductory paragraph about testing new railway technologies under Arctic conditions, followed by three expandable sections: 'How can organizations test or conduct research here?', 'What does it cost to test?', and 'About the Arctic Test Team'. Below these is a 'Fill in our digital request form' section with fields for Name (First and Last), Email (Enter Email and Confirm Email), and Purpose of the test.

Jernbane-direktoratet
Norwegian Railway Directorate

Search...

Home > Innovation on the railway > Arctic Test Arena on Ofotbanen and Malmbanan > How to Test and Conduct Research at the Arctic Test Arena

How to Test and Conduct Research at the Arctic Test Arena

Are you interested in testing new railway technologies or conducting research under Arctic conditions? To start the process, fill in our digital request form.

The Arctic Test Arena – Ofotbanen & Malmbanan offers a unique environment for innovation, combining real-world operations, cross-border collaboration, and some of the toughest railway conditions in Europe.

How can organizations test or conduct research here? +

What does it cost to test? +

About the Arctic Test Team +

Fill in our digital request form

Name (required)

First Last

Email (required)

Enter Email Confirm Email

Purpose of the test (required)

[How to Test and Conduct Research at the Arctic Test Arena - Norwegian Railway Directorate](#)

Working Group

Europe's Rail Norway - Jernbanedirektoratet

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About Arctic **test** Arena

Jernbanedirektoratet.no



[Arctic Test Arena på Ofotbanen og Malmbanan - Jernbanedirektoratet](#)



If it **works** here,
it **works** ANYwhere