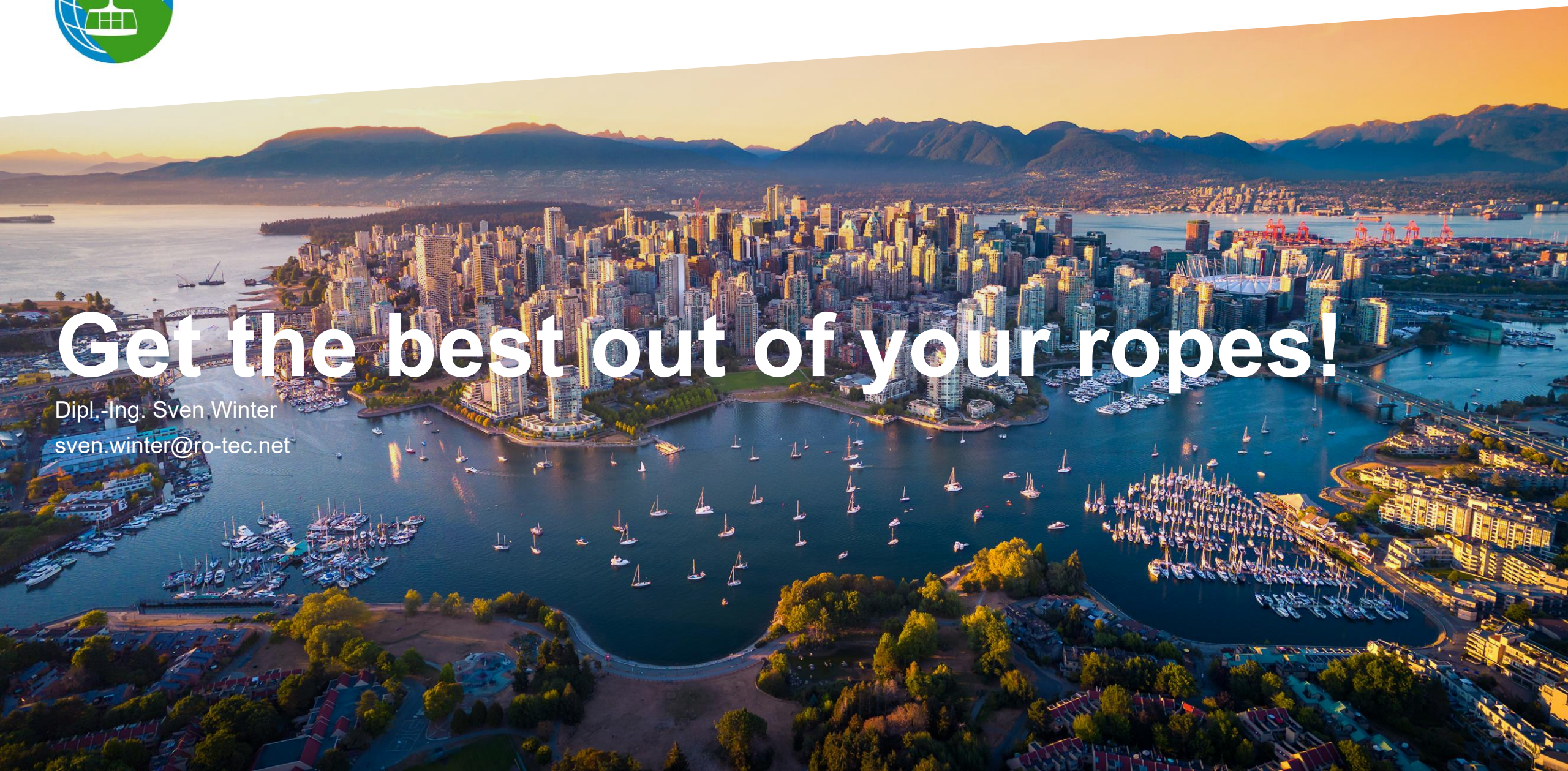


Get the best out of your ropes!

Dipl.-Ing. Sven Winter
sven.winter@ro-tec.net

Introduction

- Work Committee (WC) II “Ropes”
- Operational aspects influencing the life of stranded ropes
- Calculation method of rope life calculation based on the Feyrer method
- Service life predictions based on Magnetic Rope Test (MRT) in practice
- Progress made in MRT technologies and analyses

Introduction of Work Committee (WC) II «Ropes»

Chairman: Sven Winter, ROTEC GmbH

Vice Chair / Protocol: Konstantin Kühner, Jakob AG

- **Manufacturers:** Doppelmayr, Leitner Ropeways, Fatzer, Jakob Rope Systems, Teufelberger-Redaelli, Usha Martin
- **Testing Bodies:** IFT University of Stuttgart, IWM, Letscan, ROTEC, TÜV SÜD, TVFA
- **Authorities:** BAV, BMVIT, IKSS, INTI, STRMTG
- **Operators:** Bayerische Zugspitzbahn, Sommerbergbahn Bad Wildbad, Sandia Peak Tramway

Interested guests or new members with rope experience are welcome!

Development of Ropeway bending cycles

pioneers **ropeway boom** **sports installations** **urban installations**

Mountain Cable Car	Urban Cable Car
length 2‘000m | rope speed 3m/s	length 1.200m | rope speed 6m/s
operation 240 days à 8 hours	operation 345 days à 16 hours
10.000 bending cycles / year	**100.000 bending cycles / year**

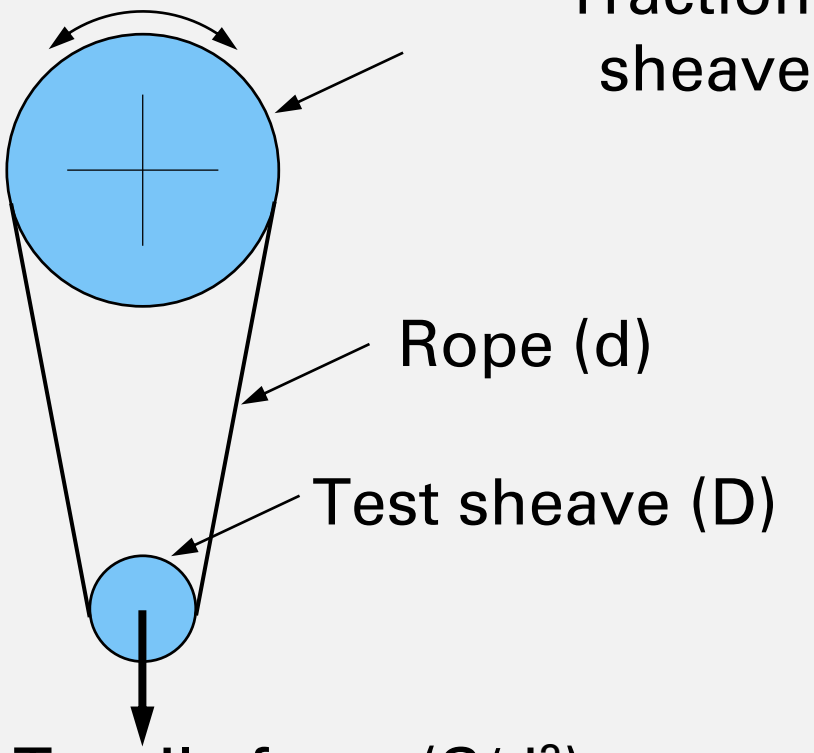
Factor 10

jennerbahn.de
seilbahn-nostalgie.ch

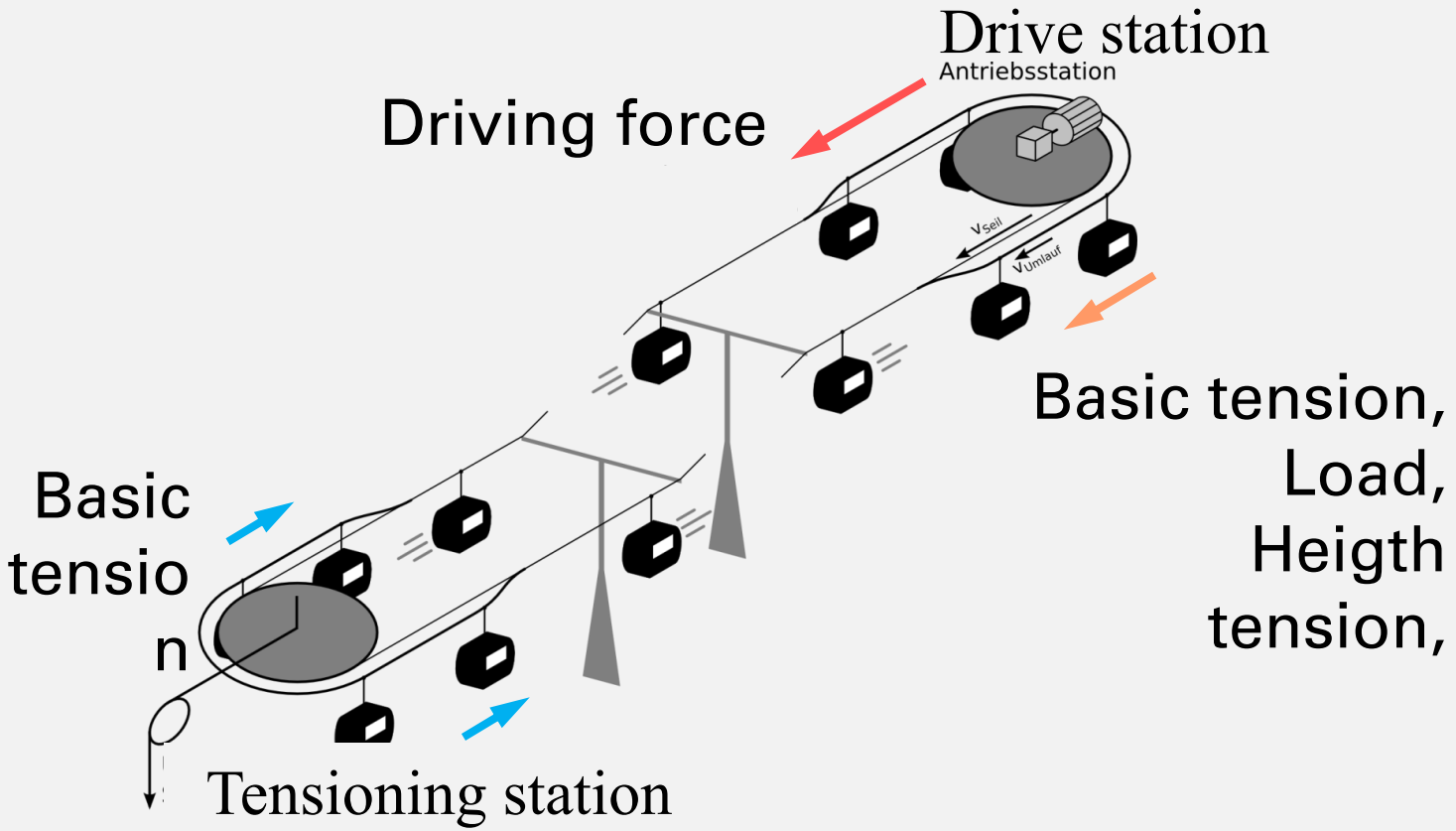
Life time estimation formula
Formula of Prof. K. Feyrer from IFT, University of Stuttgart

$$lgN = b_0 + \left(b_1 + b_3 \cdot \lg\left(\frac{D}{d}\right)\right) \cdot \left(lg\left(\frac{S}{d^2}\right) - 0{,}4 \cdot lg\left(\frac{R_0}{1770}\right)\right) + b_2 \cdot lg\left(\frac{D}{d}\right) + lg(f_d) + lg(f_L) + lg(f_c)$$

Laboratory



Cable Car Installation



Example: Calculation for Bullwheel (Mountain Ropeway)

Application area			
Number of working cycles	(ZA10; ZAm; Z10; Zm)		Zam
Rope construction	(S; F; W; WS)	(Spiral)	WS
Number of strands	(6; 8)	(18; 34)	6
Rope core	(FC; IWRC; PWRC; ESWRC)	(FC; WSC)	FC
Lay direction	(sZ; zZ)		zZ
Rope tensile force (effective, collective)		S in kN	420
Diameter sheave, drum and traction sheave		D in mm	4800
Nominal rope diameter	(not for d < 6 mm)	d in mm	50
Nominal strength		R_0 in N/mm^2	1960
Bending length	(not for l < 10d)	l in mm	16000
Rel. tensile force difference		deltaS /S = (S - S_u) /S	0.262
Simple bendings per working cycle		w sim	0
Reverse bendings per working cycle		w rev	0
Comb. fluctuating tension and bendings per working cycle		w_{com}	1

Results:

S/d² in N/mm²=	168.0	Number of simple bendings	N_{ein}	556'900
D/d =	96.00	Number of reverse bendings	N_{geg}	254'200
l/d =	320.0	Numb. of fluctuating tension and bendings	N_{zug}	126'600
fS5 =	1.458	Number of working cycles	Zam	126'600
Sequ in N	612380	Discarding number of wire breaks *)	B_{A30}	5

$$N_{korr} = N \cdot f_{N1} \cdot f_{N2} \cdot f_{N3} \cdot \cdots \cdot f_{Ni}$$

$$N_{korr} = 126600 \cdot 1 \cdot 1.3398 = \mathbf{169612}$$

Factor f_{N3} for "soft" groove material

Lubrication factor f_{N1}
Laboratory: 1.0
Reality: 0.4 – 0.8

https://www.ift.uni-stuttgart.de/forschung/img/feyrer/Seilleb2.xls

Calculation of rope life time

Mountain Cable Car

Bull wheel	Z_{Am} = 169'612
Return wheel	Z_{Am} = 12'781'376

Results in Bendingcycles !

Palmgren-Miner Accumulation:

$$Z_{Am\ acc.} = \frac{1}{\frac{1}{169612} + \frac{1}{12781376}} = 167391$$

Results in Years
10.000 bending cycles / year

Estimated rope life time: 17 years

Urban Cable Car

Bull wheel	Z_{Am} = 237'806
Return wheel	Z_{Am} = 1'944'359

Results in Bendingcycles !

Palmgren-Miner Accumulation:

$$Z_{Am\ acc.} = \frac{1}{\frac{1}{237806} + \frac{1}{1944359}} = 211890$$

Results in Years
100.000 bending cycles / year

Estimated rope life time: 2 years

Published recommendations of the working group «Ropes»

Paper 28 / 2014

– General recommendations for the **manufacturers lubrication and the re-lubrication** of steel wire ropes used in ropeway installations for Passengers

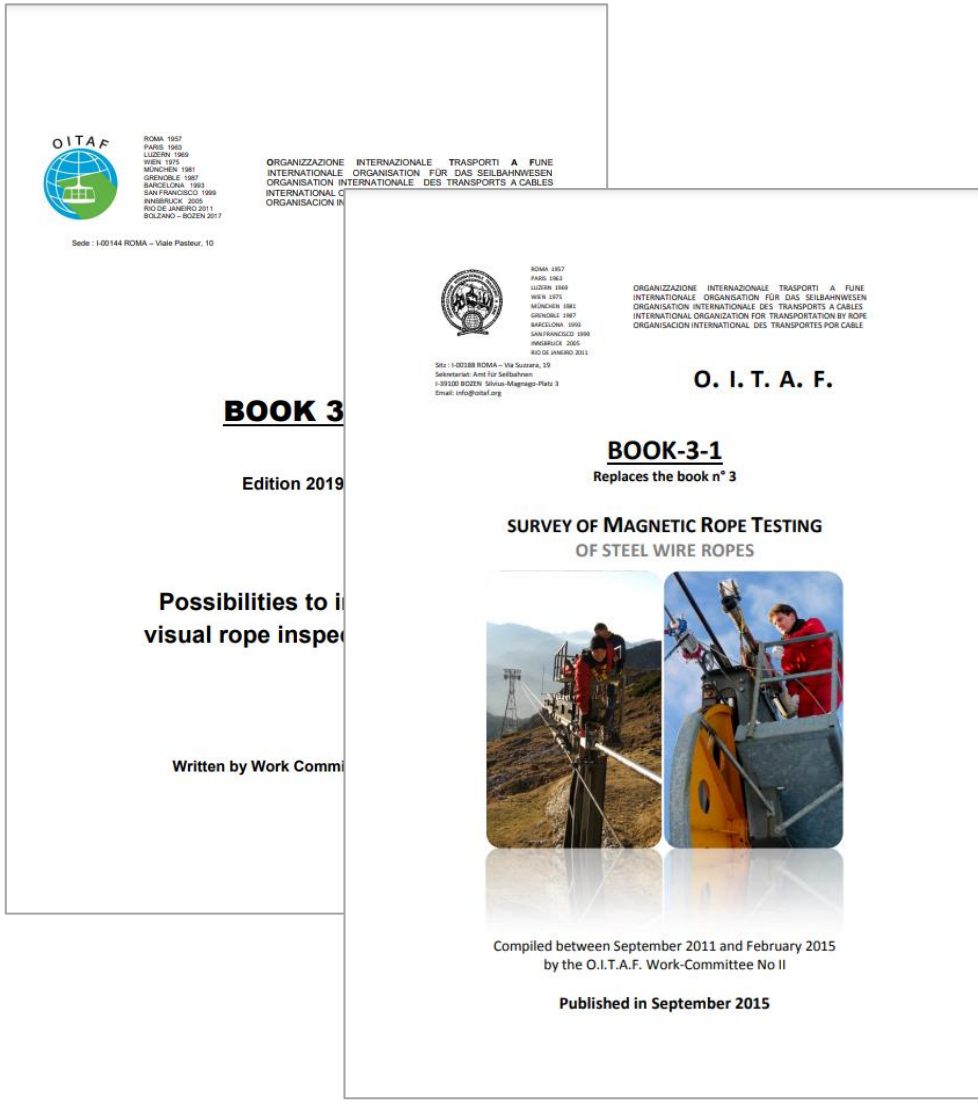
Paper 3-1 / 2015

– Survey of **magnetic rope testing** of steel wire ropes

Paper 30 / 2019

– Possibilities to improve **visual rope inspection** (VI)

– Close to finishing and publishing: **Rope life time**



Today: Safety concept of rope monitoring

Operator

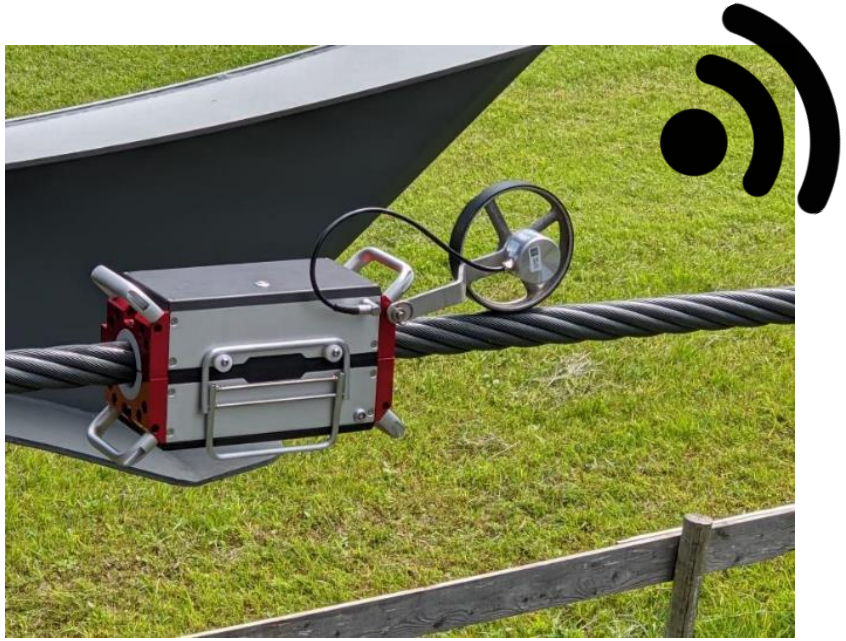
Visual rope test

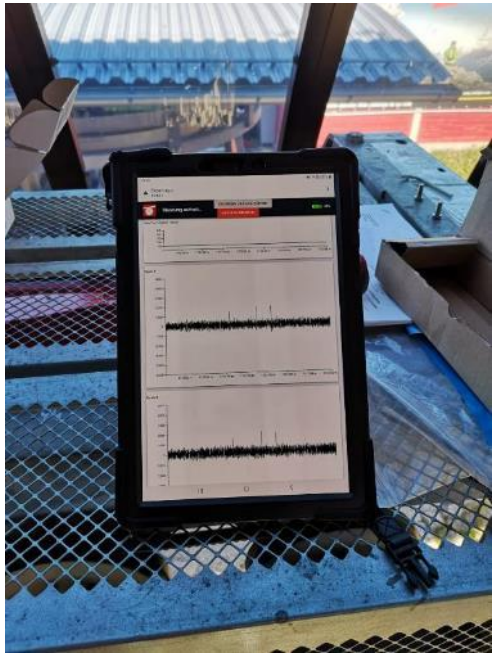
Interval: 1-6 month

Independent rope expert

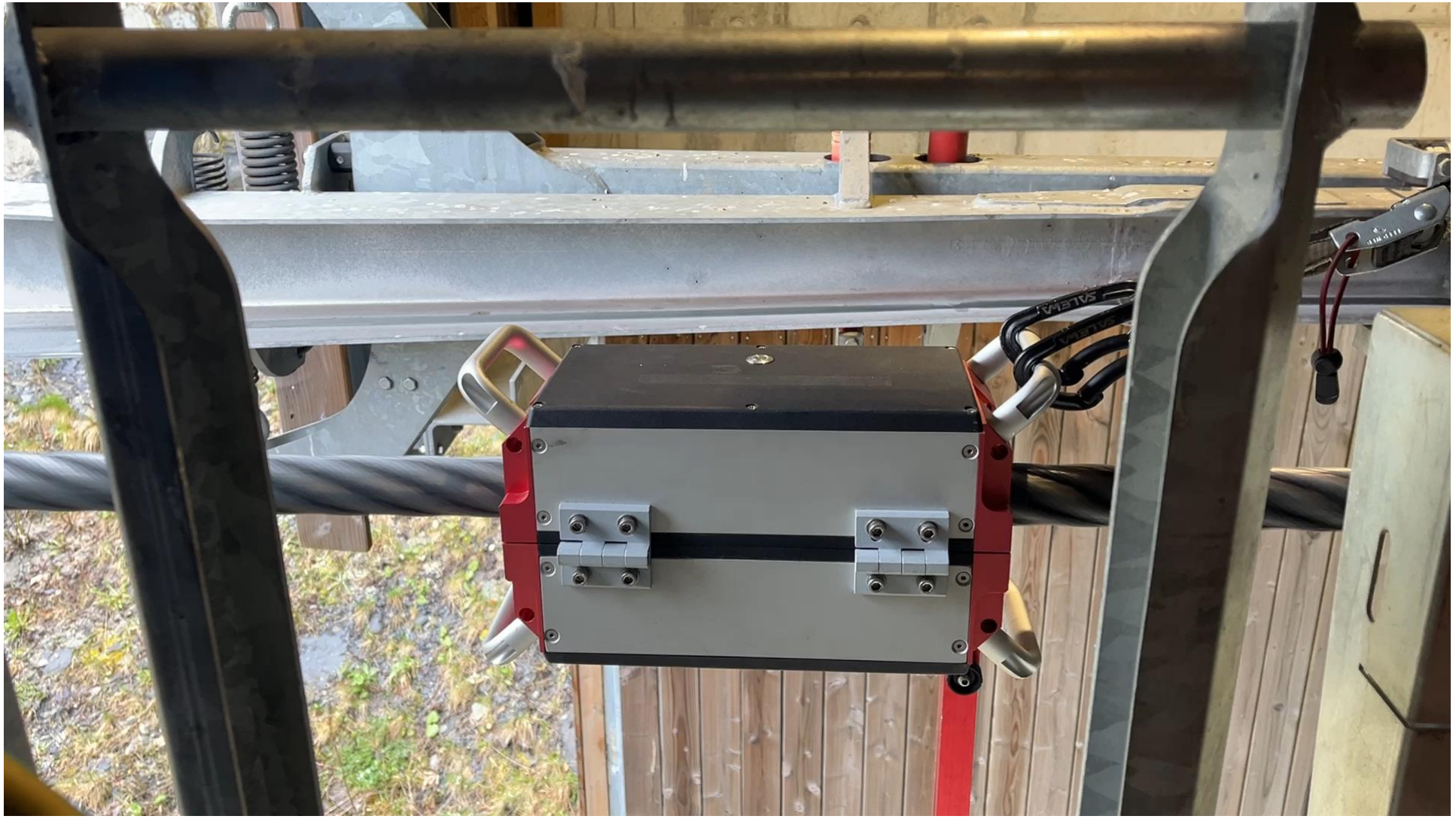
Magnetic Rope Test (MRT)

Interval: max. 3 years



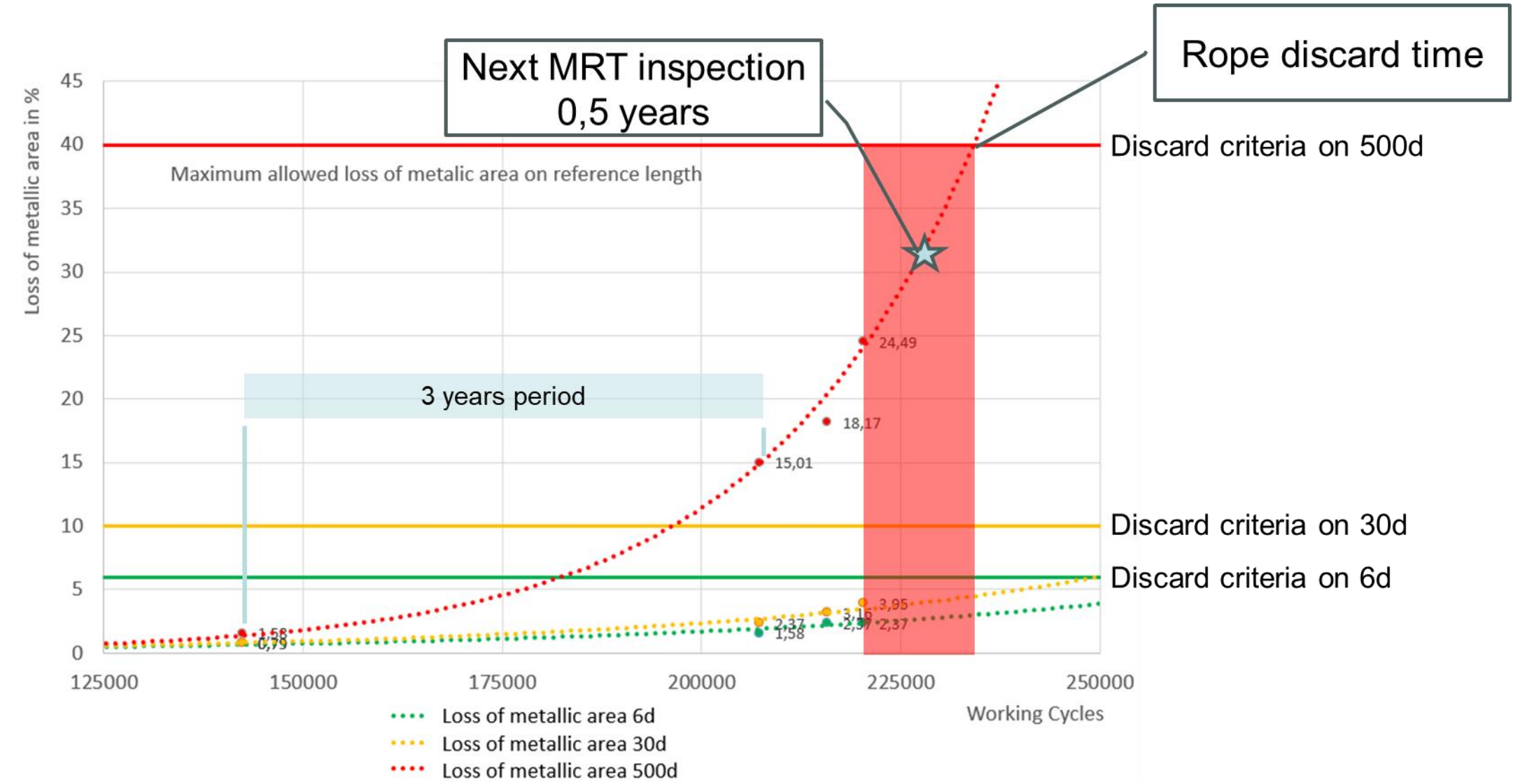


Today: Safety concept of rope monitoring



Today: Safety concept of rope monitoring

Shortening of MRT inspection interval in practice



Safety concept of permanent rope monitoring

Operator

Visual rope test

Interval: yearly

Independent expert / machine

Permanent Magnetic Rope Test (PMRT)

Interval: permanent

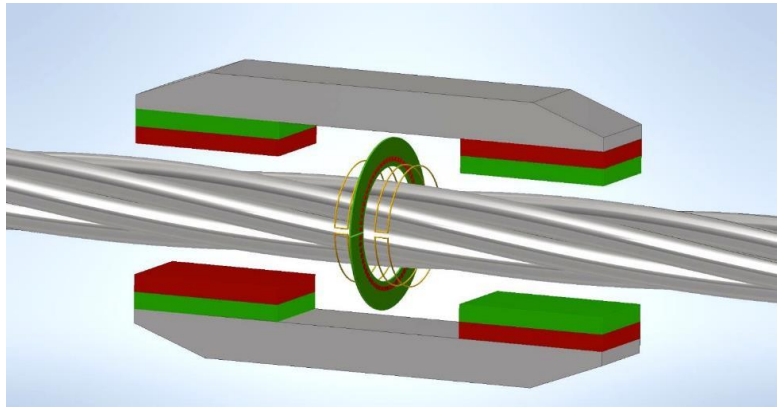
ROTEC PMRT in Florida USA

FATZER TRUSCAN in Verbier Swiss

Permanent rope monitoring

1. Inner and outer defects can be **detected**
2. Saves you **time**
3. No bad **surprises**
4. Defects can be detected as long as they are **small**:
   You can react early in time
5. In the event of incidents: statement on the condition of the rope is **immediately** available
6. Rope data is available to a competent **partner** at any time

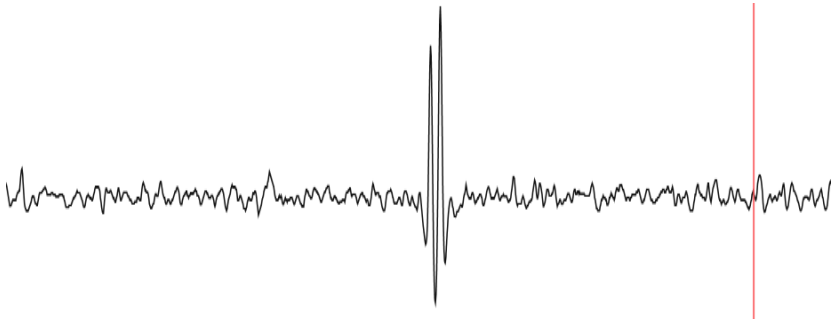
Permanent rope monitoring



Function and procedure of a magnetic rope test

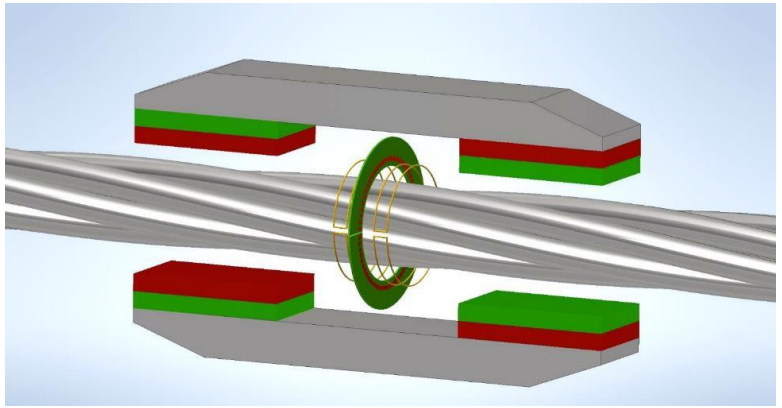
1. Magnetization of the rope with the testing device
2. Record and real time analysis of the resulting stray field
3. Evaluation of the rope condition
4. Output of the overall rope condition to the operator

Real time analysis



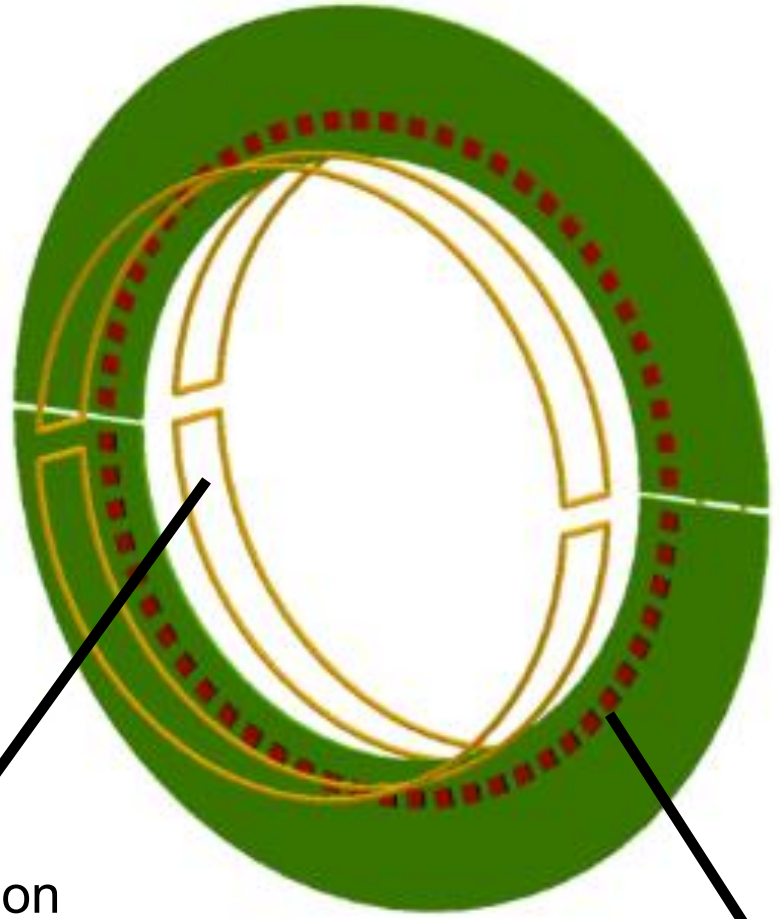
Permanent Magnetic Rope Test
„Monitoring“

Diverse Multi Channel Sensor Concept



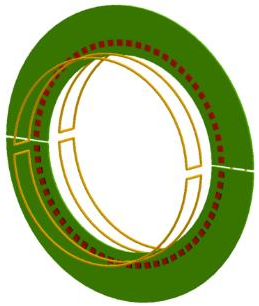
multichannel systems examines:

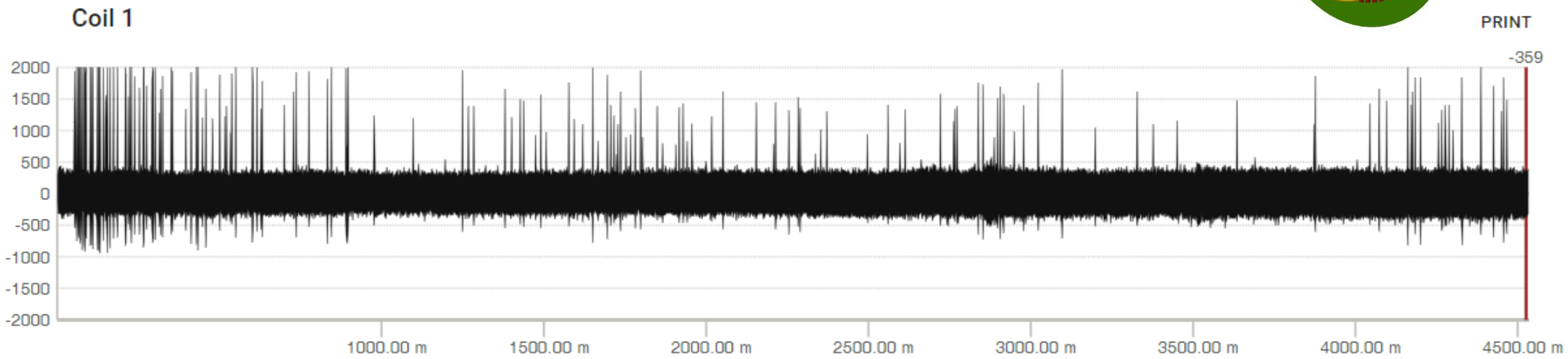
- Local faults (LF) such as broken wires
- Locally resolved thanks to 3D heatmap
- Corrosion and wear
- Loss of metallic area (LMA)
- Lay length
- Changes in geometry

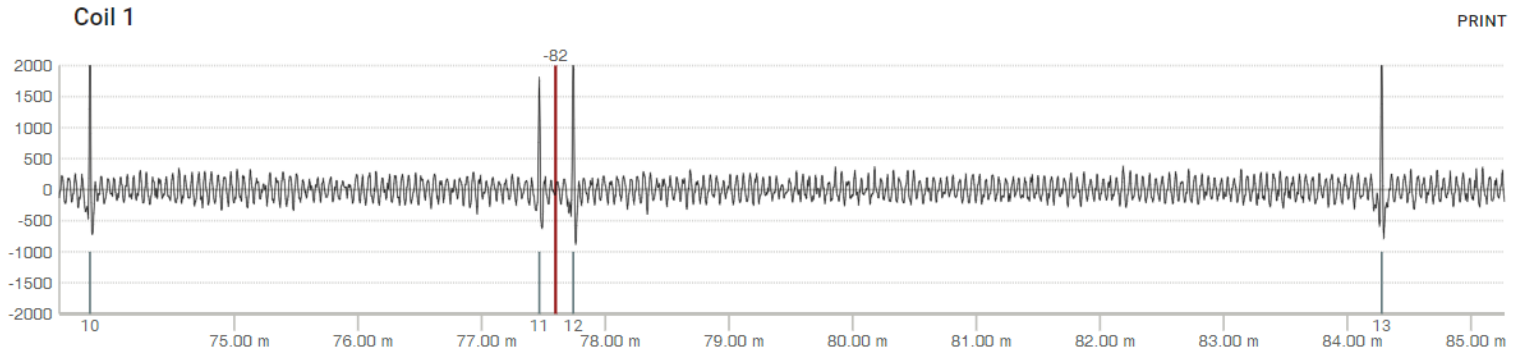


Permanent rope monitoring new features

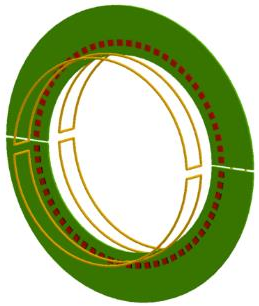
Local faults (LF) with coil sensors; such as broken wires



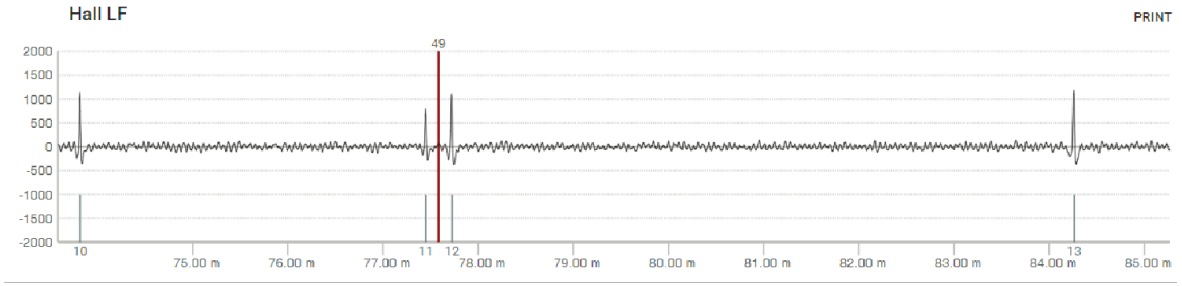




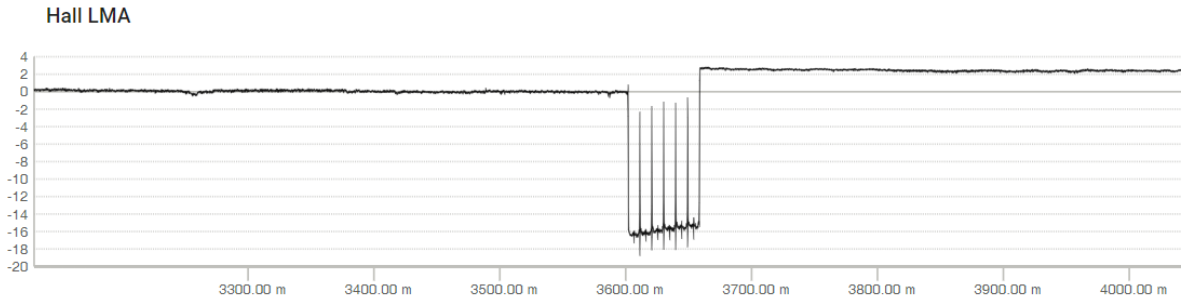
Permanent rope monitoring new features



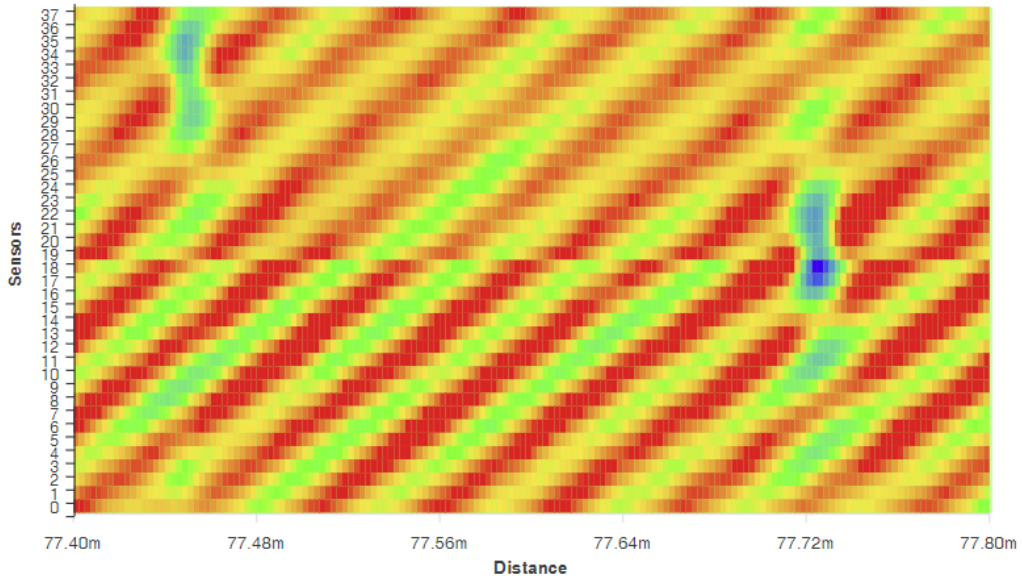
Local faults (LF) with magnetic field sensors



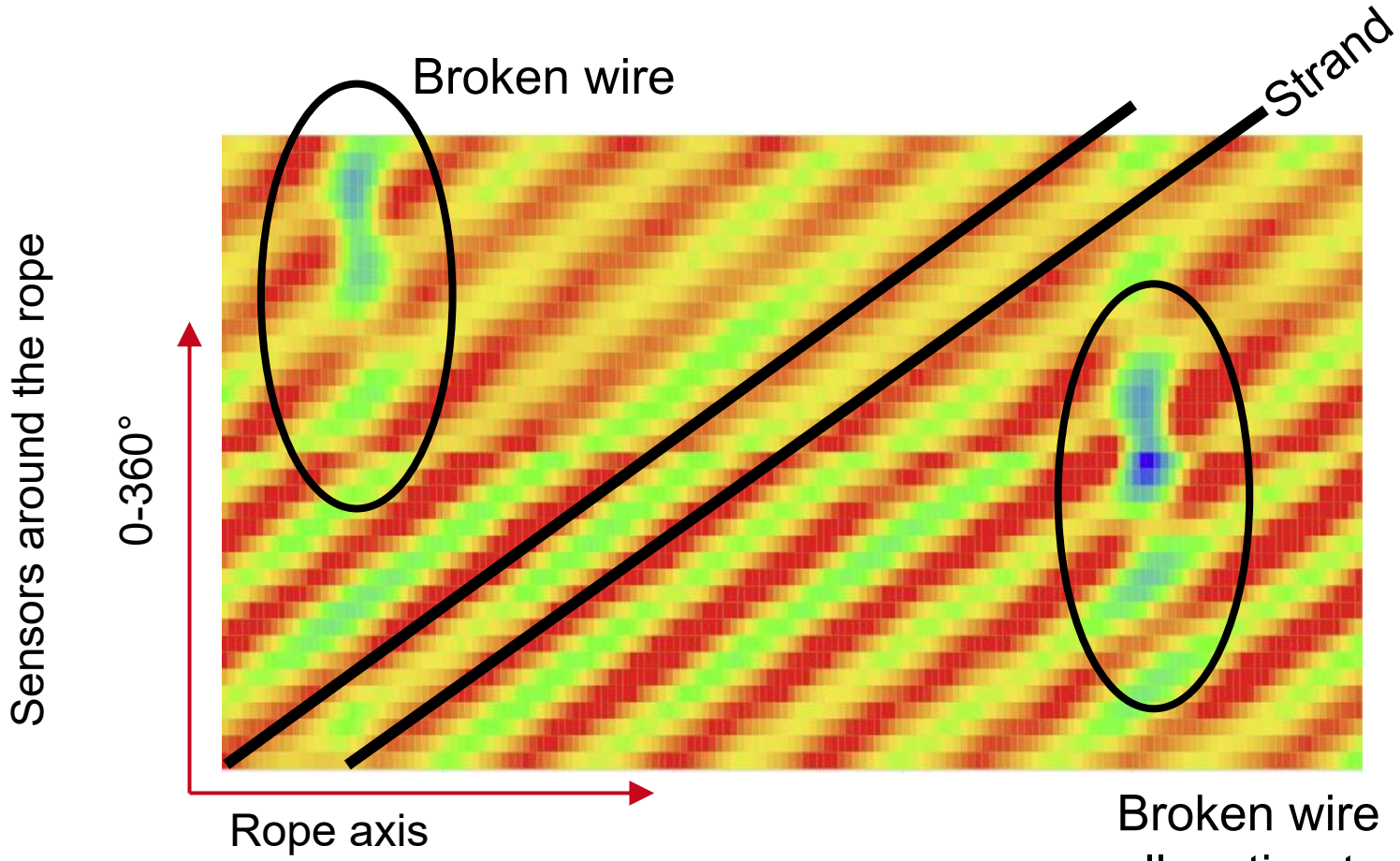
Loss of metallic area (LMA) in %

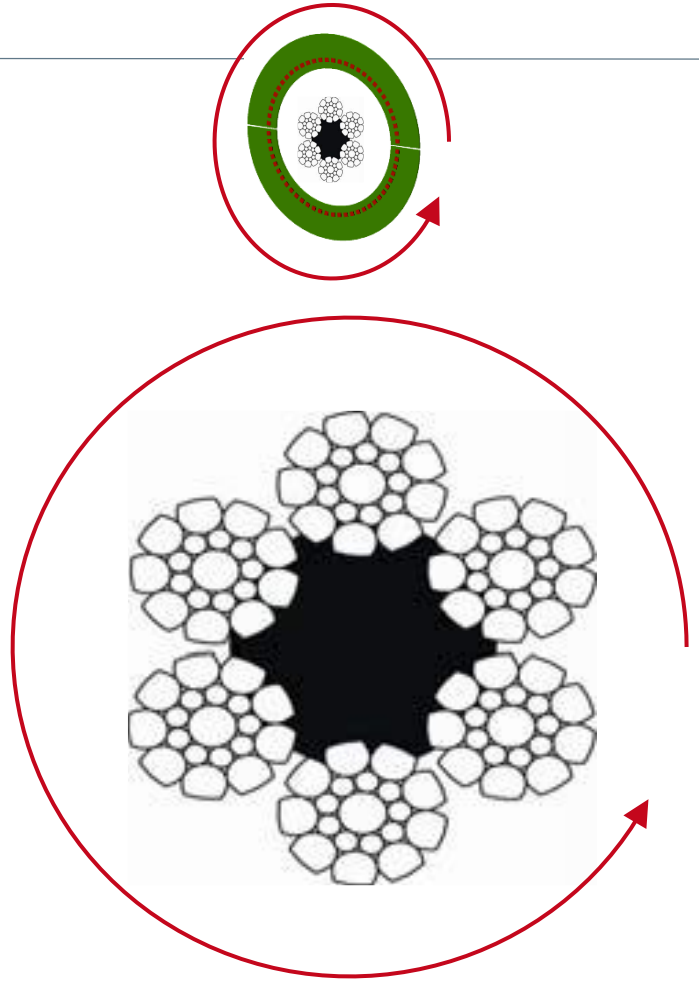


3D Heatmap



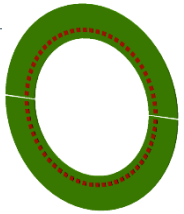
Multi Channel Sensor Concept
3D Heatmap “High resolution broken wire detection”

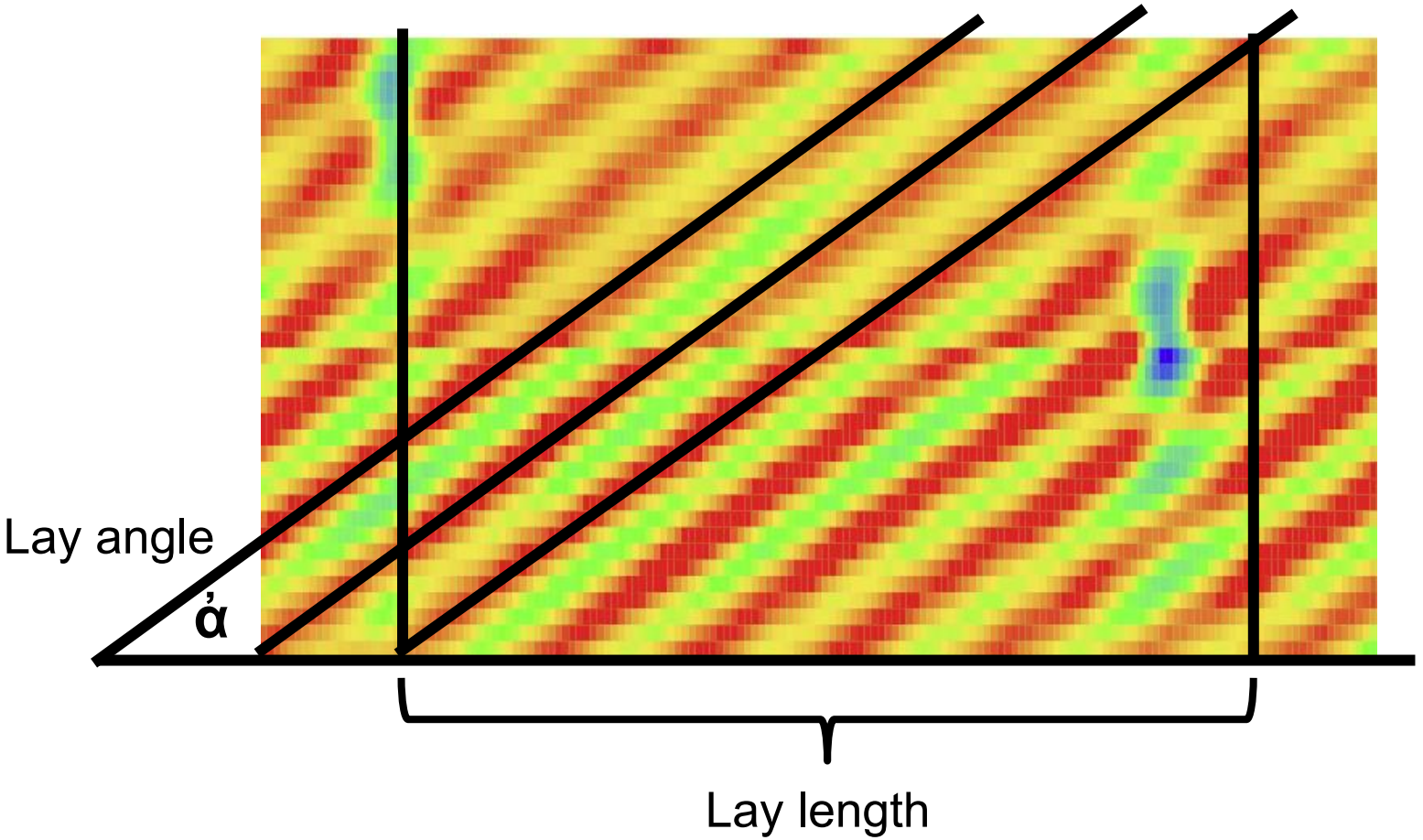




Broken wire
allocation to strand

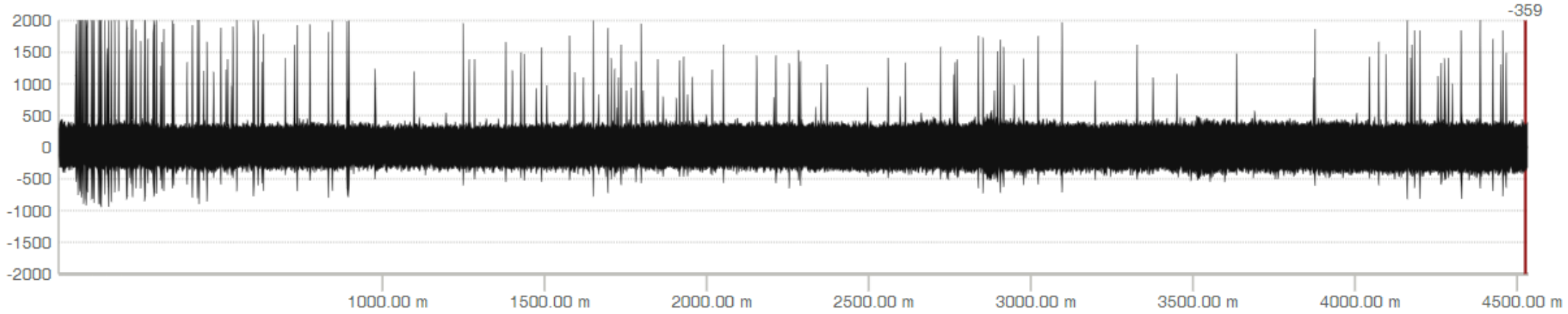
Multi Channel Sensor Concept: Lay length
Calculation of Lay length





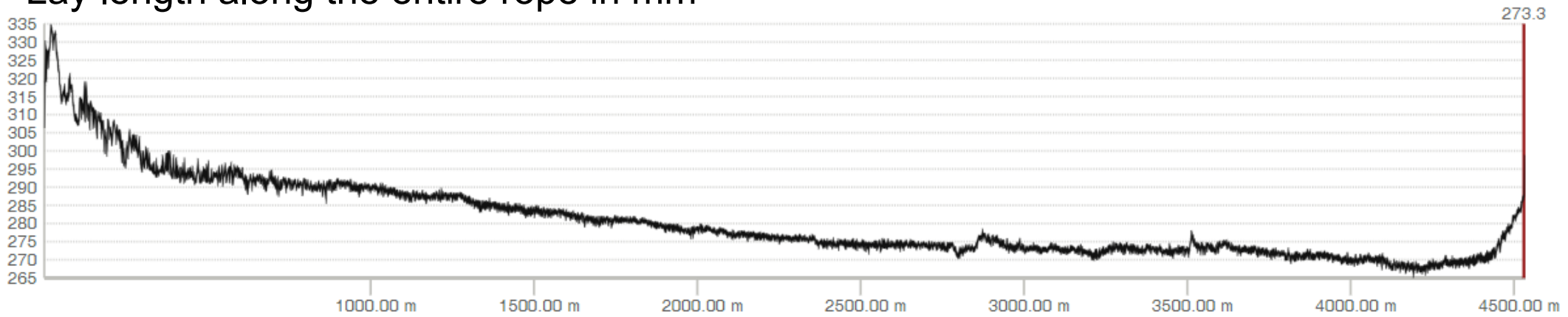
Multi Channel Sensor Concept: Lay length

Local faults (LF) with coil sensors



Rope in m

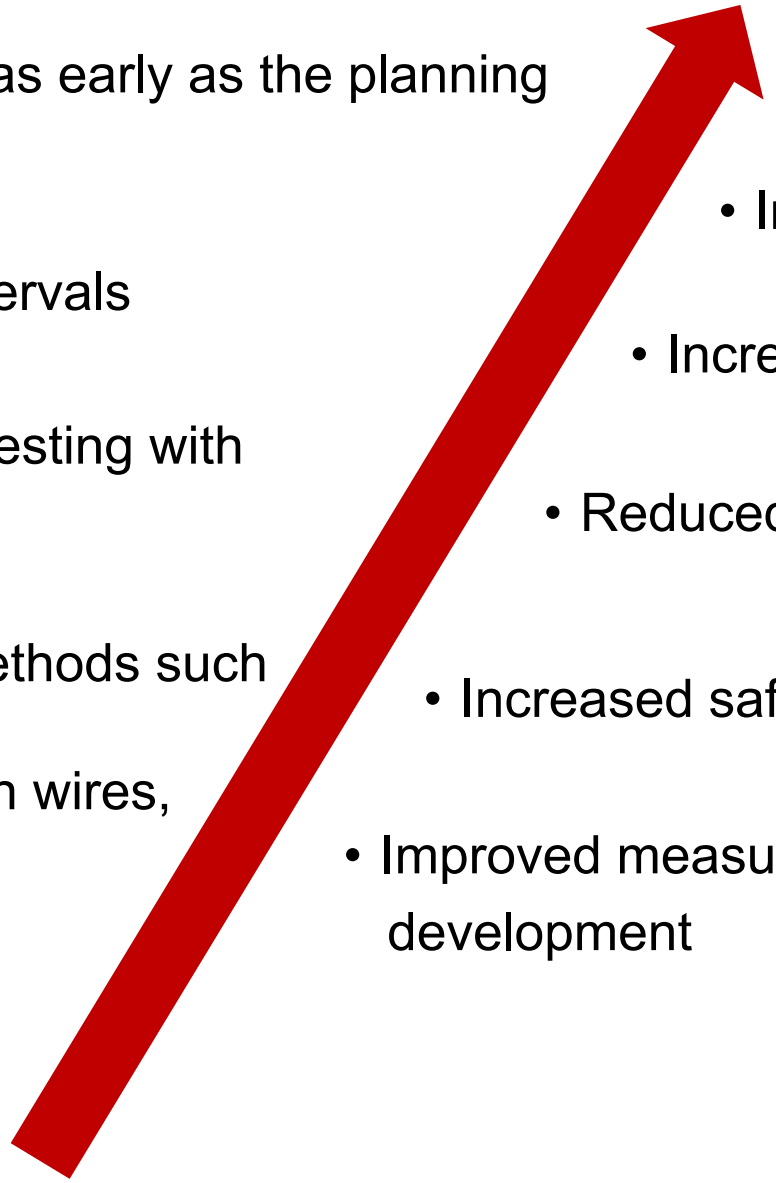
Lay length along the entire rope in mm



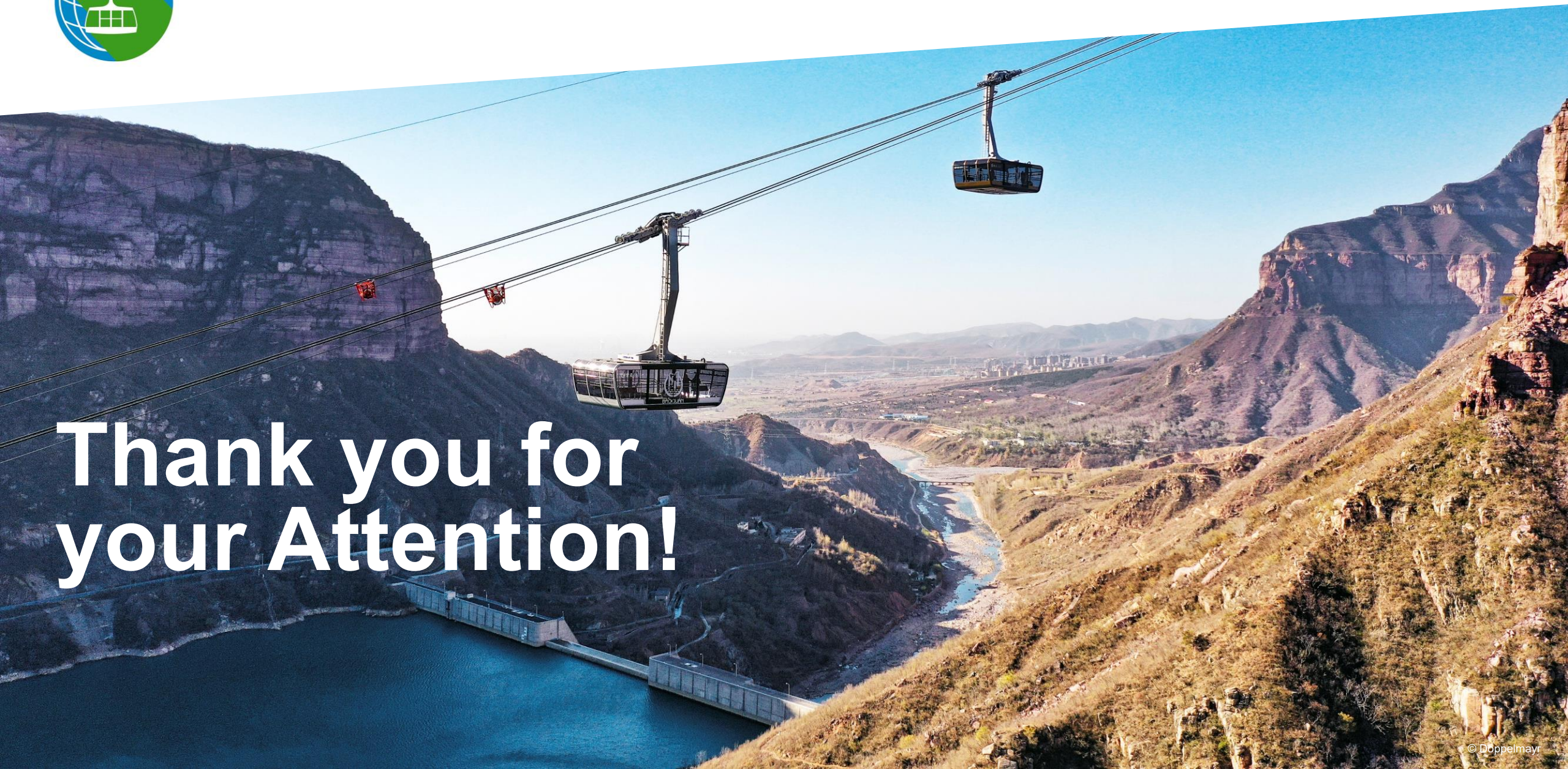
Rope in m

Summary

- Rope service life calculation as early as the planning phase (Feyrer method)
- Magnetic Rope Testing at intervals
- Permanent Magnetic Rope Testing with live analysis
- Additional new measuring methods such as lay length, localisation (strand assignment) of broken wires, 3D heat map



- Improved plannability of maintenance
- Increased cable car availability
- Reduced costs through remote monitoring
- Increased safety through permanent testing
- Improved measurement method through further development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your Attention!
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