

Sensor-integrated wear-particle monitoring in lubrication circuits: fusing in-oil particle events with explainable machine-data analytics

We give industrial equipment
a voice



INMOX
Intelligent monitoring systems

The company

Since our journey has started ...



Vienna

Austrian based start-up,
started in 2019, founded in
2021.



Team

of **12 experts** with a highly
growth strategy for 2026.



Vision & Mission

Technology forward.
Together.

Pioneering the way of
condition monitoring.

Focus

Gearboxes are in every industry...



Energy

such as **windmills** or
gas turbines.



Heavy-Duty

such as **construction vehicles**,
mining and **oil and gas**.



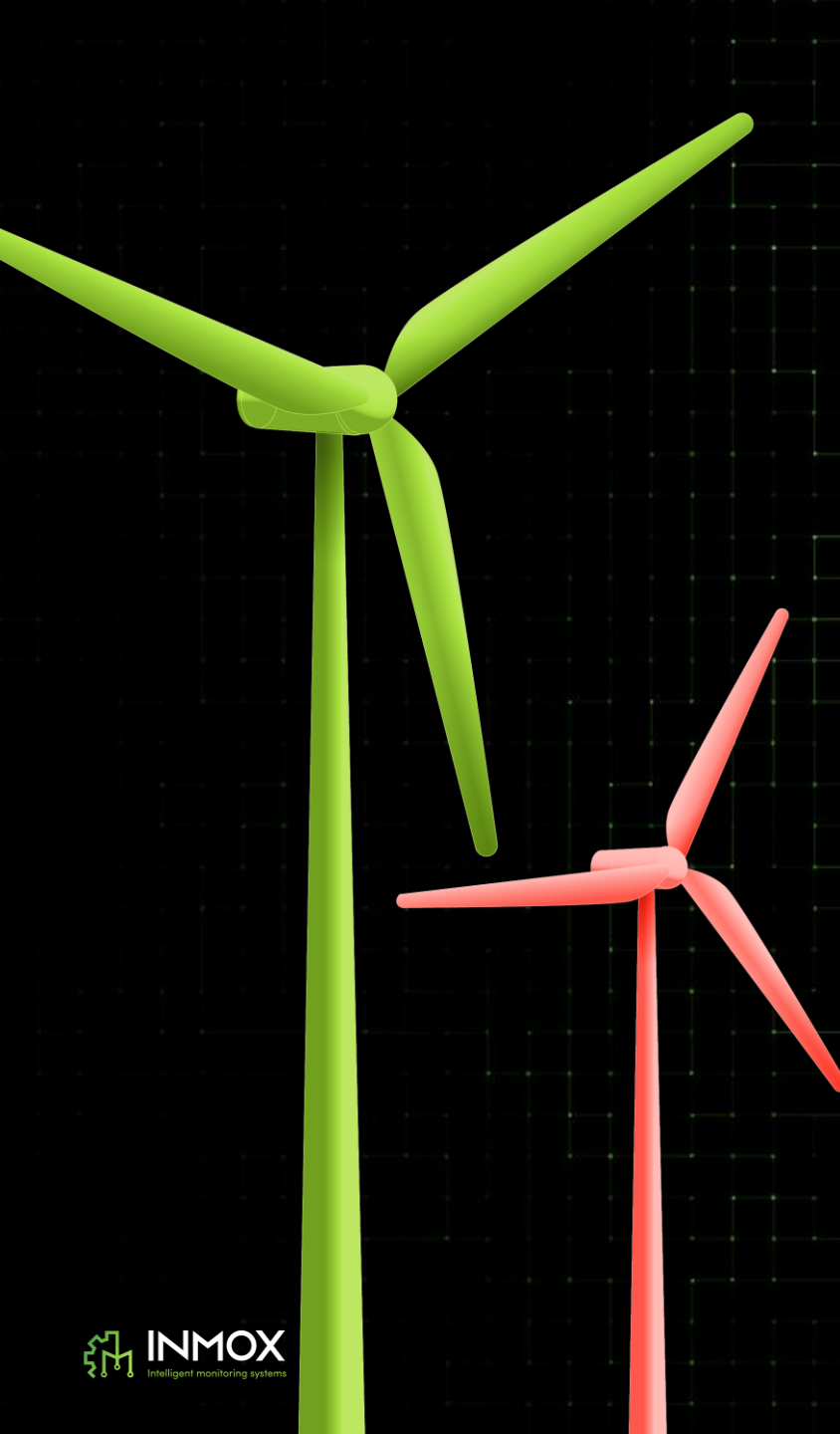
Transportation

such as **aviation**, **shipping**
and **rail**.



Production

such as **steel**, **wood** and
paper.



Problem Case

...and they fail, frequently and unplanned.

Drivetrain failures account for over **60%** of unplanned **maintenance costs** in wind energy:

More than **€4.8 bn** in annual losses across Europe and the US alone.

Solution

Accurate, independent data and **deep system understanding** are essential to preventing damage. We deliver both...



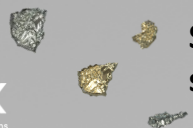
...through a **hardware-enabled data analytics platform** for predictive maintenance.

Stress, friction, and temperature degrade gear teeth over time. This wear can be seen in the pieces that break off of parts as they wear.

EARLY



Types of wear:

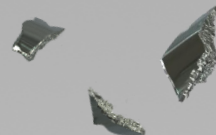


Small surface shavings

PROGRESSING



Types of wear:



Large surface shavings

ADVANCED



Types of wear:



Large interior fragments



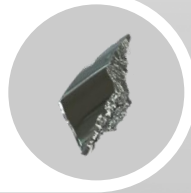
Interior shavings

Other parts of the gearbox also wear and break. However, each shaving has a unique signature due to different metals and their placement.

HIGH
RISK

STEEL #7, HARDENED
Tooth Wheel

Large fragment



MEDIUM
RISK

STEEL #1
Bearing

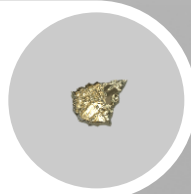
Mid-sized fragment



MEDIUM
RISK

BRASS
Plain Bearing

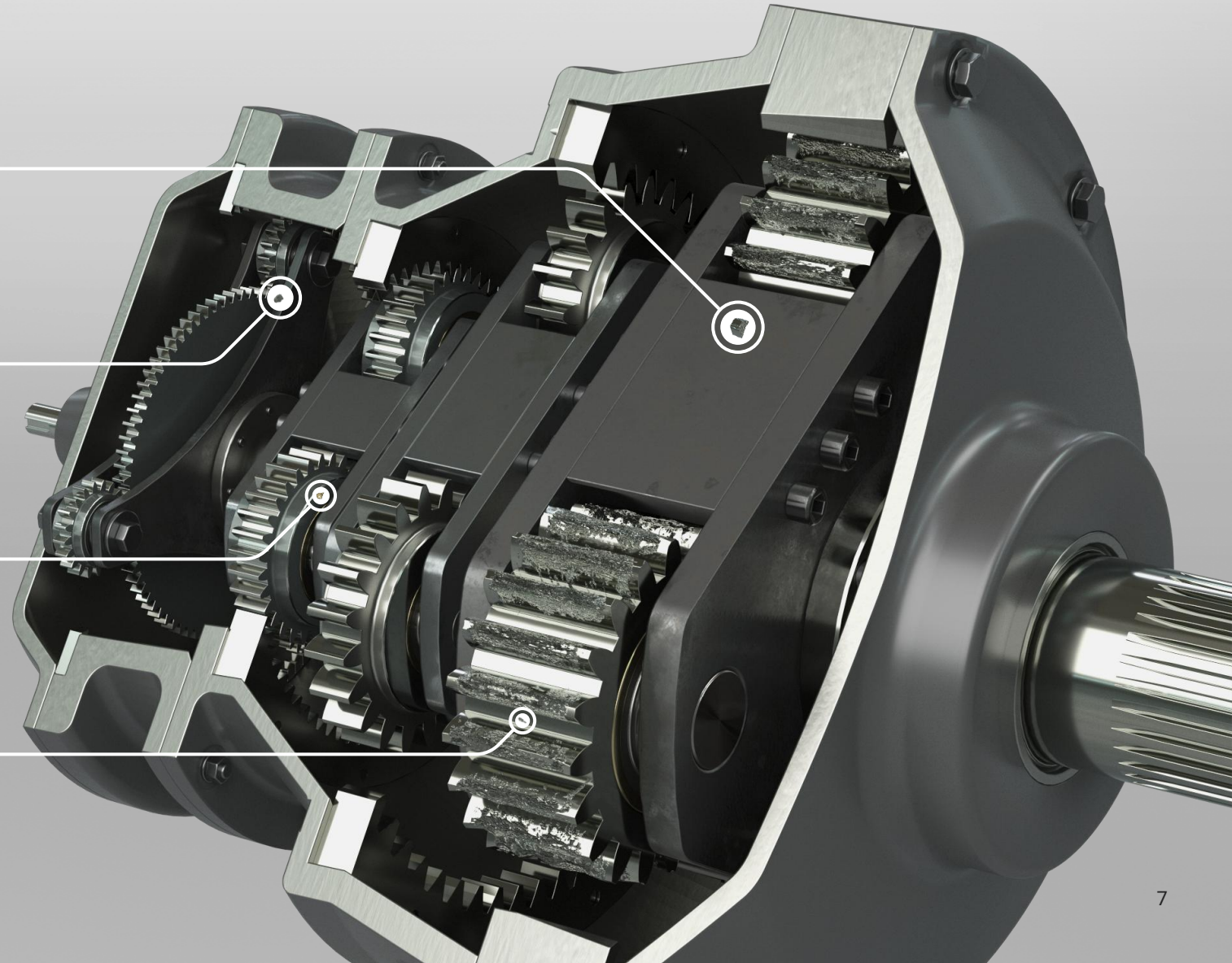
Small fragment



LOW
RISK

STEEL #7, HARDENED
Tooth Wheel

Small fragment



Our sensors read the magnetic field of these fragments, identifying them based on unique material and size. Our system then flags location, progression, and risk of damage.

HIGH
RISK

STEEL #7, HARDENED
Tooth Wheel

Large fragment

Magnetic
Field
Match

Damage progression:

Advanced

Damage location:

Forward Gear Assembly

Solution

Inmox is **not** another vibration monitoring company – we are offering a **holistic condition monitoring system**.

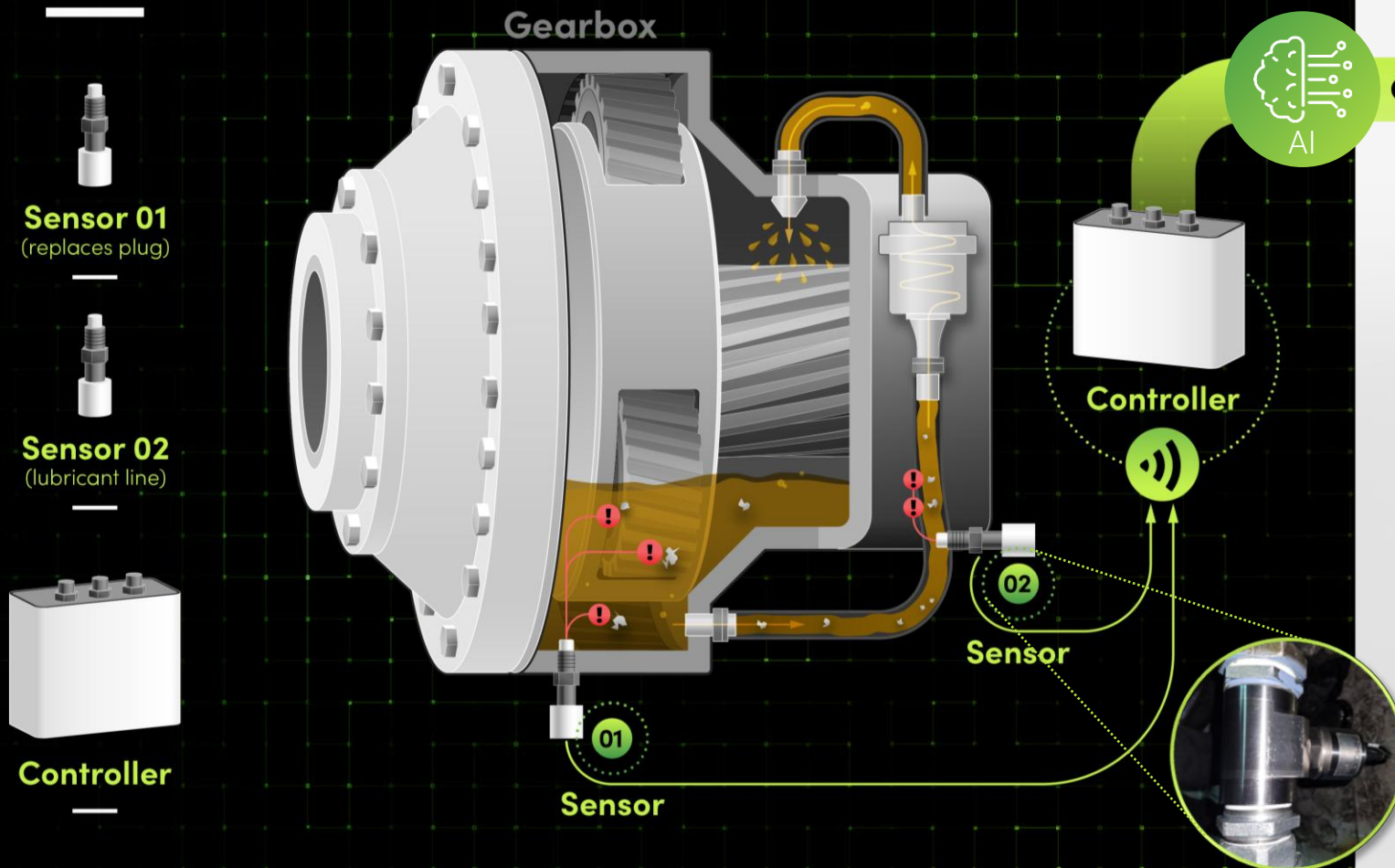
We provide a **unique sensor technology** (patented) for condition monitoring by means of **wear characterization** in real time, enhanced by **specialized AI models** for failure detection.

Trained models with **proprietary data**, for **10x** earlier failure prediction and maintenance scheduling for **reduced downtime** and **cost savings**.



Product

Hardware



Software



Particle Characterization

Classification of particles

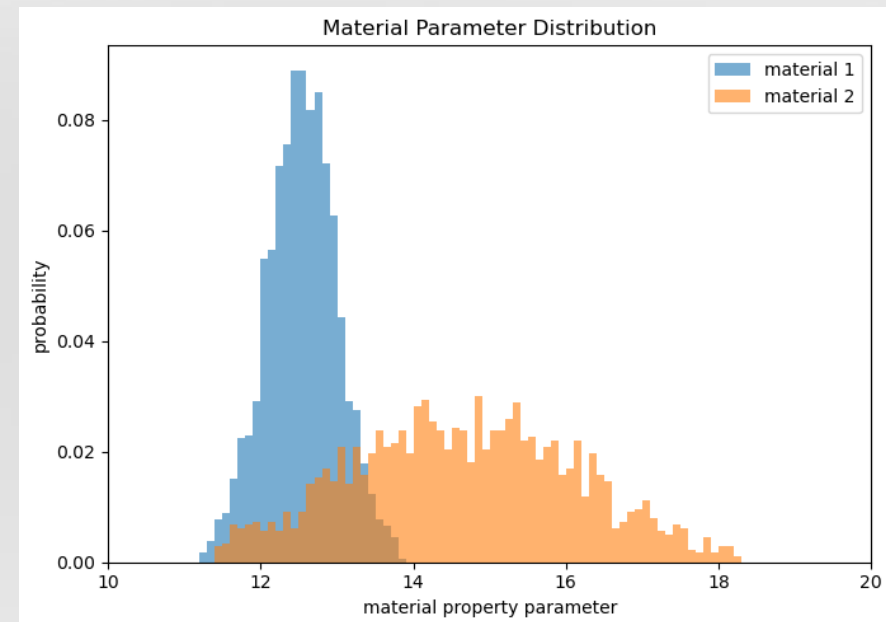
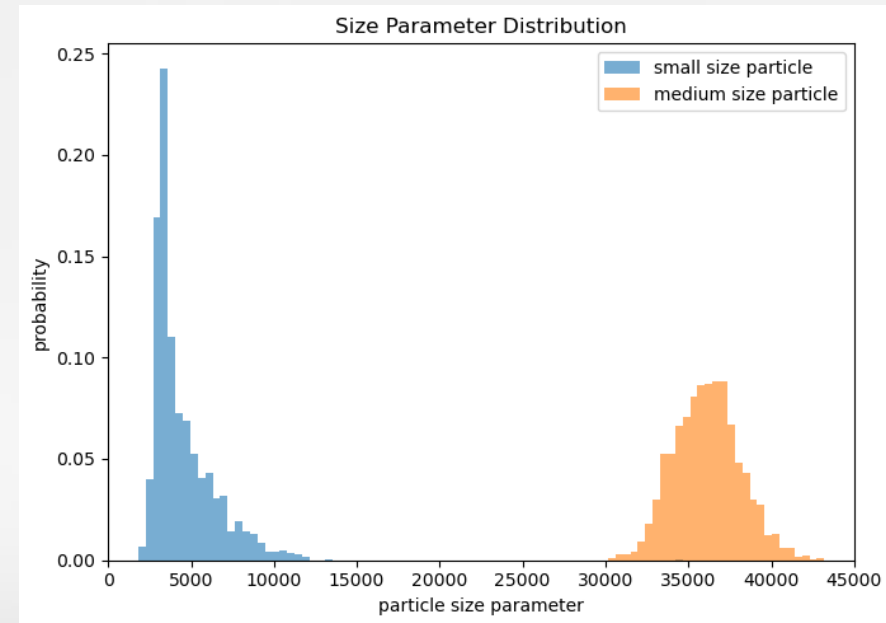
size classes:

- $< 200 \mu\text{m}$
- $200 \mu\text{m} - 600 \mu\text{m}$
- $600 \mu\text{m} - 1.000 \mu\text{m}$
- $> 1.000 \mu\text{m}$

material classes:

- bearing material
- tooth wheel material

Different classes produce
different amplitudes and
magnetic signatures.





Field Data

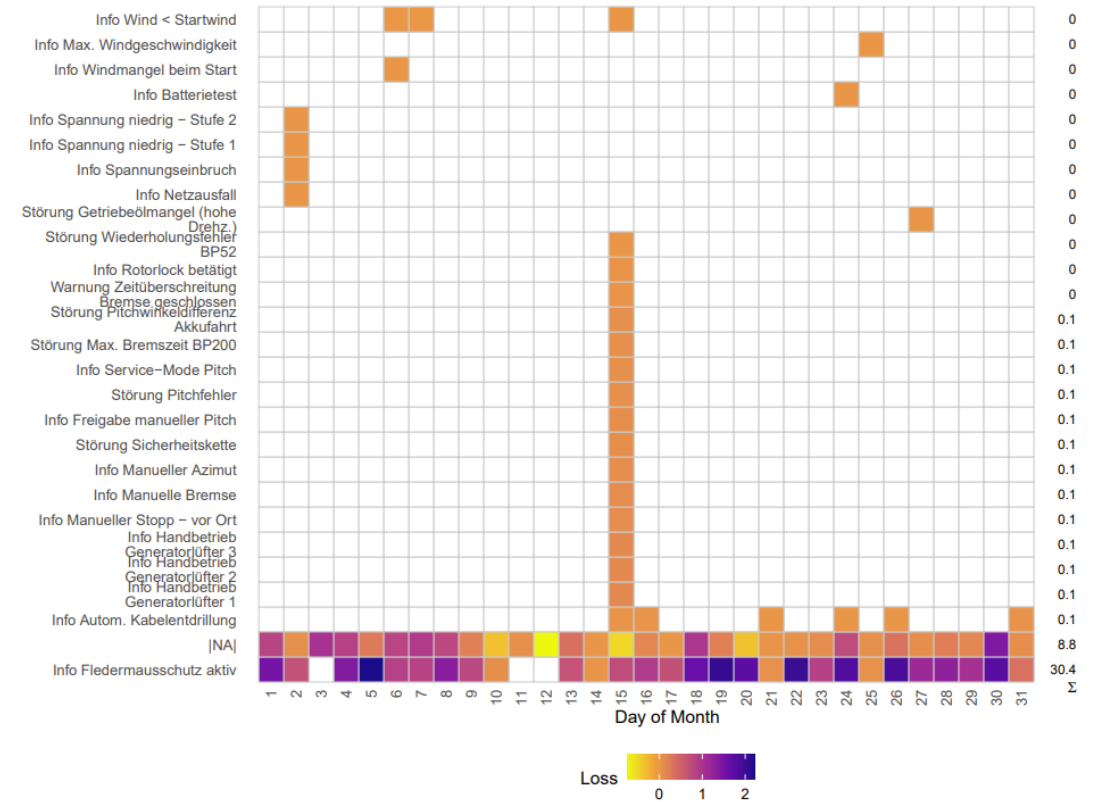
Extracting valuable information from **SCADA** data and **status-code logs**.

Status-code logs automatically **mapped** onto **uniform 10-minute SCADA records**

A **generalized additive model (GAM)** predicts expected power from environmental inputs.

Allows **attribution of losses** to their **cause**.

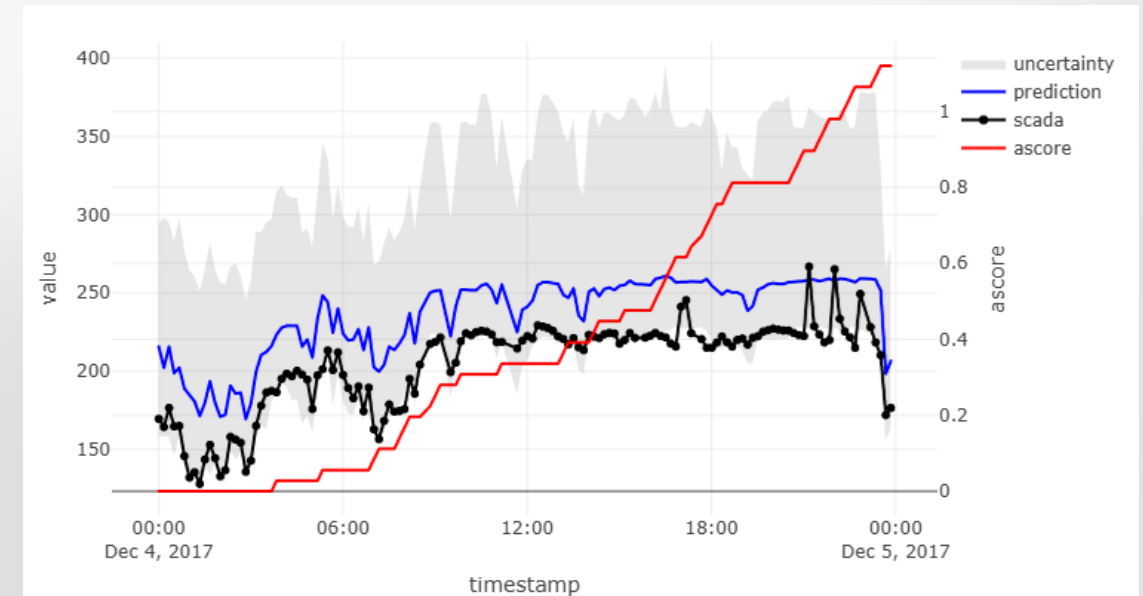
August 2017



We use **AI models** (e.g. XGBoost) to predict **normal behavior** of SCADA parameters at **different operating conditions**.

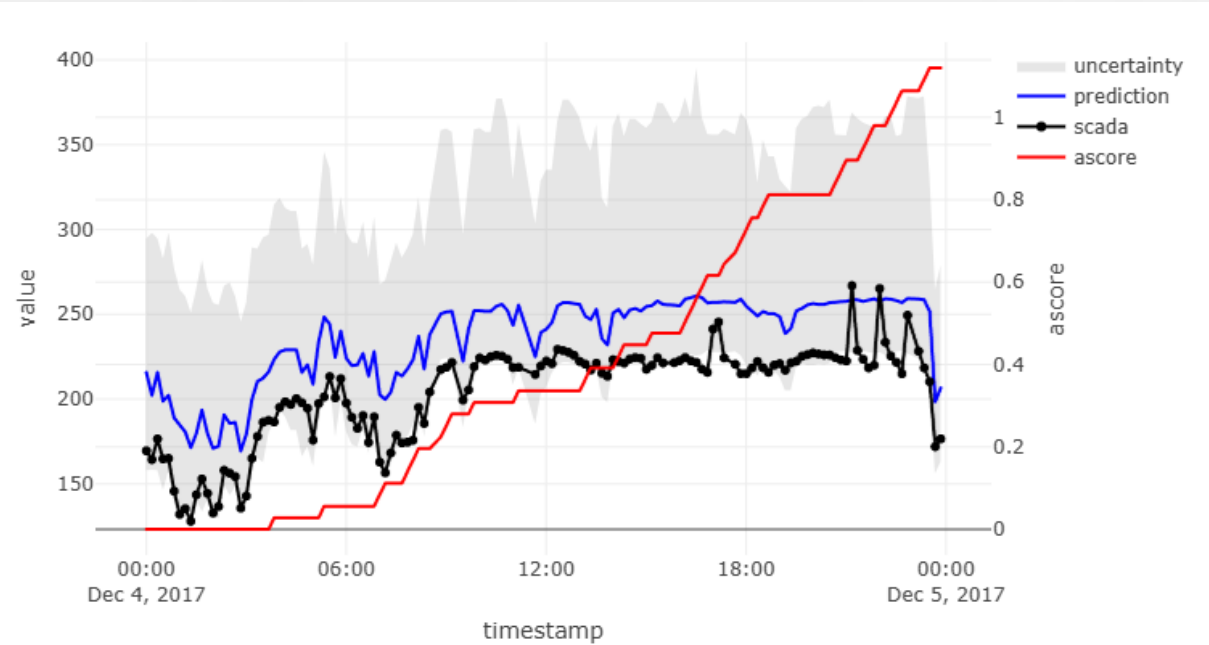
Deviations from normal behavior are quantified as an **Anomaly Score**.

Allows **real-time detection** of general machine issues.



Investigation of a gearbox damage:

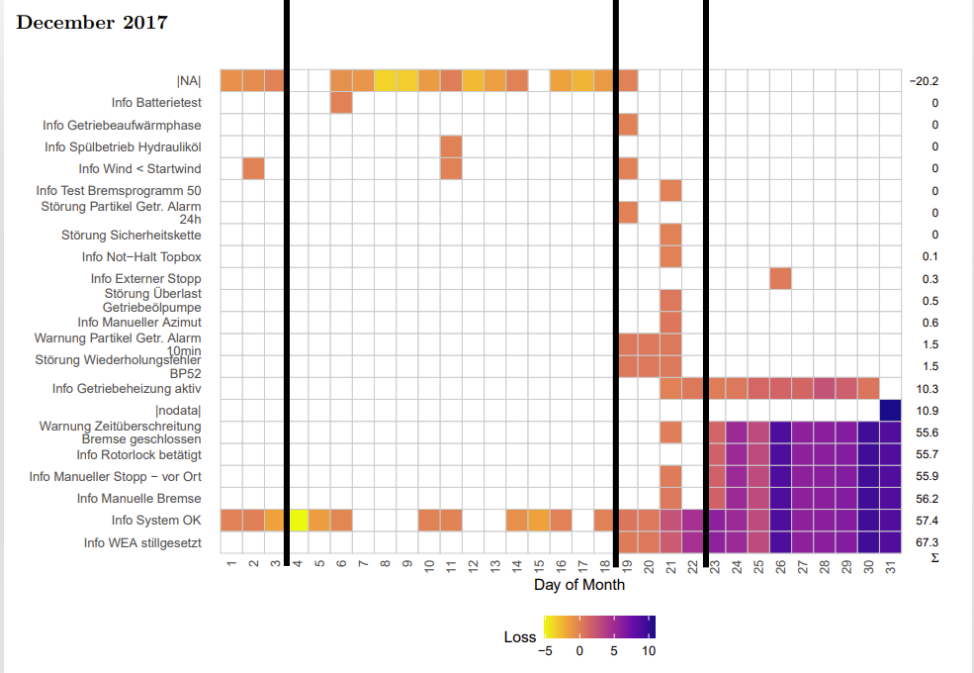
14 days earlier warning by only using our anomaly score evaluation



Anomaly score alarm

Particle counter alarm

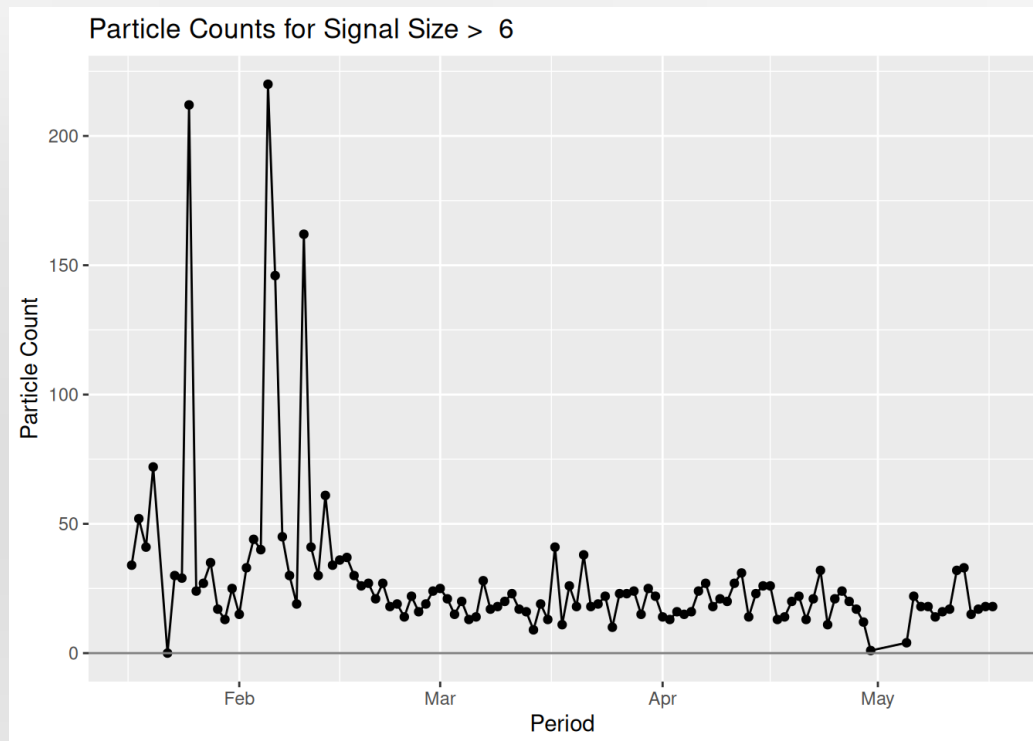
Damage detected



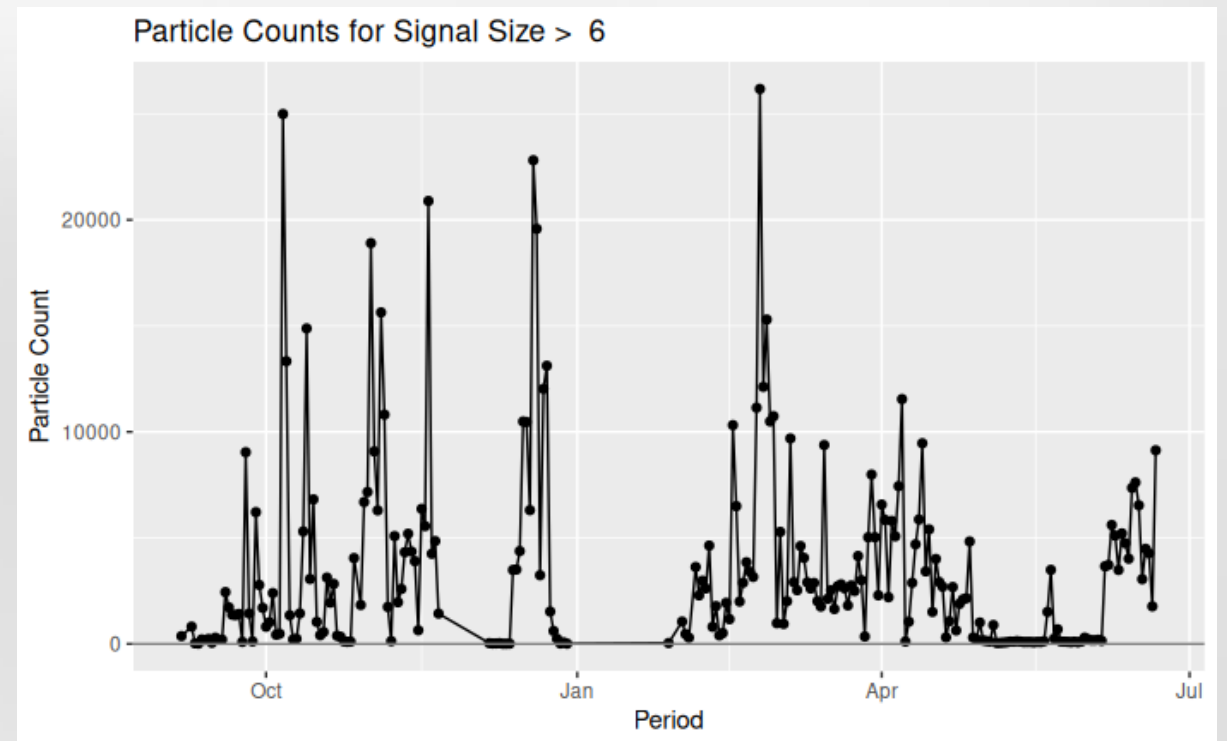
Wind Turbine Particle Count Comparison

- Innox Sensor System Prototype Version 3 installed in different wind turbines
- Differences in particle counts between normal operation and starting drive train problems

normal behavior

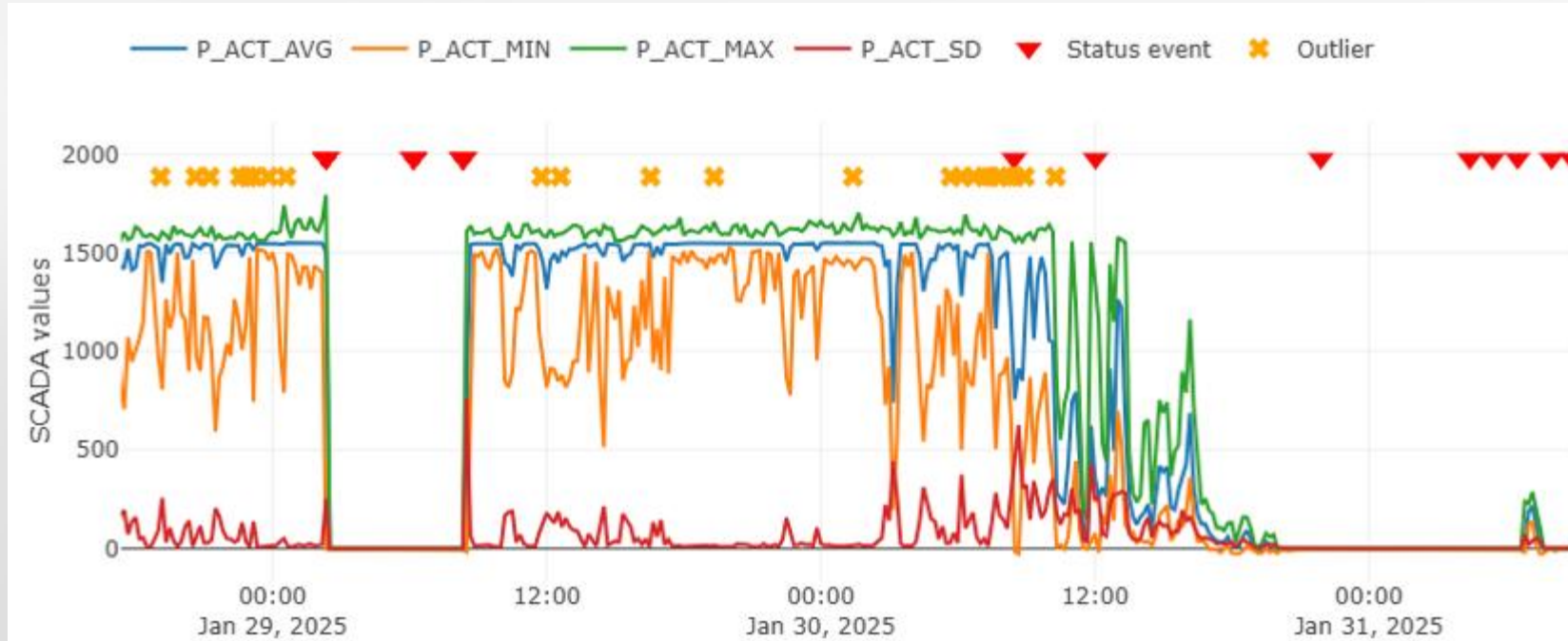


suspicious behavior



Confidential

Combining SCADA and Particle Events

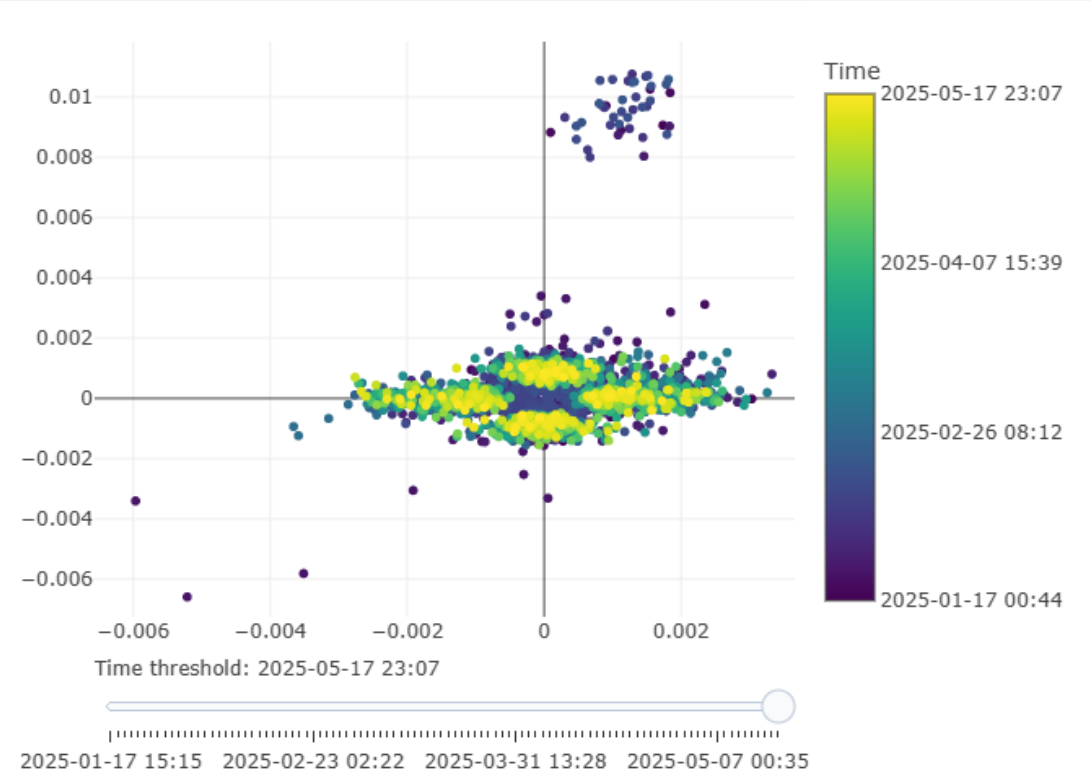


- **Overlap of SCADA data and outlier events from the Inmox System**
- **Correlation between higher outlier density and higher power output standard deviation**
- **Elevated outlier density correlates with high power output variability, consistent with increased mechanical load cycling.**

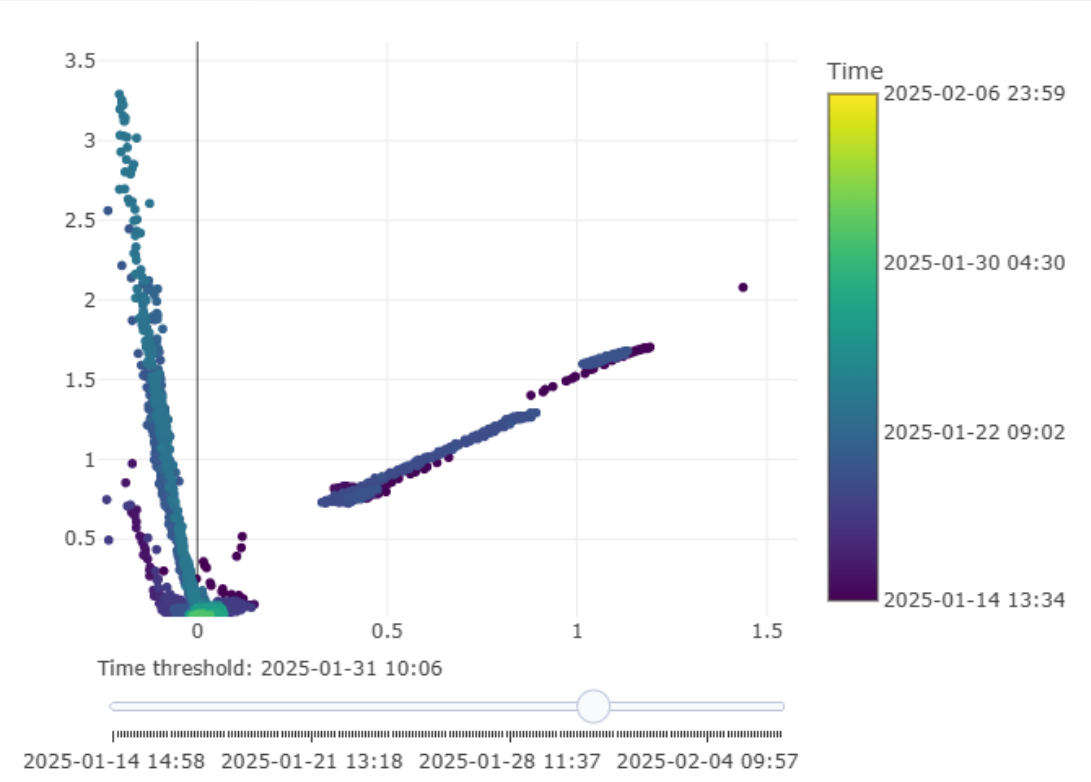
Material Differentiation

- Innox Sensor System Prototype Version 3 installed in different applications
- Differences in material composition over time shown as 2D plot representation

normal behavior



suspicious behavior



Outlook/Remaining Lifetime

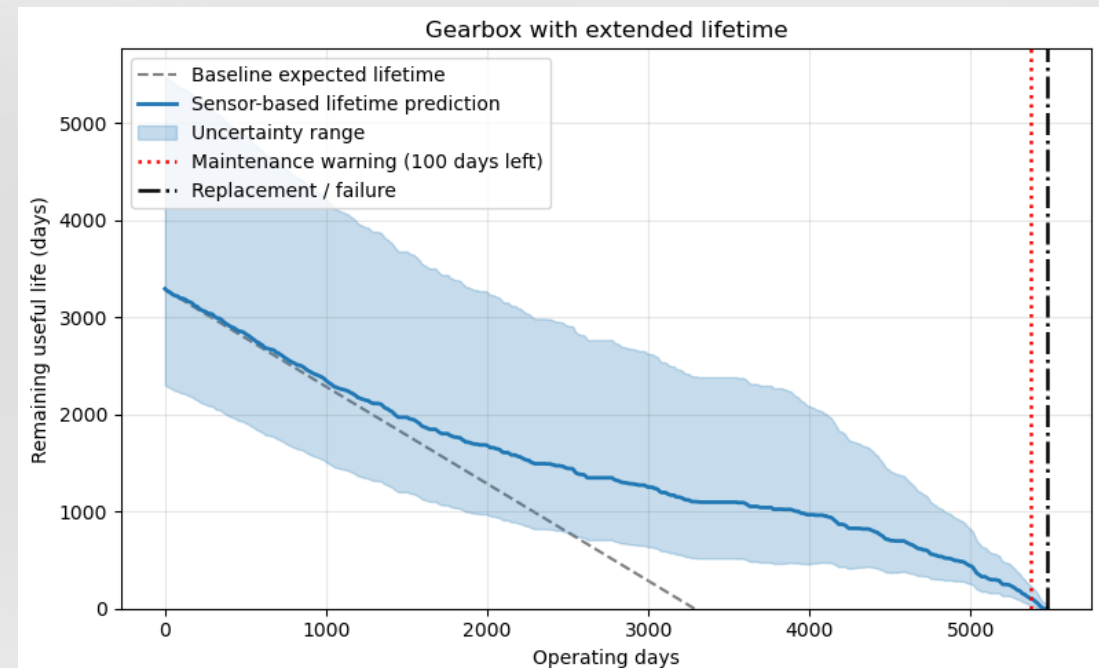
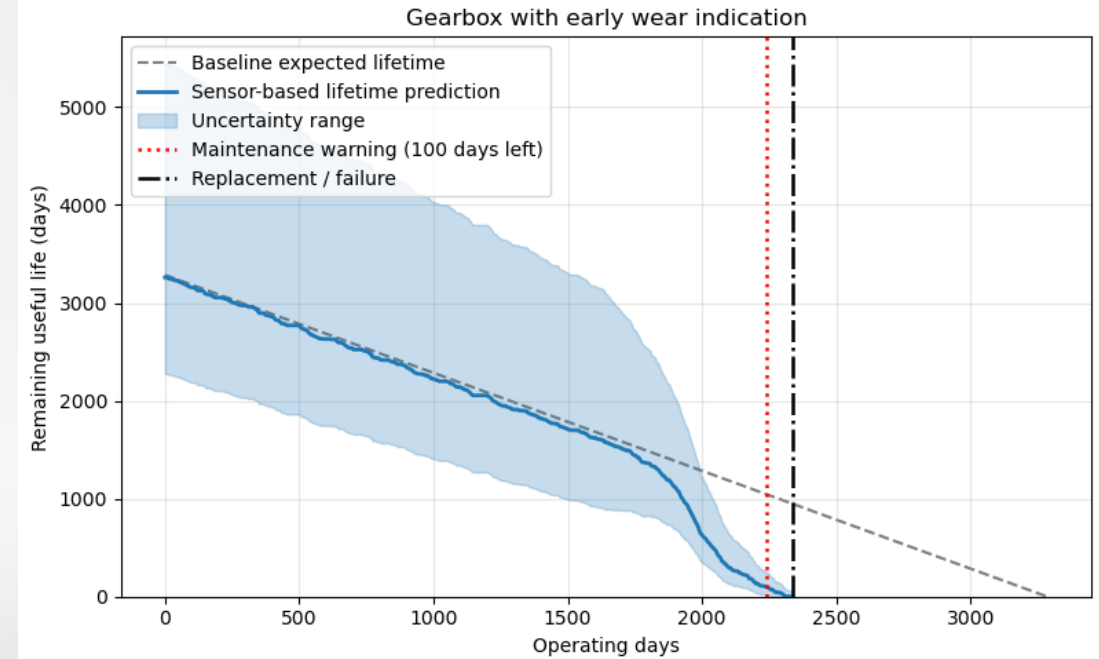
Inmox Sensor Data and an inhouse developed **AI model** is used to predict the remaining lifetime of a gearbox.

Early wear indication:

- Lifetime of the gearbox is shorter as design lifetime
- Early warning is issued to plan the maintenance

Extended lifetime:

- The data indicates that the lifetime of the gearbox exceeds the design lifetime due to good maintenance





INMOX

Intelligent monitoring systems



Phoenix Founder Award '23 "Start-up"



State Prize for Innovation '23 Special prize "VERENA"



EY Scale-Up Award '24 "Rising Star in Industry & Sustainability"



Startup of the year '24 "Industry Tech"

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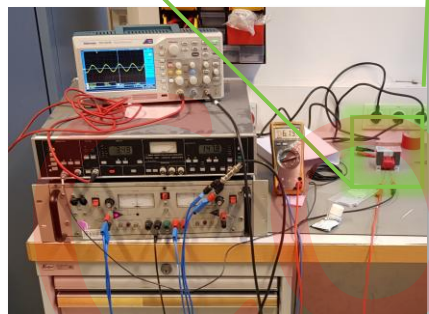
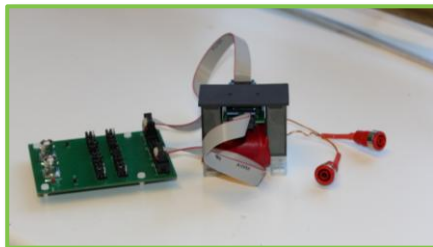
*Technology forward.
Together.*



Appendix

Hardware Development Progress

2022



2 people

2023



4 people

2024



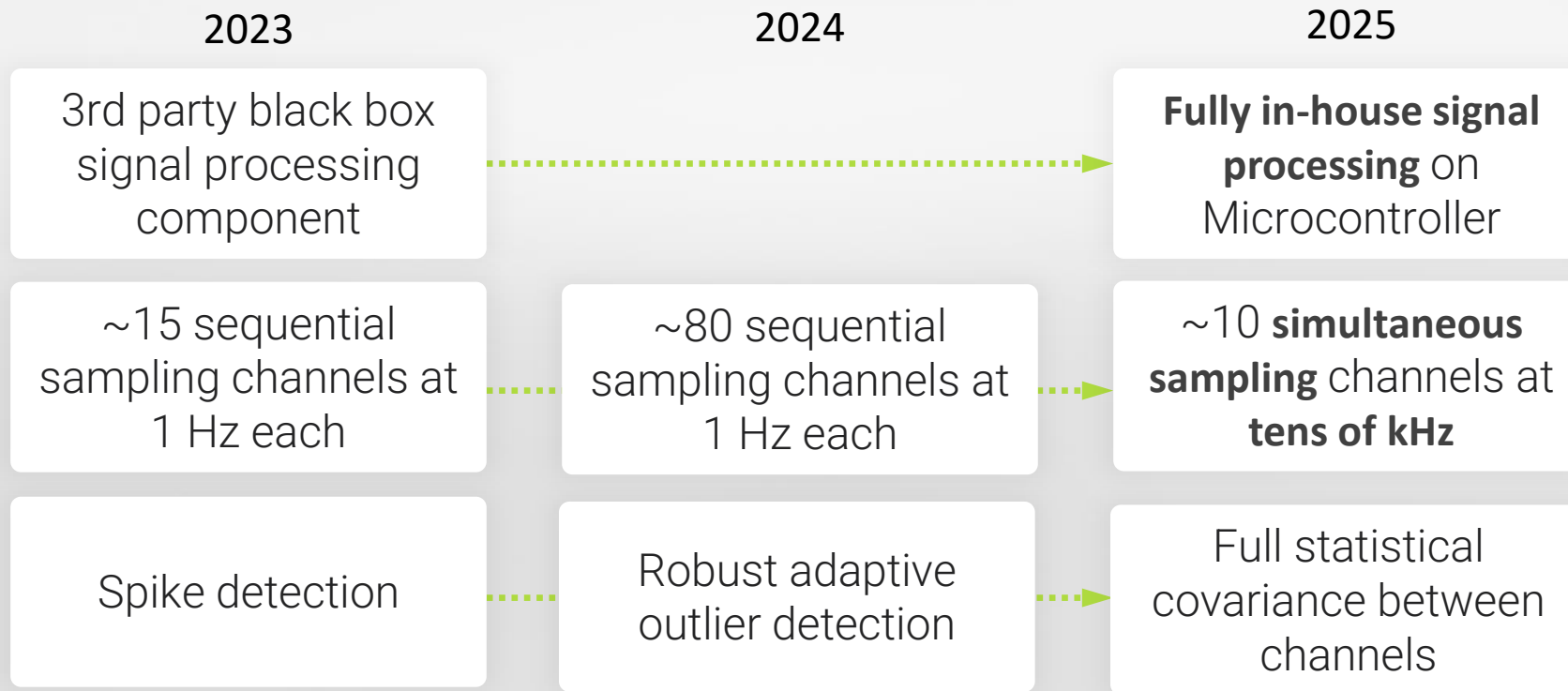
5 people

2025



6 people

Sensing Stack Development **Progress**



FEM magnetic simulations

- Ongoing optimizations in magnetic component geometry
- Maximizing Particle Signal while minimizing Background

