



DRIVING INNOVATION IN MANUFACTURING

Optimizing Offshore Wind: Corrosion & Bearing Monitoring

Pieter Bovijn
Flanders Make

How Flanders' 4 strategic research centers **kick-start your R&D success**

IMEC

5.500 researchers

- Micro- and nanotechnology
- Digital technology

VIB

1.920 researchers

- Biotechnology
- Life sciences

VITO

1300 researchers

- Sustainable chemistry, materials and energy
- Land-use & health

FLANDERS MAKE

+900 researchers

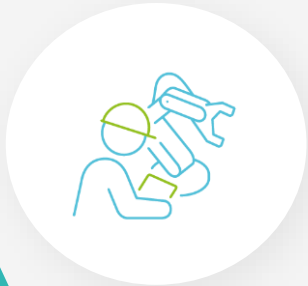
- Product & production technology and processes
- Digital transformation & Industry 4.0



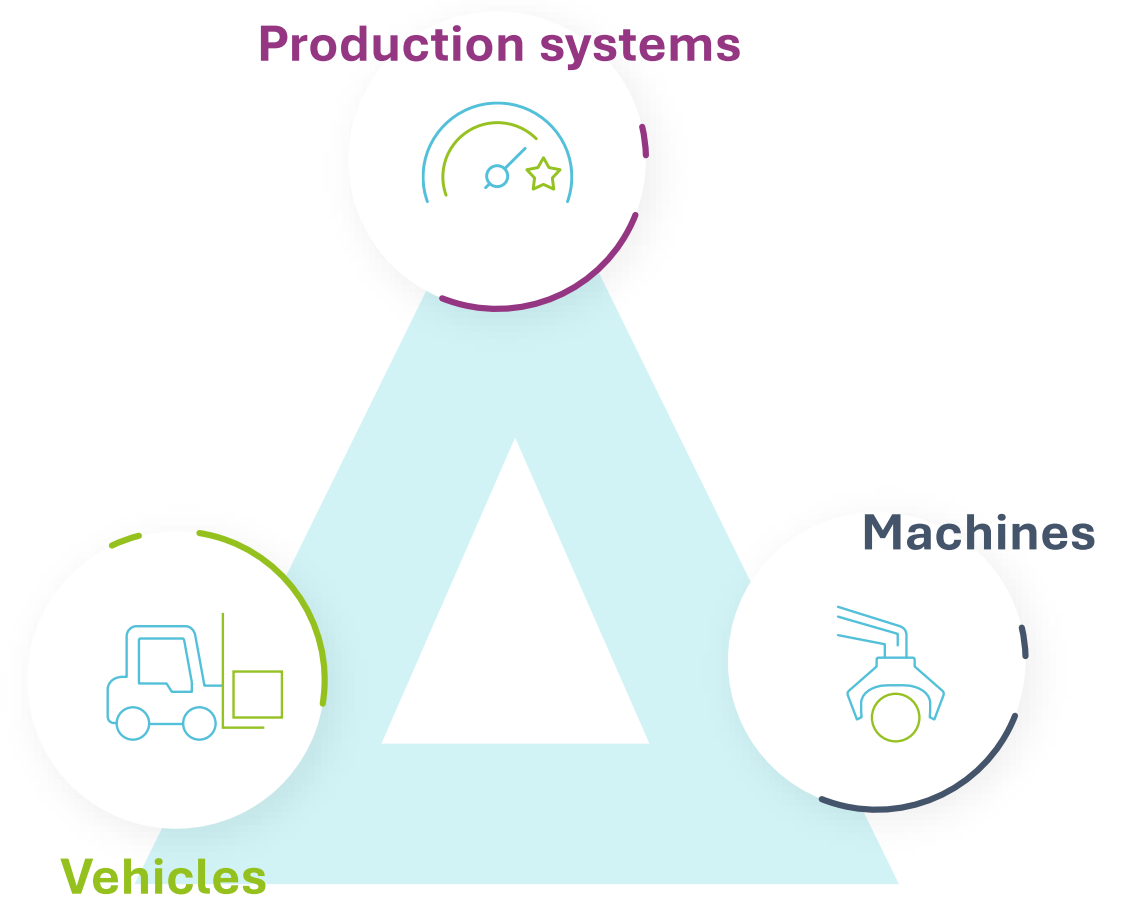
Flanders Make supports the industry to increase its international competitive strength



**Manufacturing
industry**



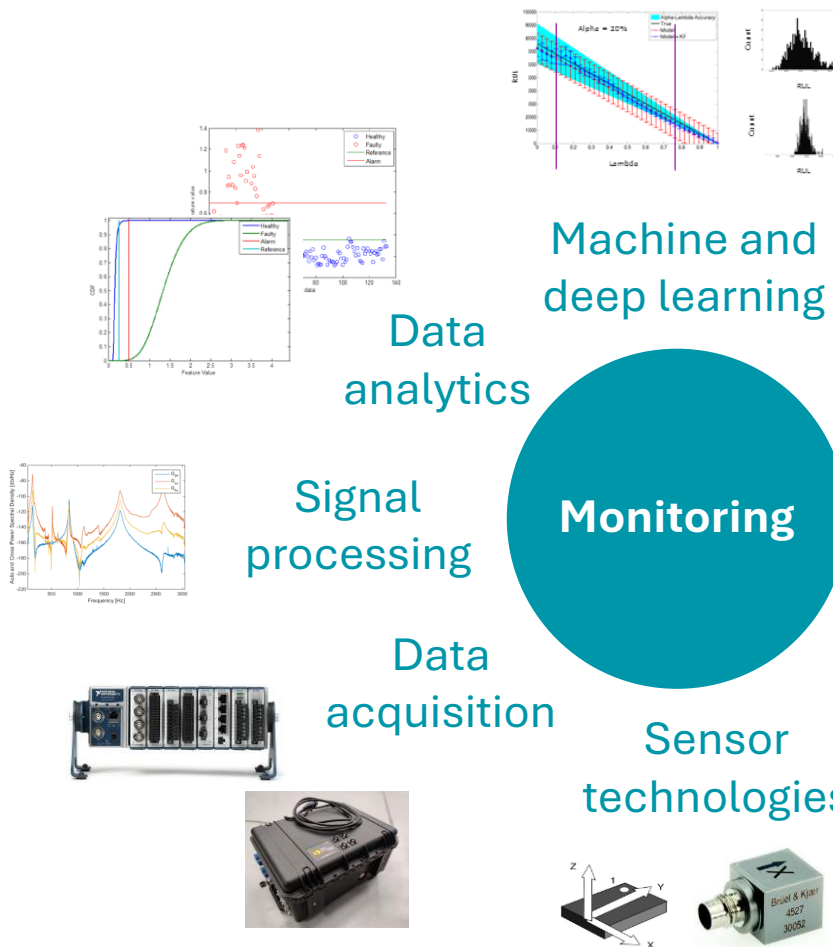
**Industry with
manufacturing challenges**



Monitoring Technology Domain

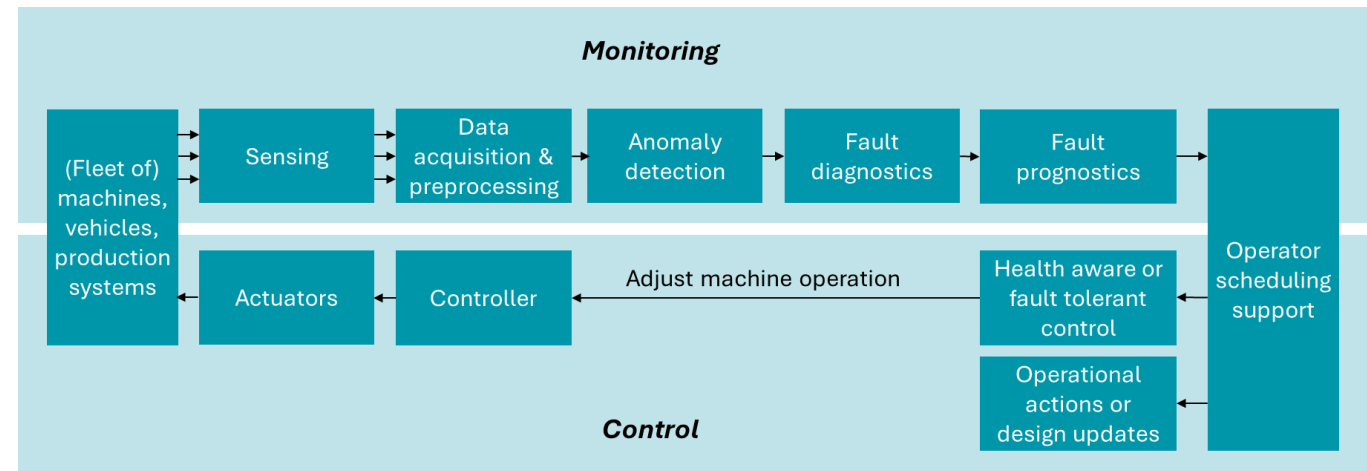
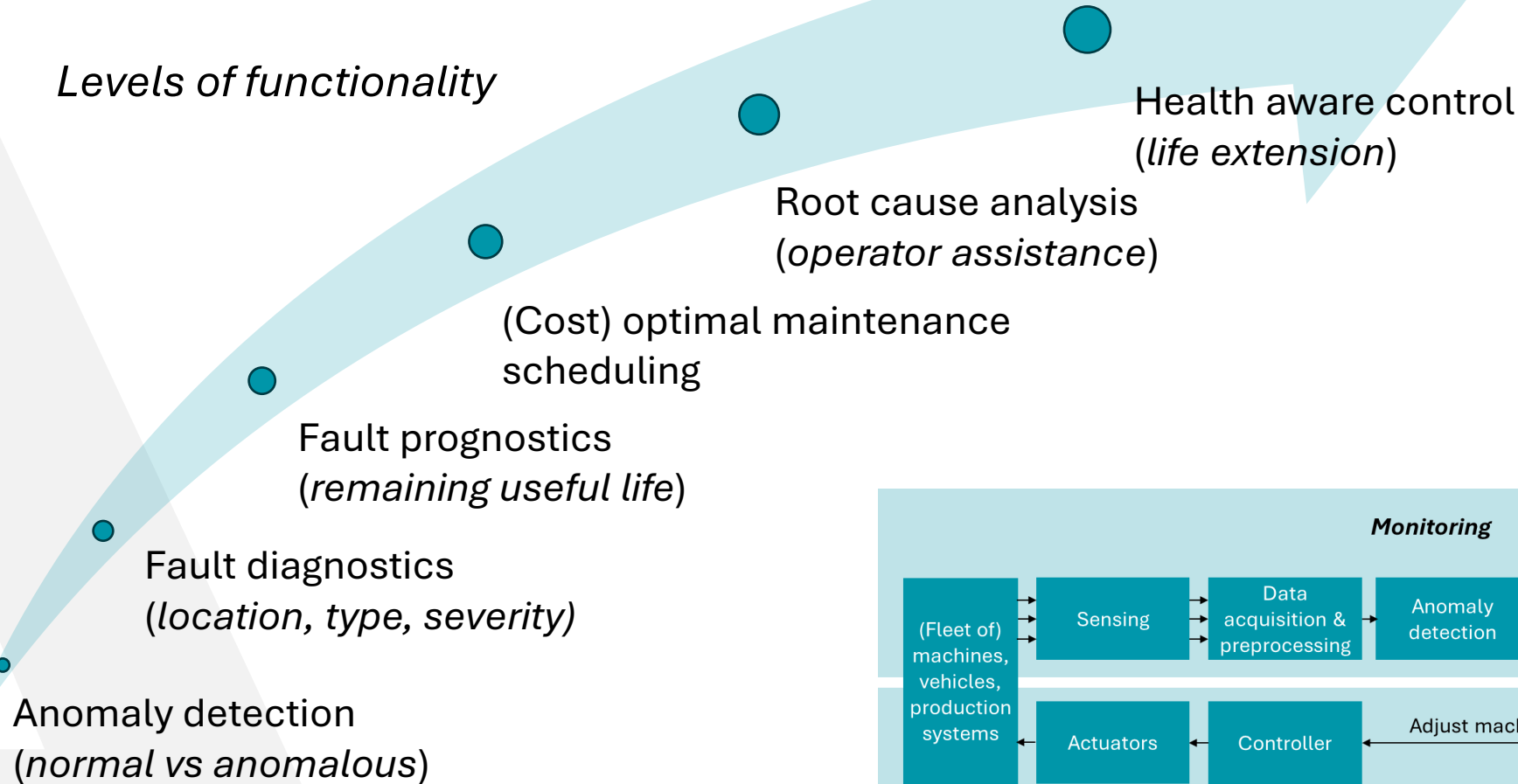


The process of **collecting data** using sensors about a system or its environment, the **analysis and interpretation** of that data to **identify the current state, detect changes or predict future events.**

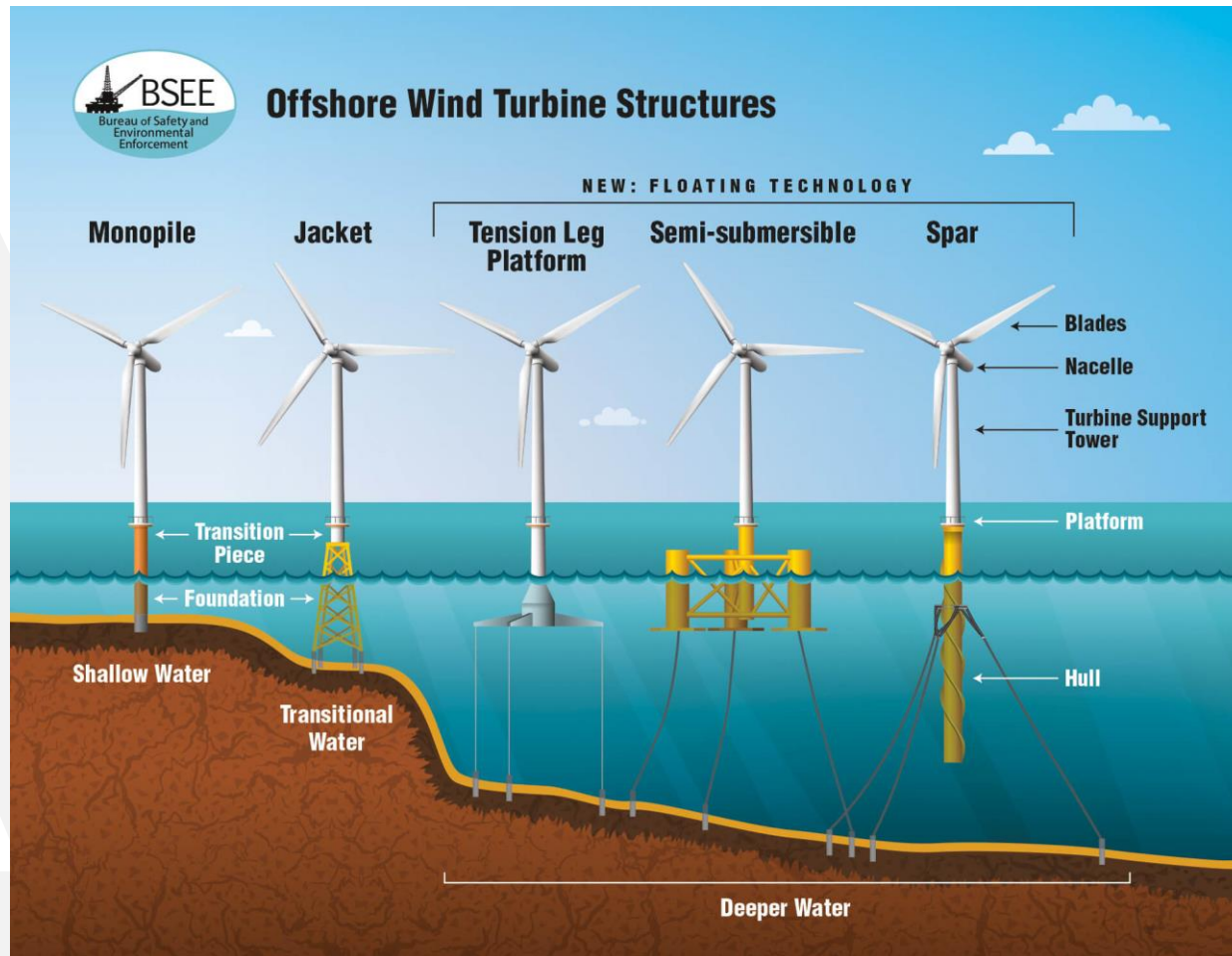


Industrial health management for optimal maintenance

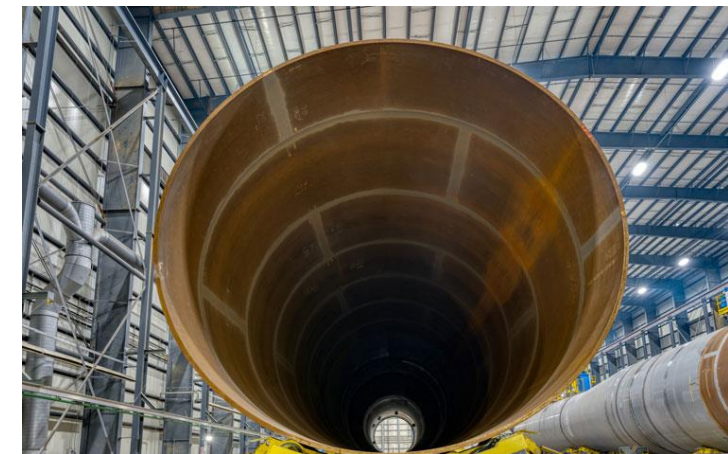
Levels of functionality



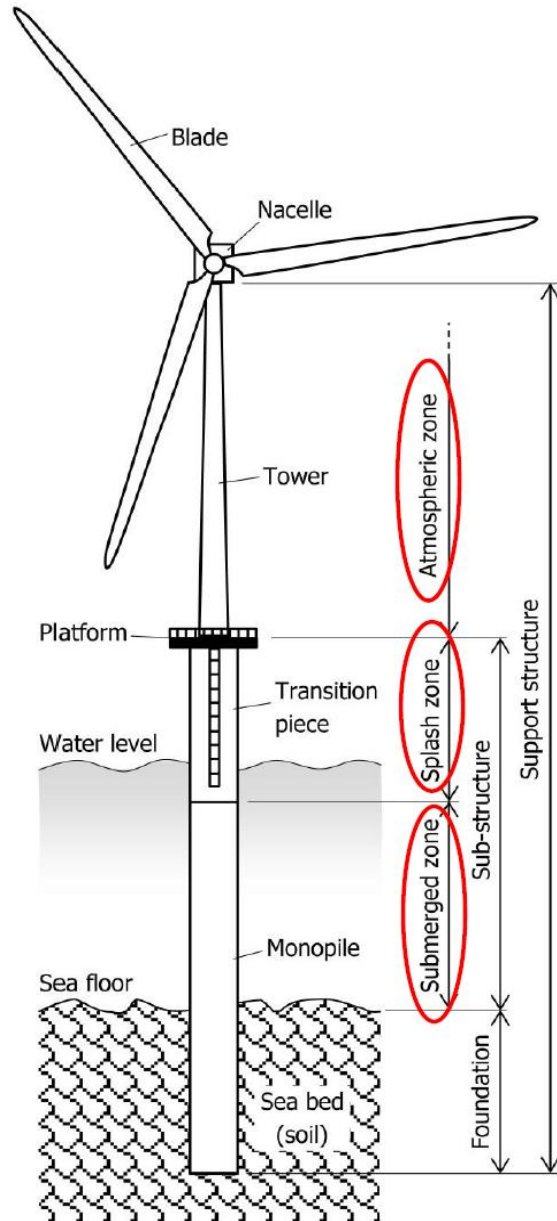
Offshore wind turbines



A Monopile with sub-components



Corrosion

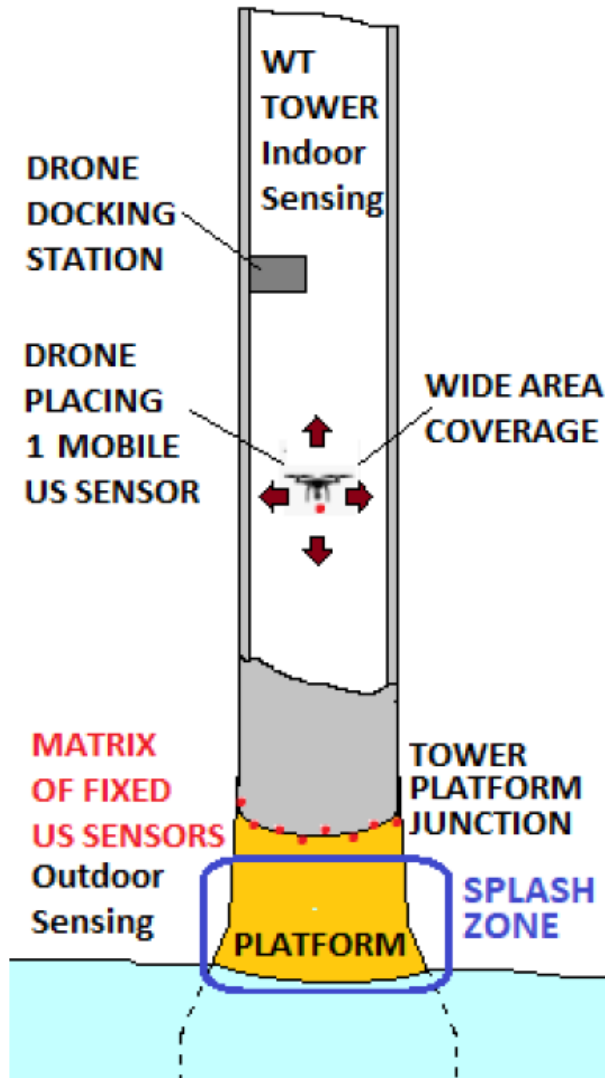


Exposure conditions	Typical coating system	Lifetime expectancy
Atmospheric zone	Zinc epoxy: 60 μm Epoxy barrier coat: 150 μm UV resistant topcoat: 70 μm	Time to first major maintenance is normally about 10 years.
Splash zone	2-coats polyester Mean dry film thickness: > 1000 μm	Lifetime of 20 years or more is usually achieved
Submerged zone	2-coats epoxy Mean dry film thickness : 350 μm	According to design life. Degradation of the coating is compensated by sacrificial anodes.



[O. Knudsen, A. Bjorgum, 'Corrosion protection of offshore wind turbines – long life protective coatings']

Corrosion



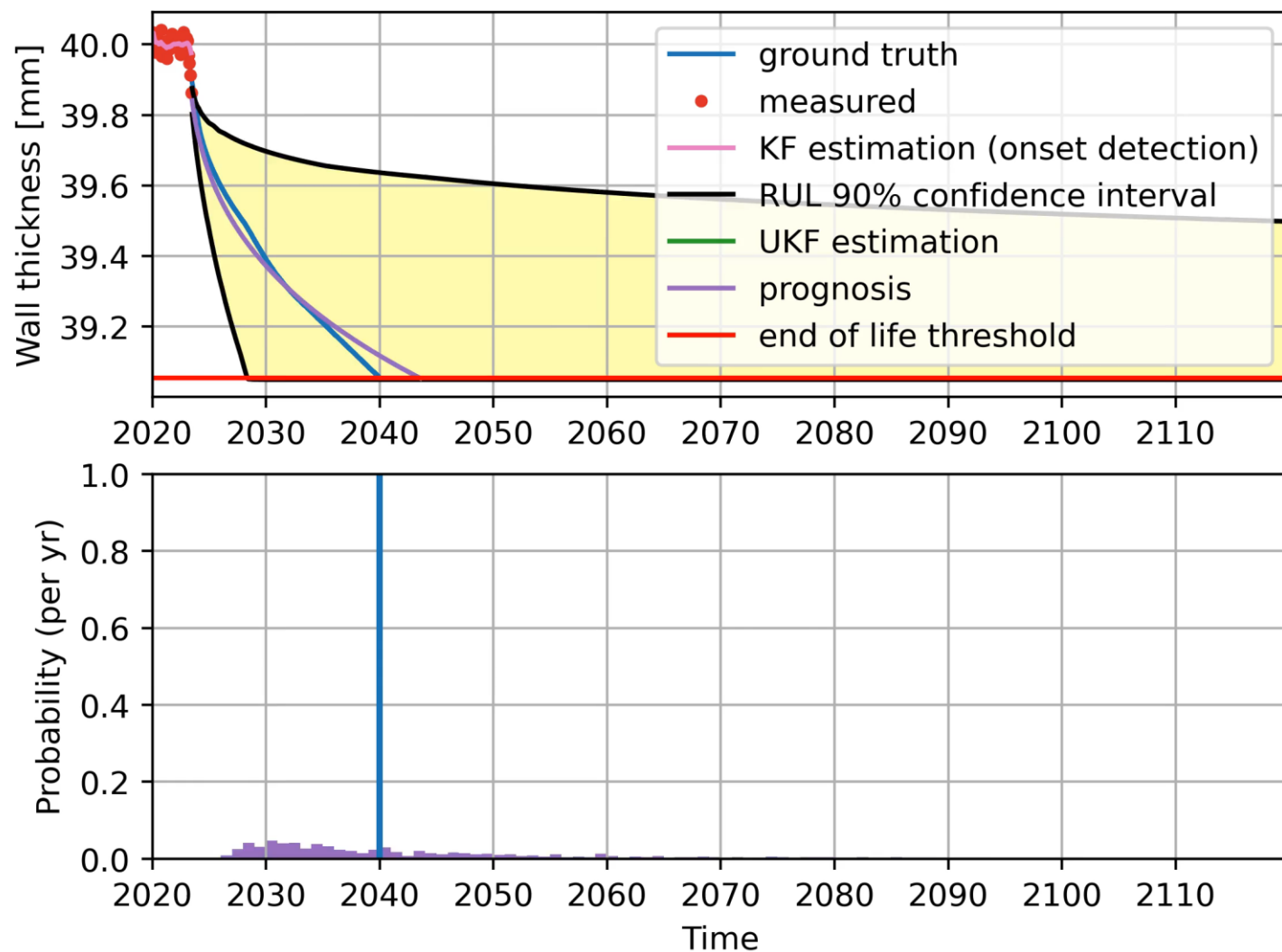
Ultrasound-based measurements of wall thickness

Monitoring of corrosion in Atmospheric and Splash zones:

- Fixed sensors in splash zone
- Drone with attached sensor for atmospheric zone

Corrosion Prognostics

End-of-useful-life estimate at
2023-06-01



End of life estimation using Kalman filtering

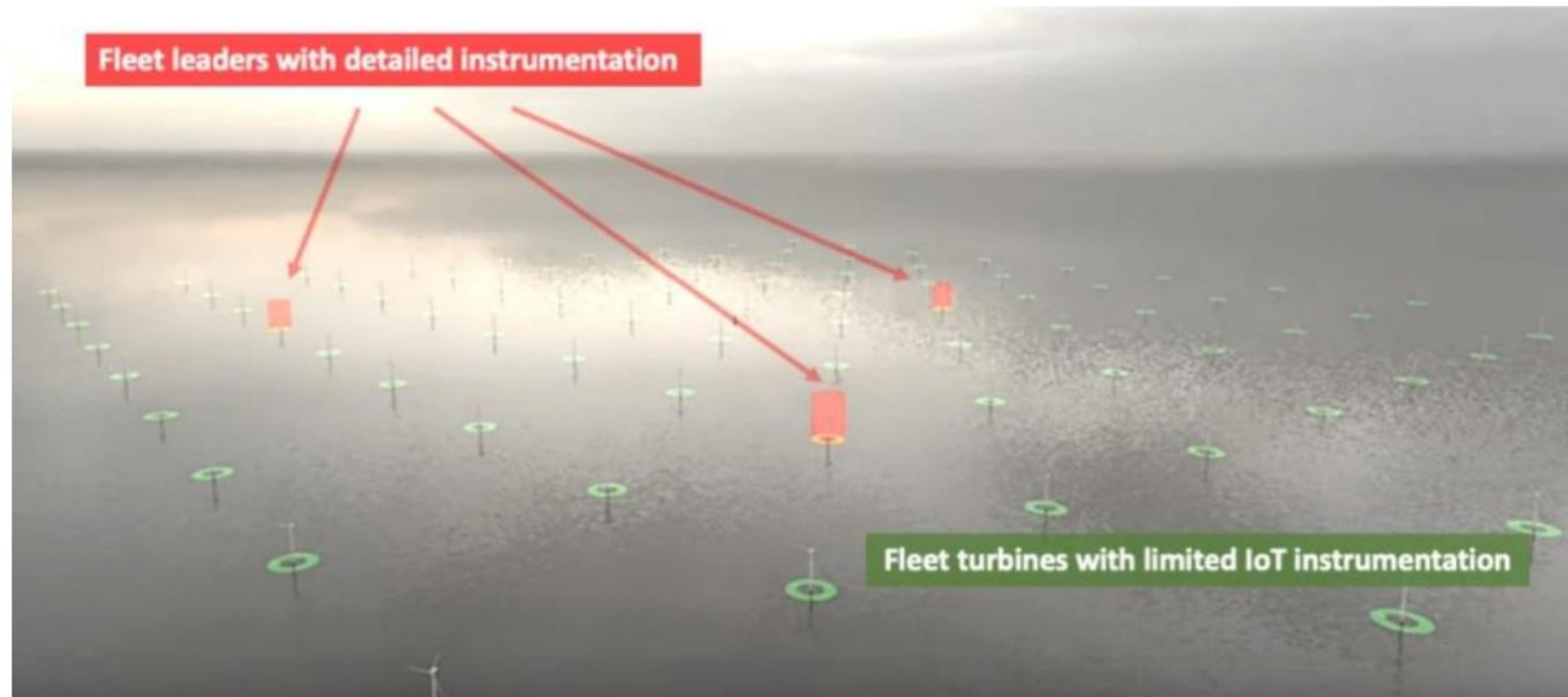
With confidence intervals

Fleet leaders

Sensors are expensive

Wind farms have a lot of turbines

How do we get RUL for all turbines?



ICCP (Impressed Current Cathodic Protection)

Active Cathodic Protection with DC current

No massive sacrificial metal added to the structural load, and dissolved in water

Enabling remote control and monitoring through SCADA system



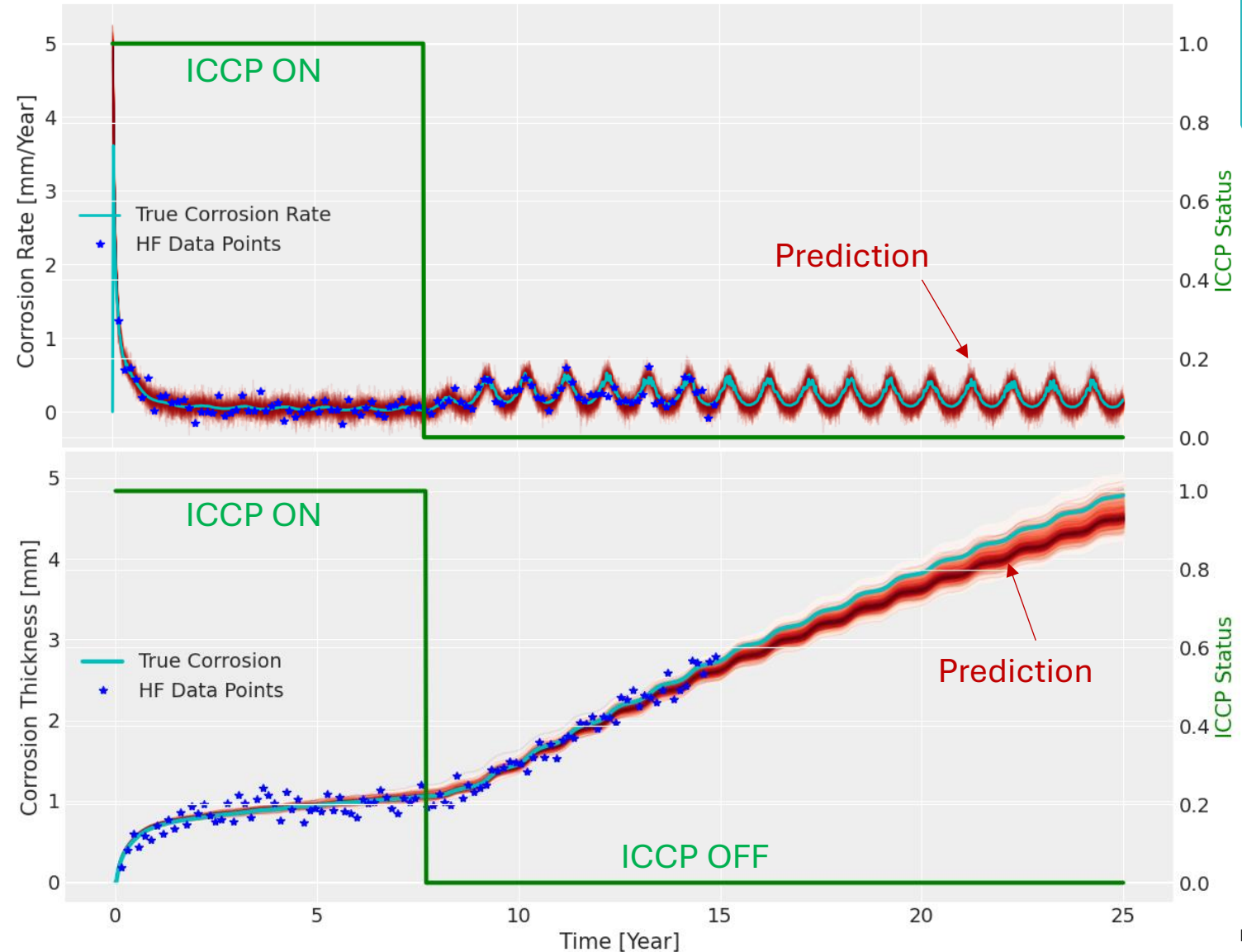
<https://www.youtube.com/watch?v=opNwNvxFjUw>

The ICCP voltage is typically an input signal for a closed loop control of ICCP, that tracks a setpoint of ICCP current. The current measurement may contain information on historic degradation protection.

Corrosion Prognosis: Fleet Leaders

An exercise using the Generic Corrosion Model

- Evaluated on an **extreme case** with virtual noisy data
 - Non-uniform data
 - Corrosion rate
 - Corrosion thickness
 - Seasonal effect
 - ICCP switching
- Parameters being inferred:
 - Corrosion rate power n together with its
 - seasonal (harmonic) component, and
 - an ICCP protection degradation

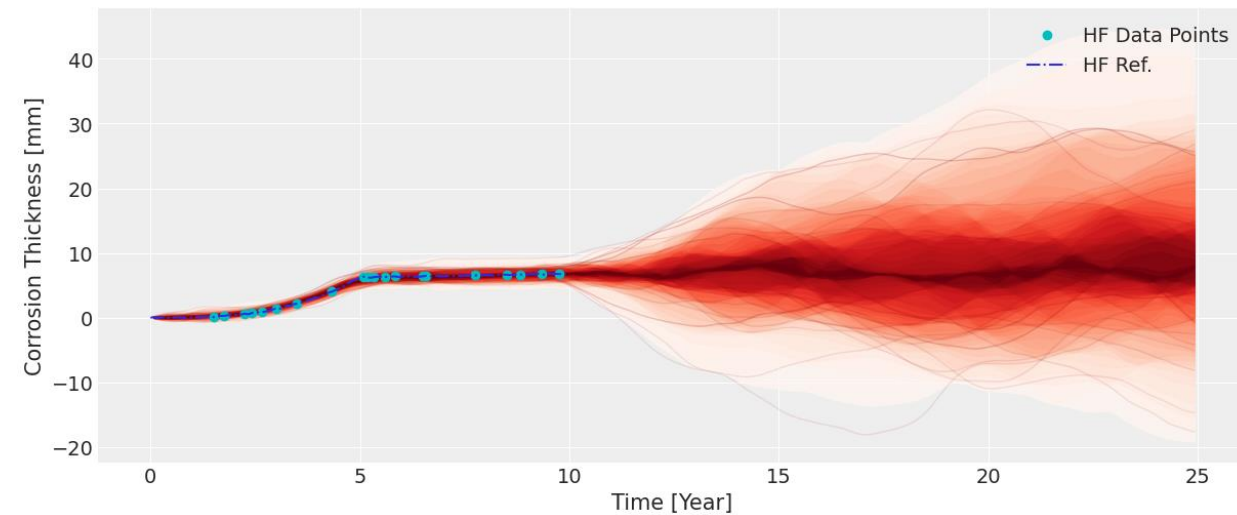
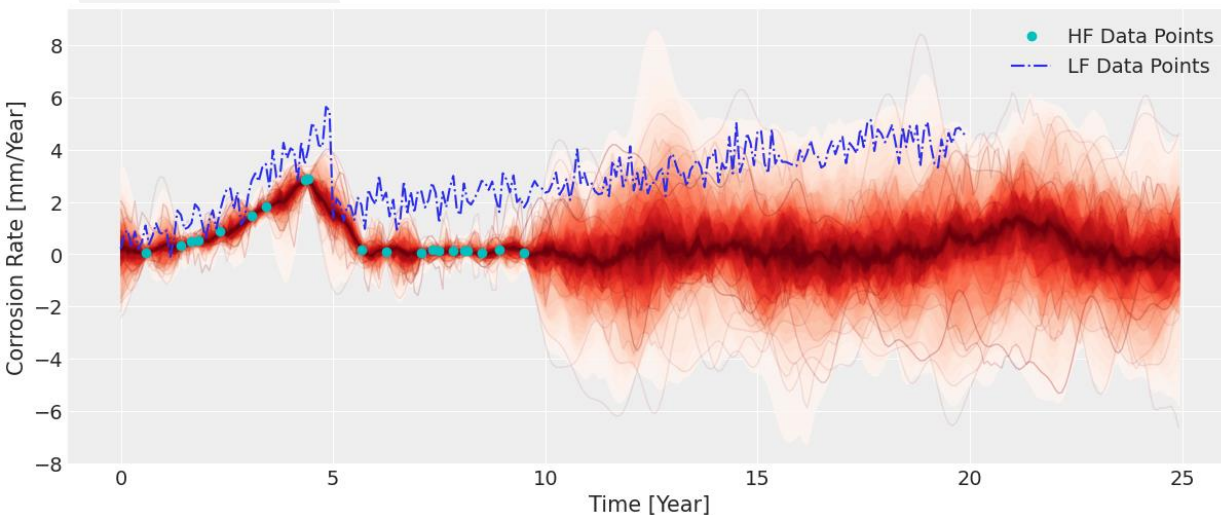


Corrosion Prognosis: Farmwide

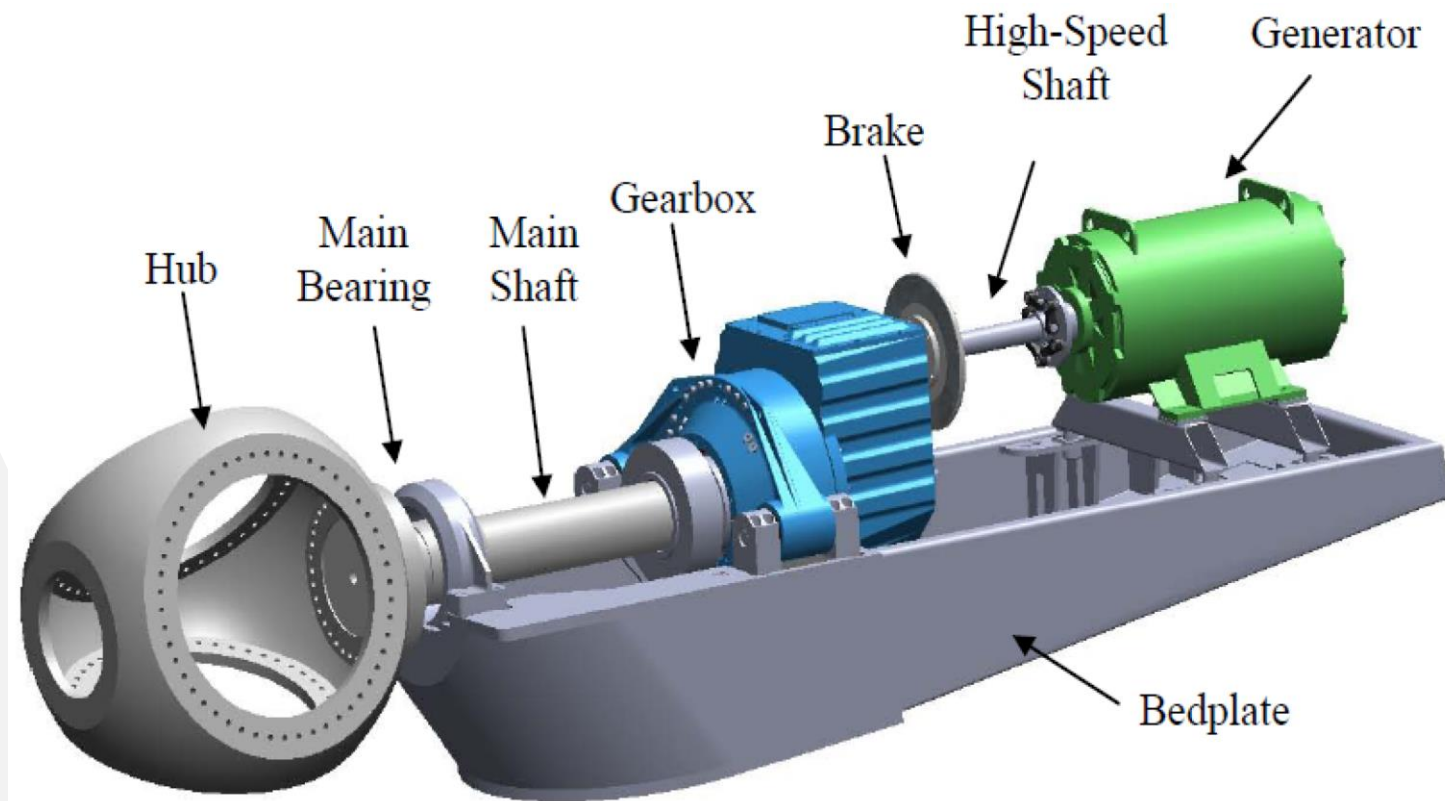
Fleet leaders: (High-fidelity) corrosion rate sensors

Farmwide: (Low-fidelity) ICCP data

- Find spatial correlations from ICCP data to map the high-fidelity data



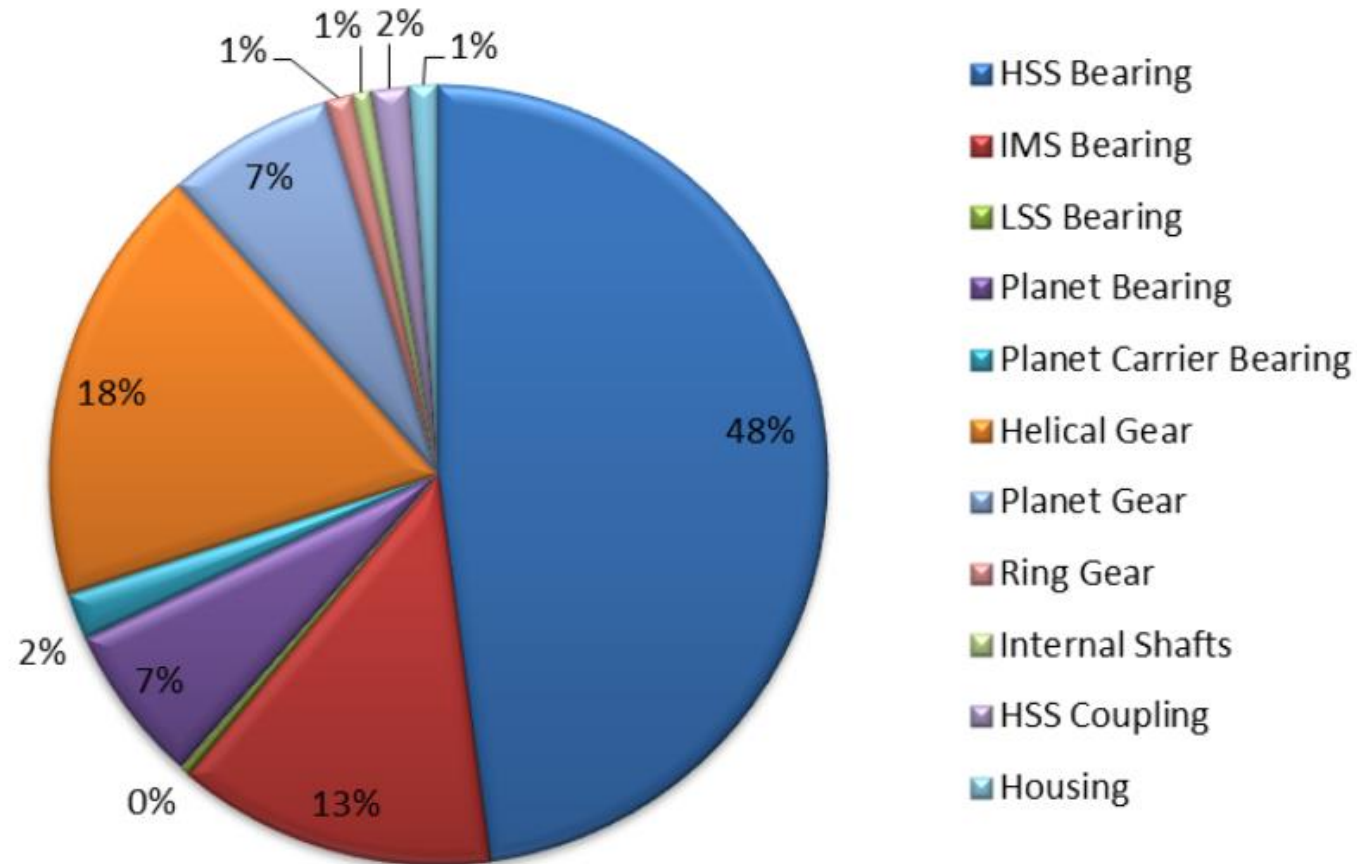
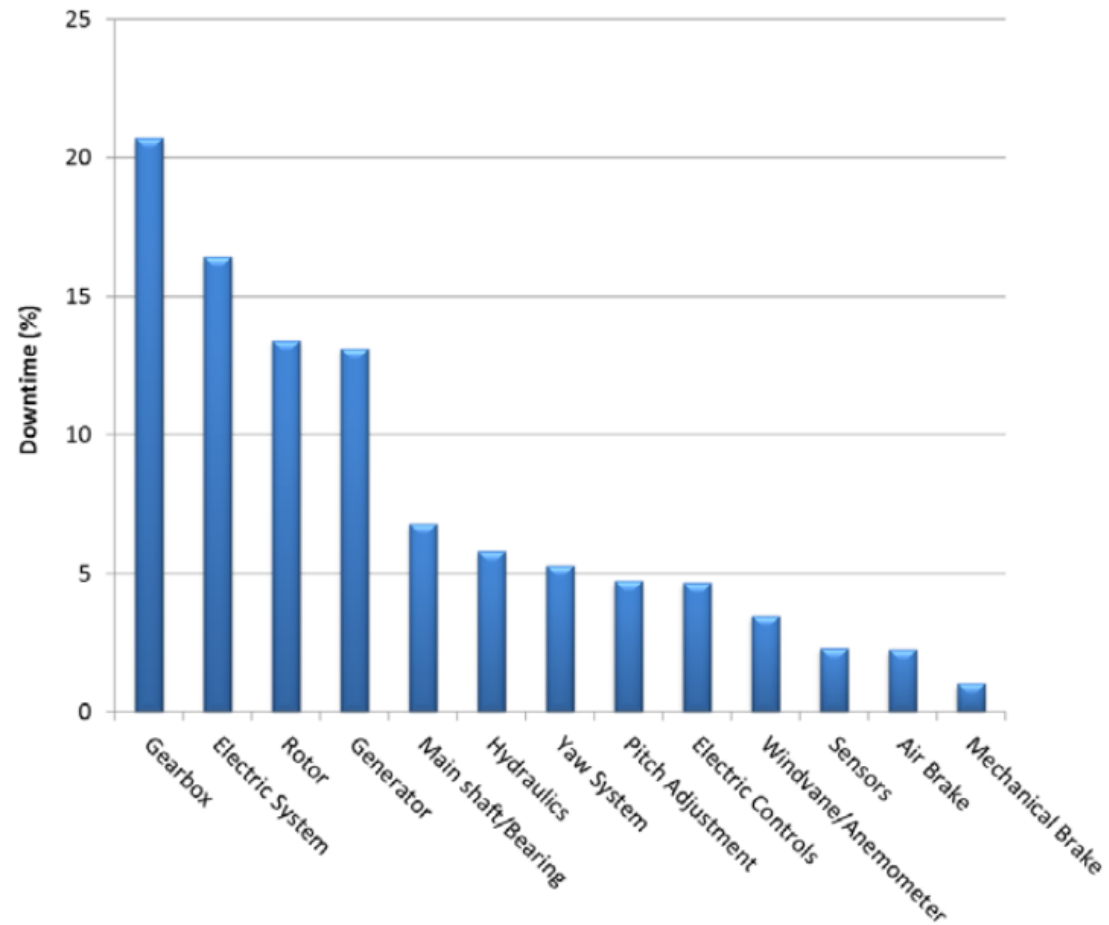
Drivetrain



Bearing failures

Gearbox Typical Failure Modes, Detection and Mitigation Methods
Shawn Sheng
National Renewable Energy Laboratory/National Wind Technology Center
AWEA Operations & Maintenance and Safety Seminar
January 15–16, 2014
NREL/PR-5000-60982

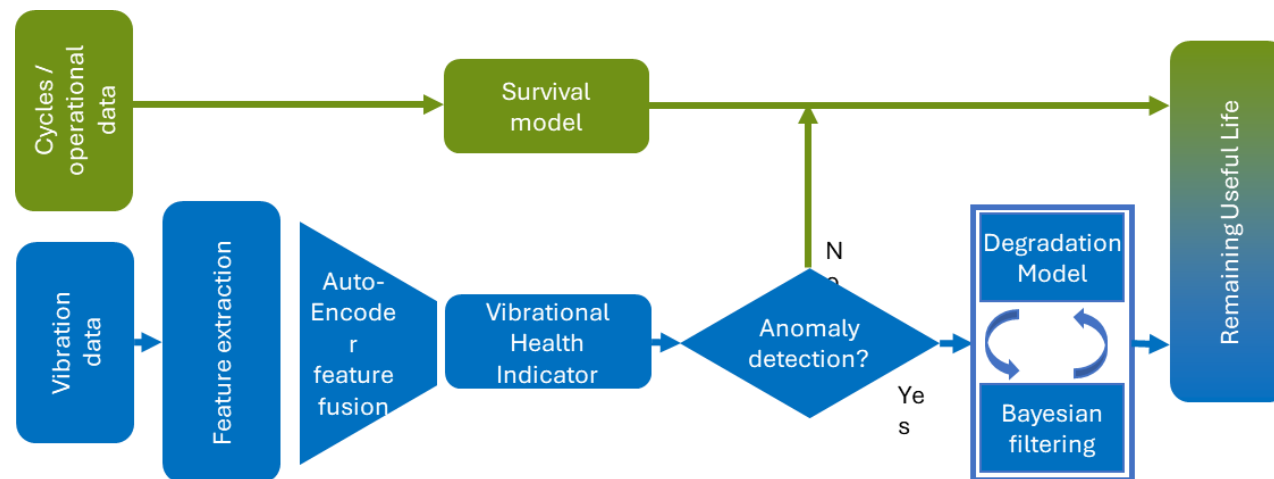
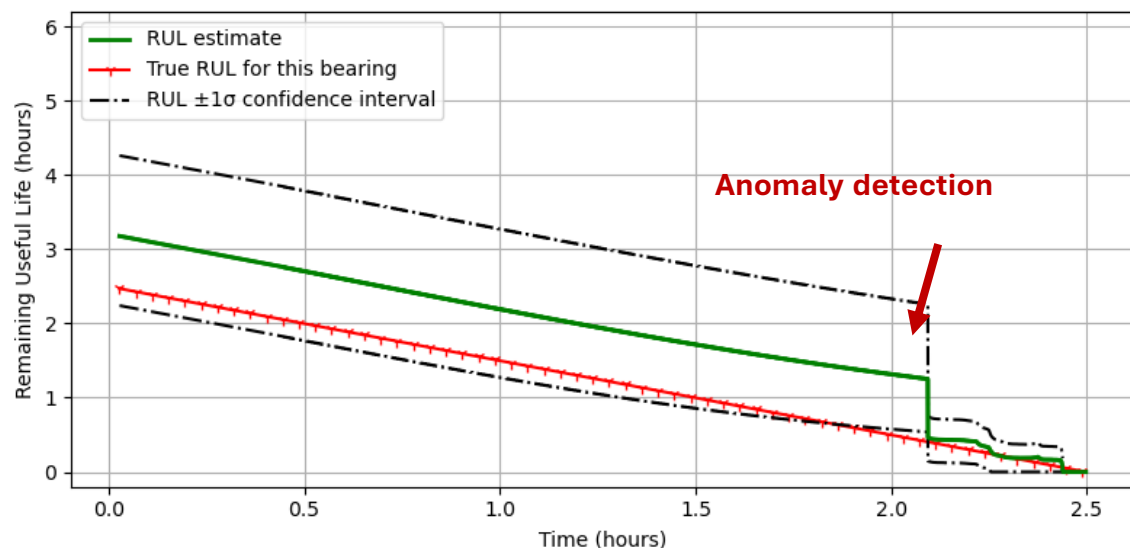
Wind Stats: 2008-2012 Aggregated Downtime per Turbine Subsystem



Bearing RUL

survival model based -> before anomaly detection

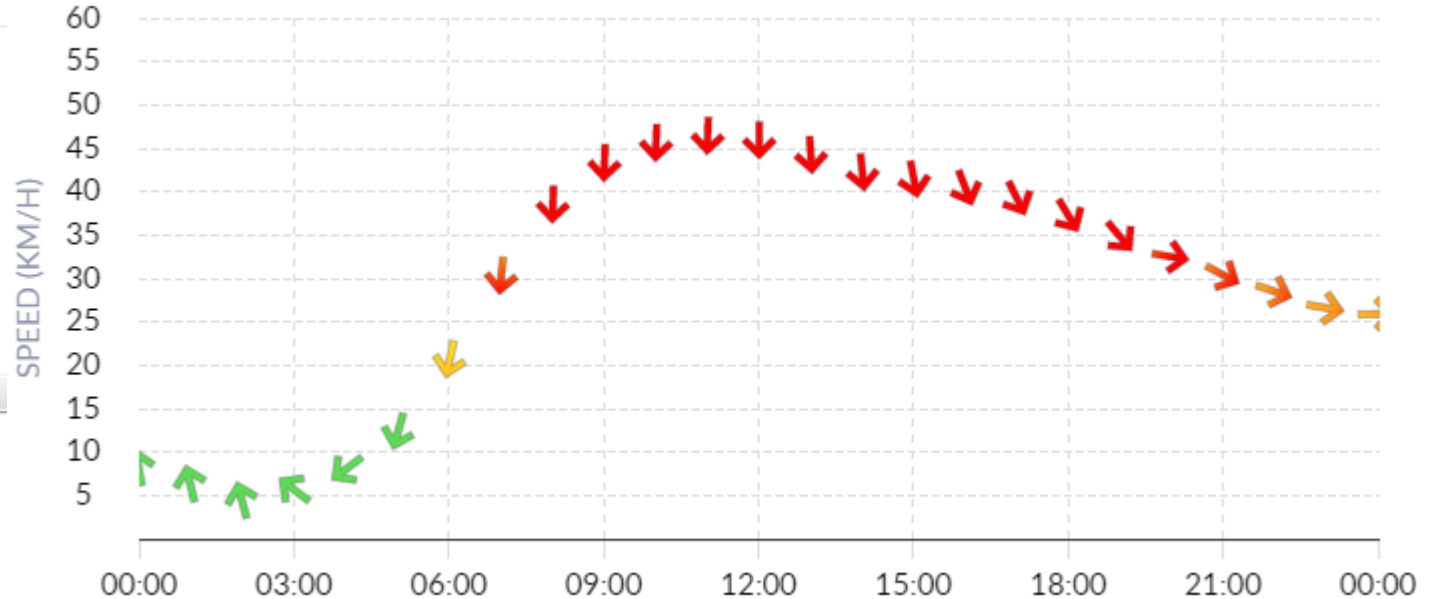
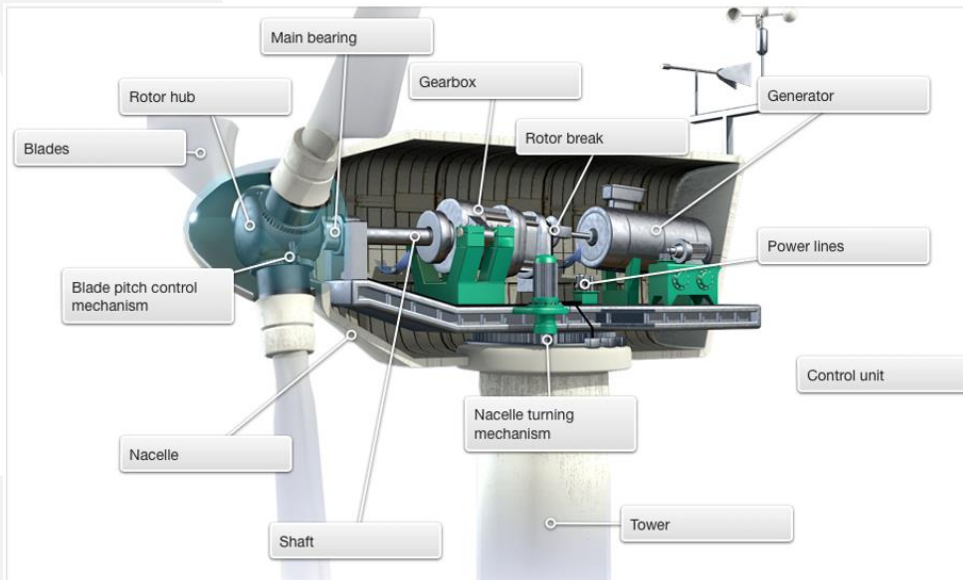
vibration-based degradation model for RUL prediction



New research

Loads on the bearing vary over lifetime

Turbines see strong variation in wind loads



Contact

Interested in the details of this research?
Struggling with similar problems?

Pieter Bovijn

pieter.bovijn@flandersmake.be