



Flettner FLEET



Konzept und Entwicklung eines digitalen Zwillings für Flettner-Rotoren zur Betriebsoptimierung

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Fraunhofer Workgroup
Sustainable Maritime Mobility



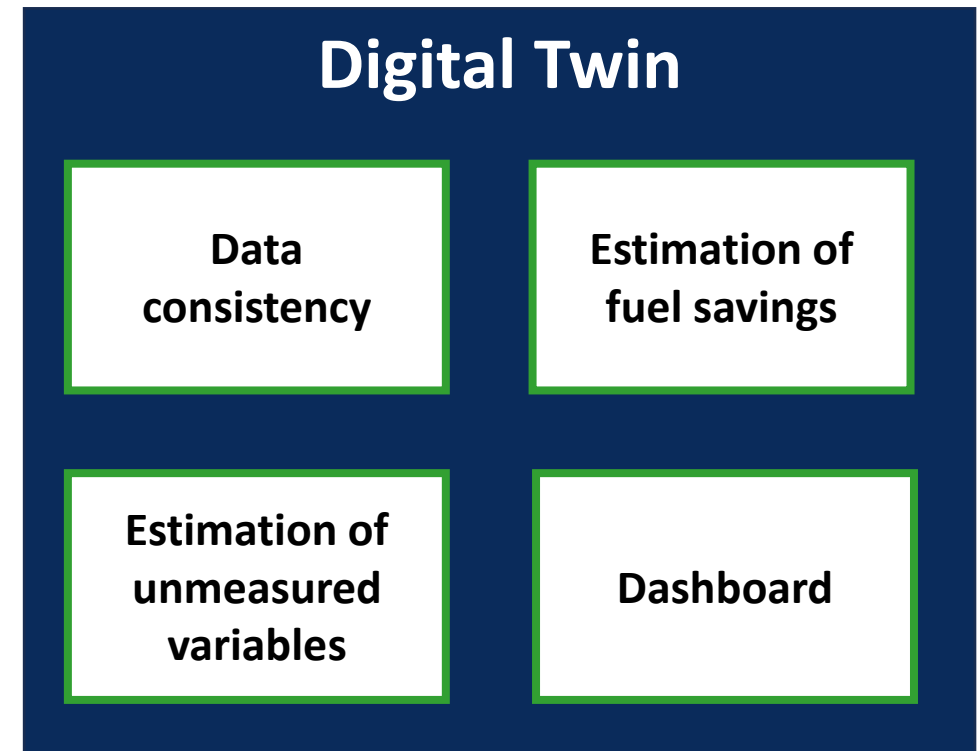
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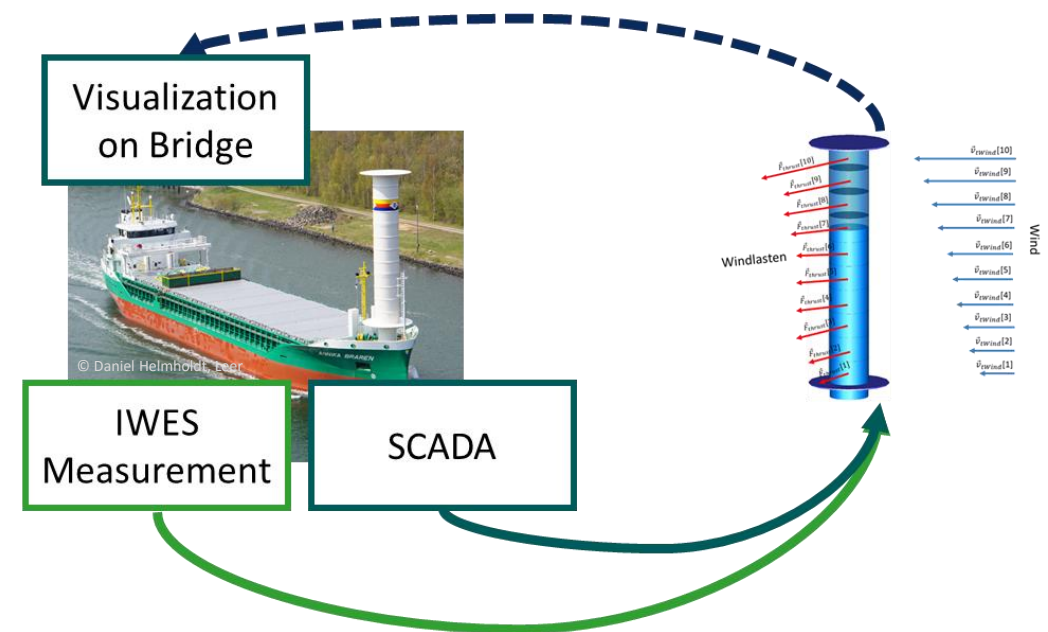
What is a digital twin?

- The digital twin combines models and data
- Benefit
 - Source of additional results
 - Aligning data
 - Identify mistakes in data structures
 - Integrated data processing
 - Visualization



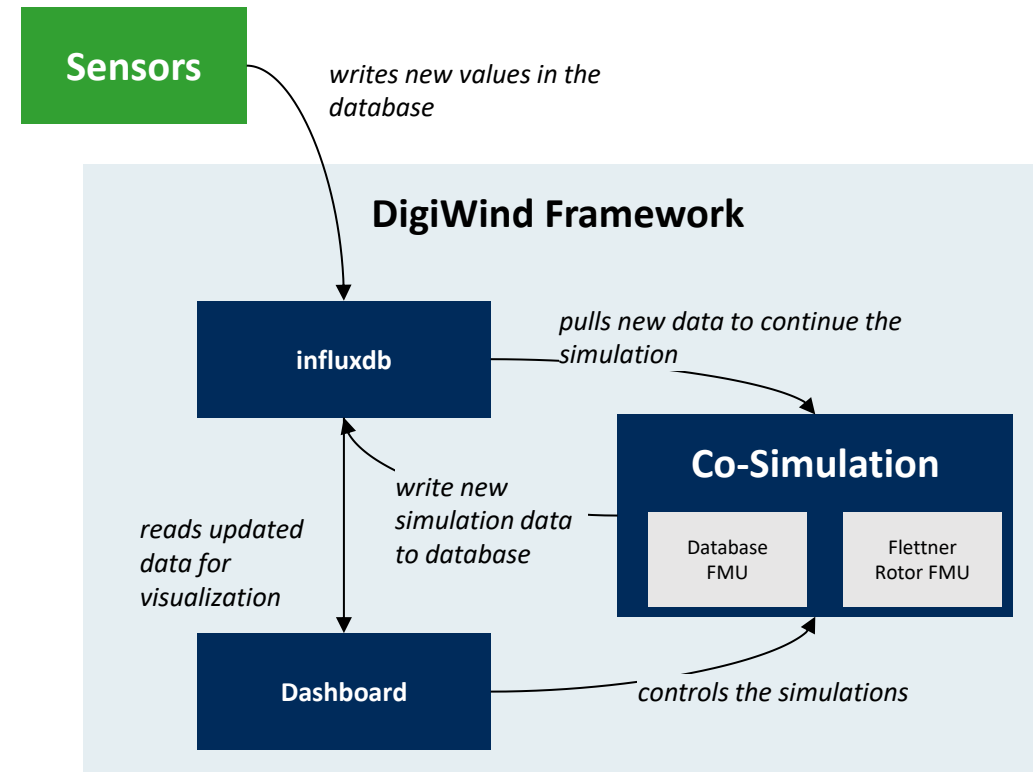
Digital Twin on the Annika Braren

- Installed since November
- Update mechanism works well
- System availability
 - Nov 2025 – Feb 2026
 - Downtime in December
 - SCADA: 93%
 - DT (total): 45%
 - DT (since Jan. 16th): 100%
- Automated data transfer into our Nexus database

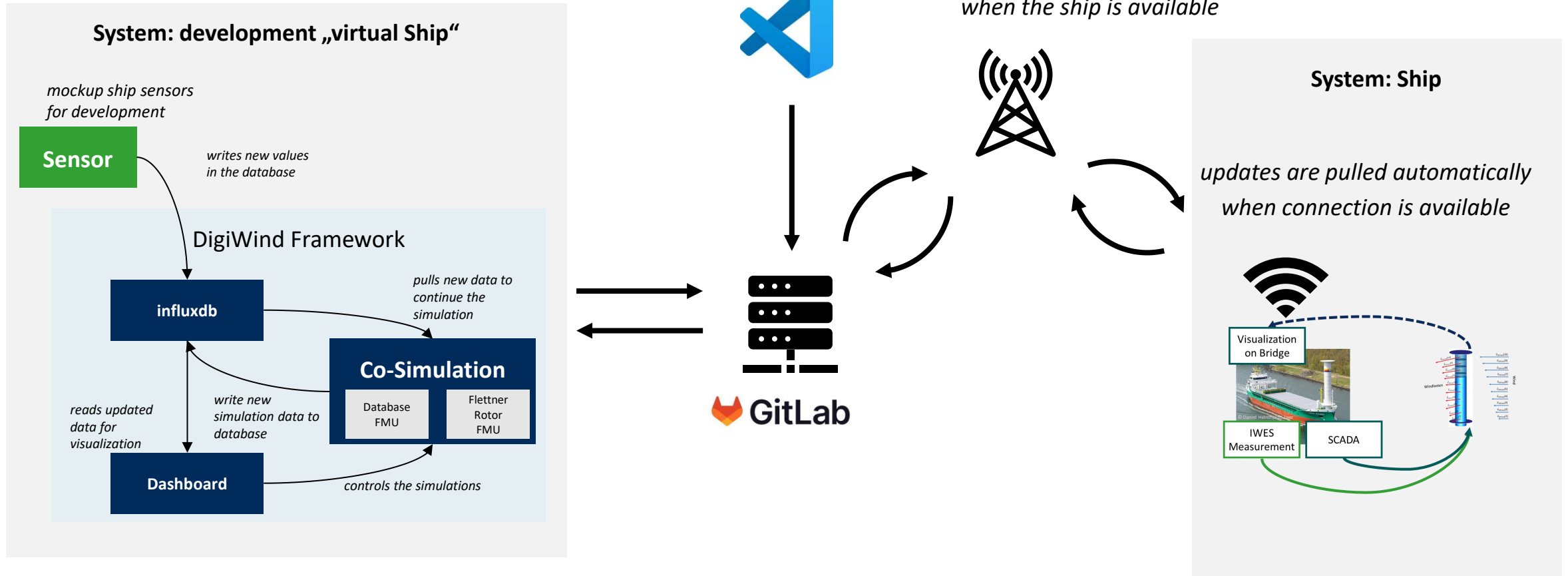


How does it work?

- Computer on the ship running multiple services
- Database for measurement and simulation data storage
- Dashboard for system interaction and visualization



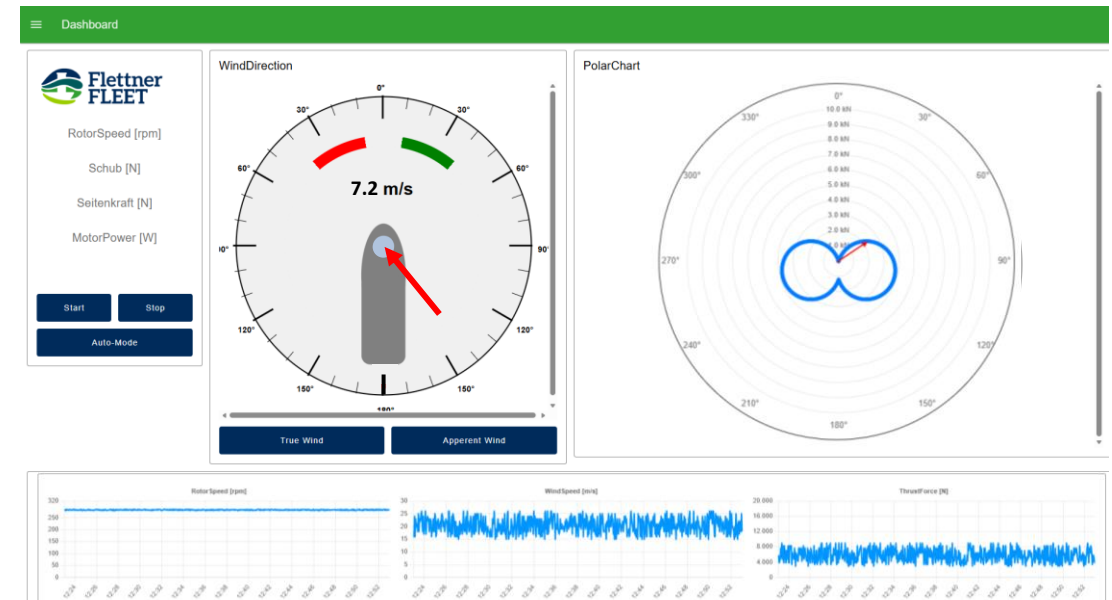
Twin for the development



Dashboard as the controller

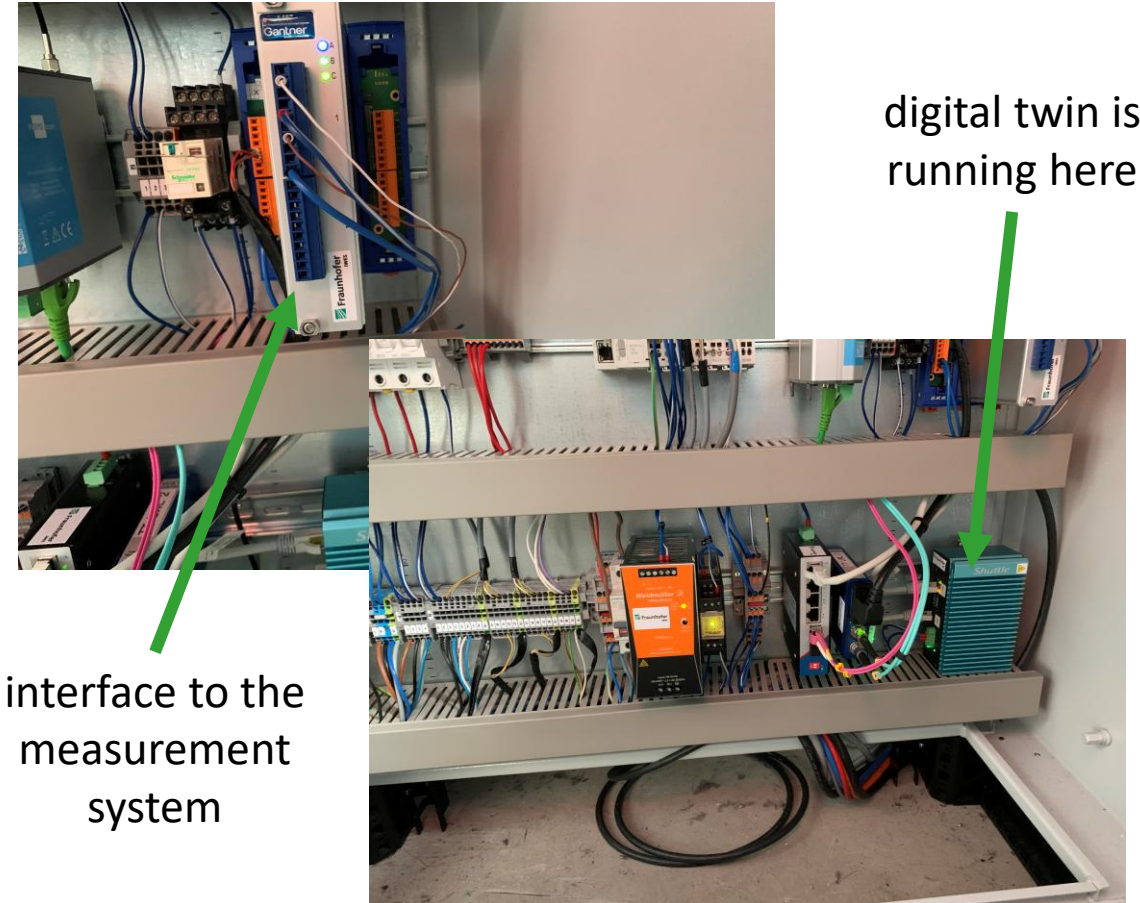


- Wind direction visualization
- Polar curve estimation
 - Indicates potential operating points
 - Calculated by vector rotation
- Time series plots of wind and thrust force
- Simulation control
- Currently only accessible remotely



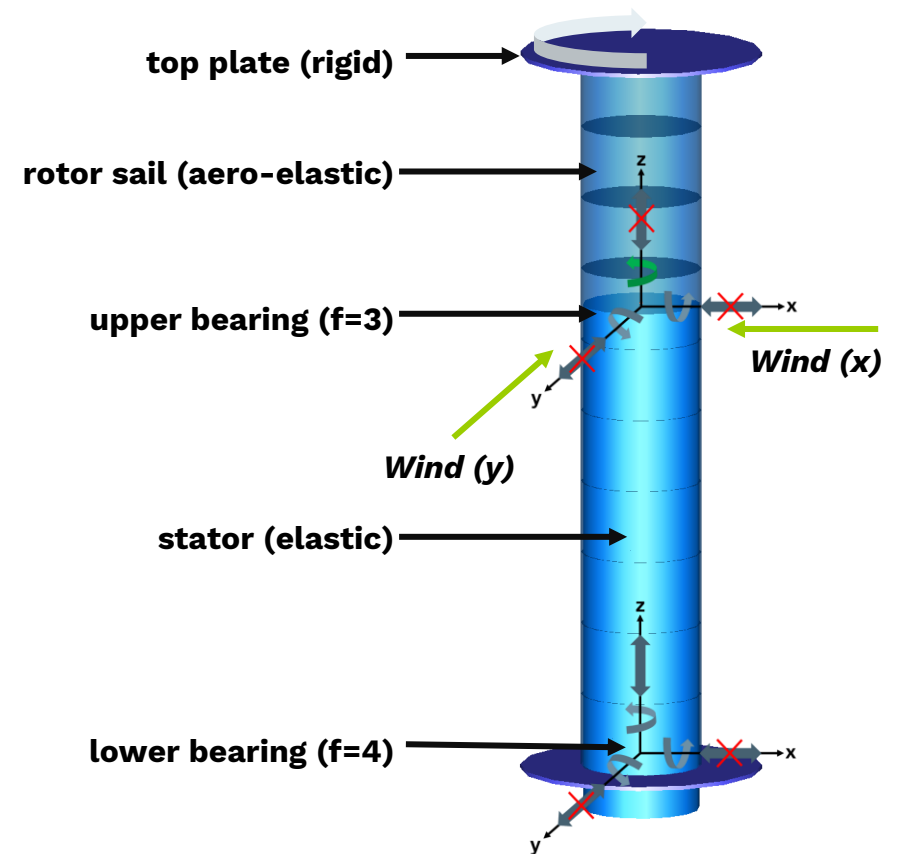
Installation the ship

- Currently, only computing hardware is installed
- On the next opportunity, we will install a monitor for the crew



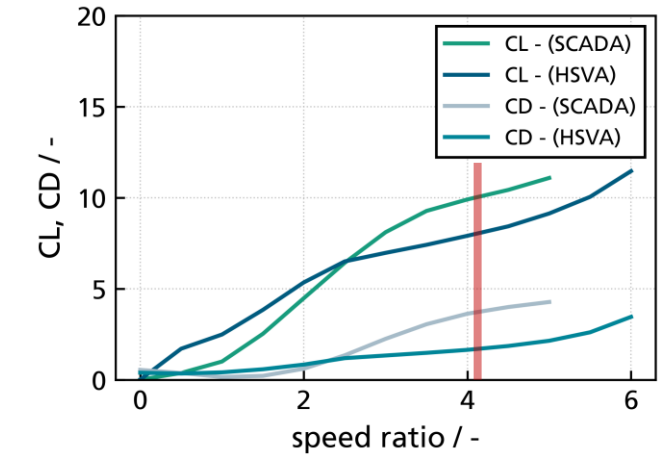
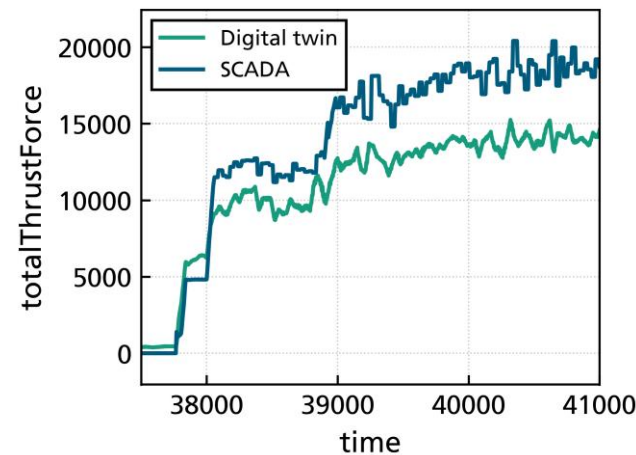
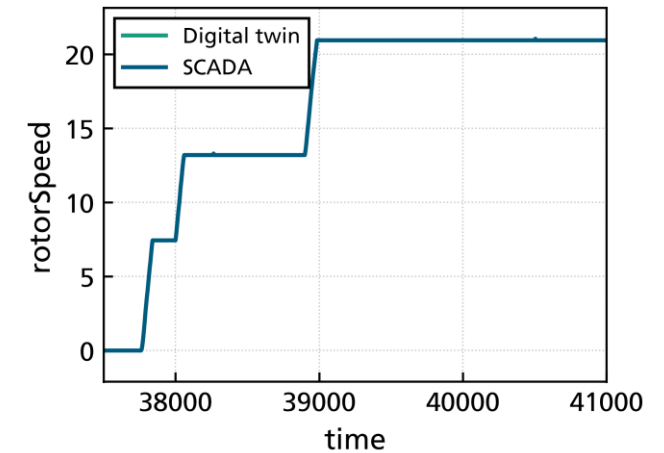
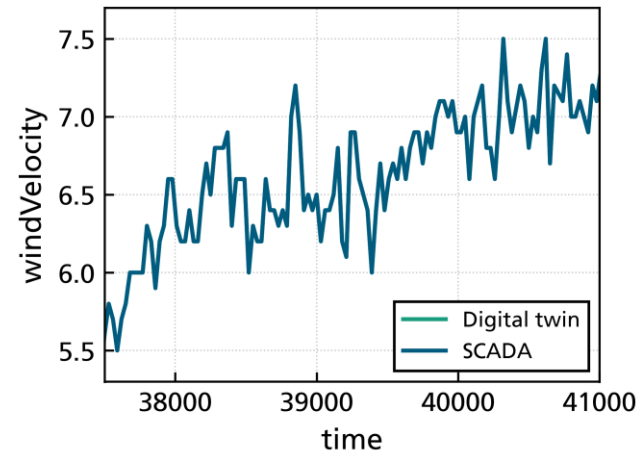
Simulation model as the backbone

- Modelica model of the Flettner Rotor
 - Not just a C_l/C_d curve
 - Developed at the beginning of this project
 - Dynamic multi-body model
 - Mechanical loads and vibrations
- Simulation run live on the ship
- Interface to the wind measurement
- Estimate thrust forces and mechanical loads



Digital twin vs. SCADA

- SCADA system predicts a thrust force
- Our DT uses CL/CD from HSVA
- Differences in thrust force prediction

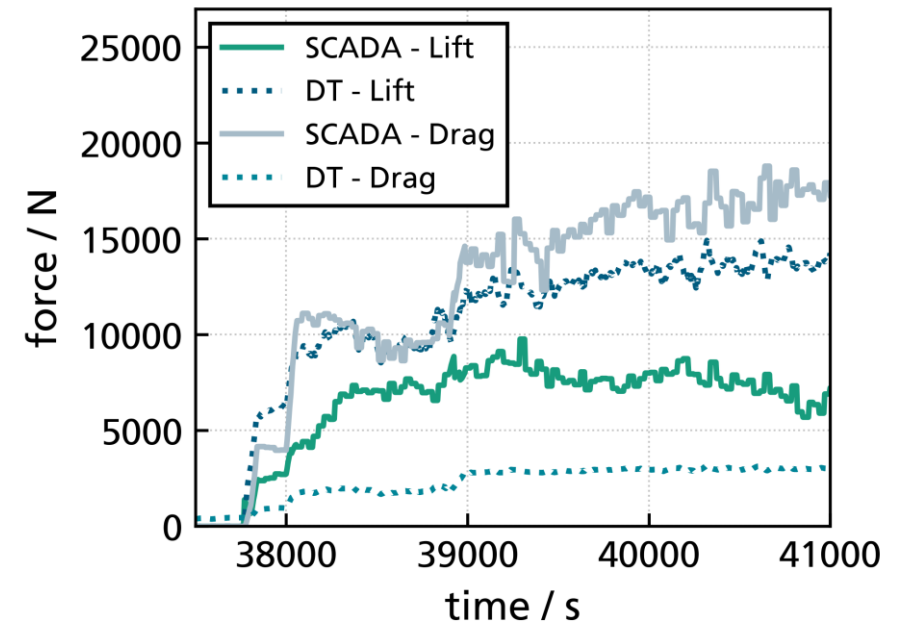
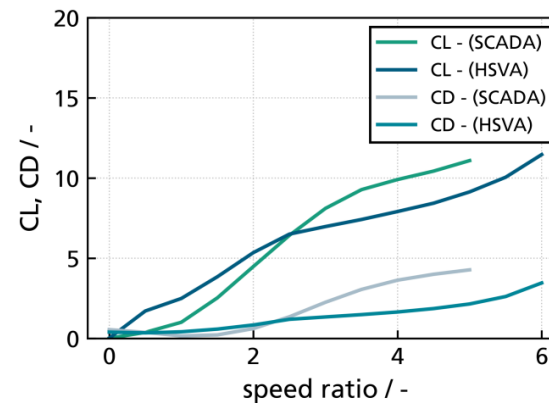


Digital twin vs. SCADA

- Analysis showed that the labels for lift and drag are switched
- CL usually higher than CD
- Lift force should be greater than drag force

$$F_L = C_L(SR) \frac{\rho}{2} A V_{app}^2$$

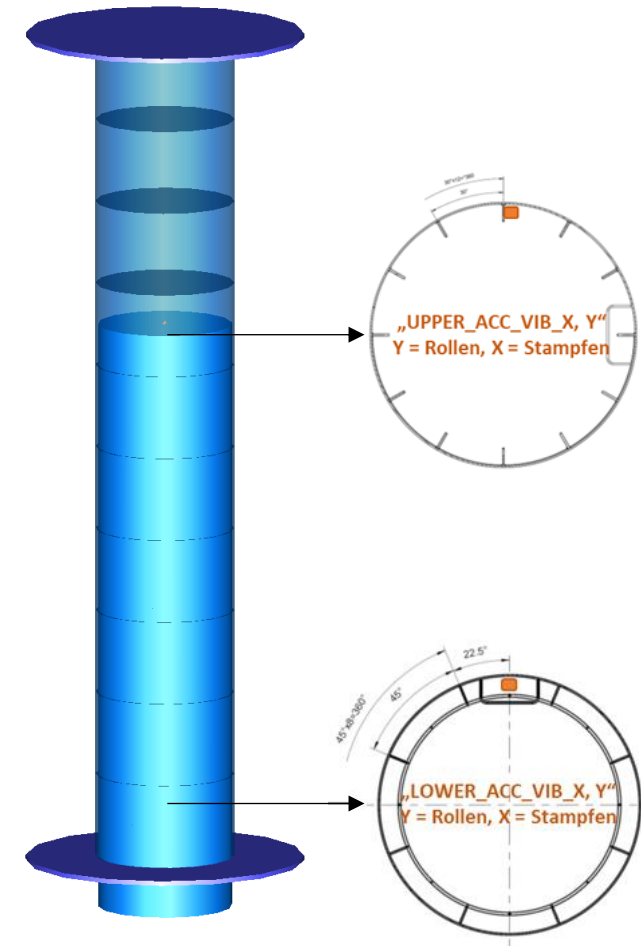
$$F_D = C_D(SR) \frac{\rho}{2} A V_{app}^2$$



Model validation

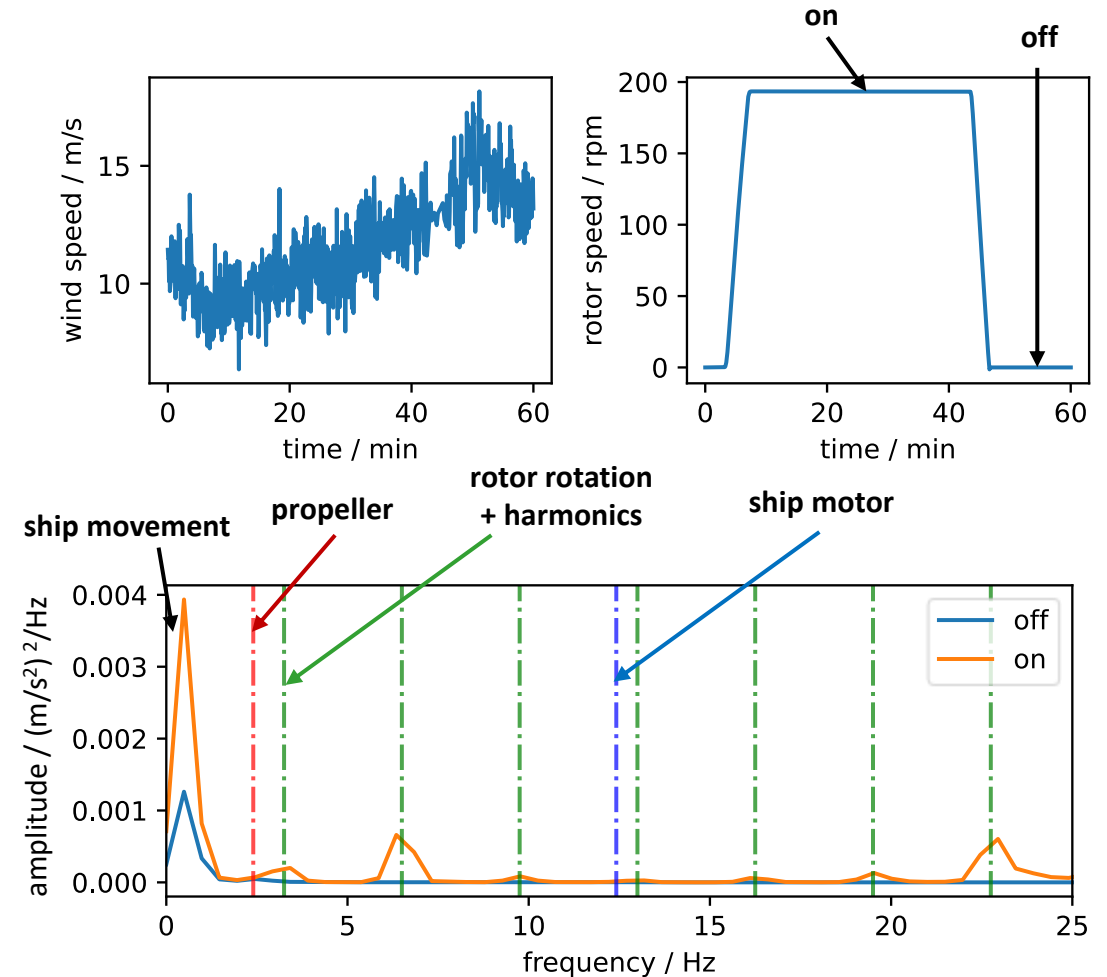
Measurement of rotor vibration

- Measurement system from IWES on the ship
- Acceleration sensors at the top and bottom of the stator
- Lidar sensor for wind conditions



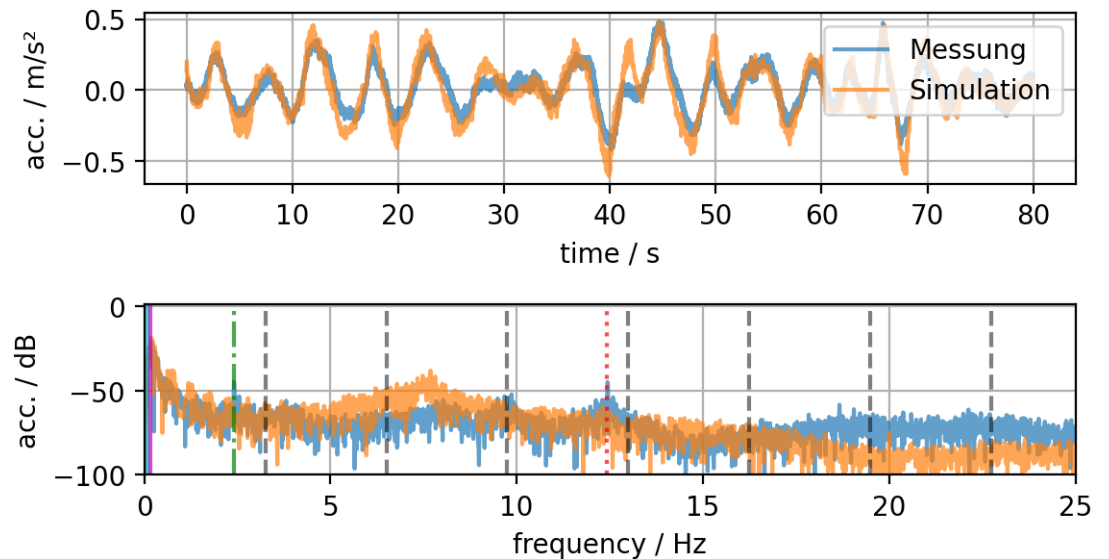
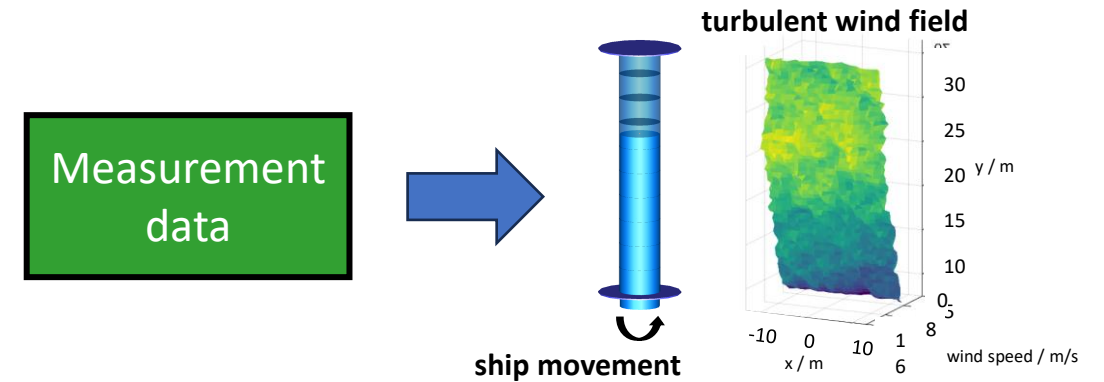
Frequency analysis

- Expected rotor structural frequency at 4.6 Hz
- Not visible in the measurements
- Measurements dominated by ship movement and rotation speed harmonics



Adjustment of structural parameters

- Matched simulation setup
 - Wind conditions
 - Ship movement
 - Rotor speed
- Adjust model stiffness to align with vibration measurement
- Final results will be in the project report



Summary

- Successfully installed a digital twin on the Annika Braren
- Remote development cycle
- Continuously monitoring the Flettner Rotor performance
- Digital twin platform as the basis for future developments





Vielen Dank für Ihre
Aufmerksamkeit!

Kontakt

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