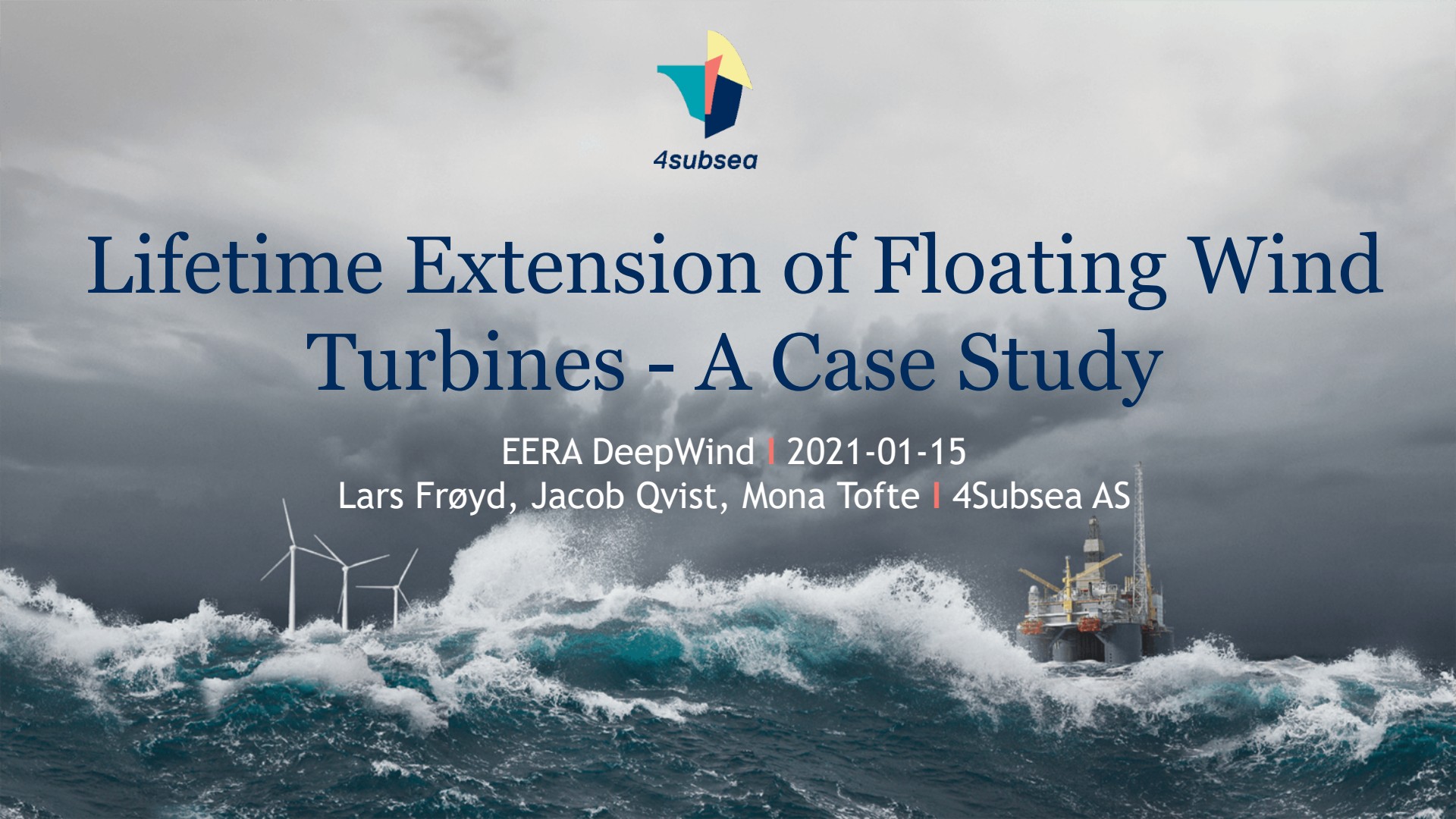

Lifetime Extension of Floating Wind Turbines - A Case Study

EERA DeepWind | 2021-01-15

Lars Frøyd, Jacob Qvist, Mona Tofte | 4Subsea AS

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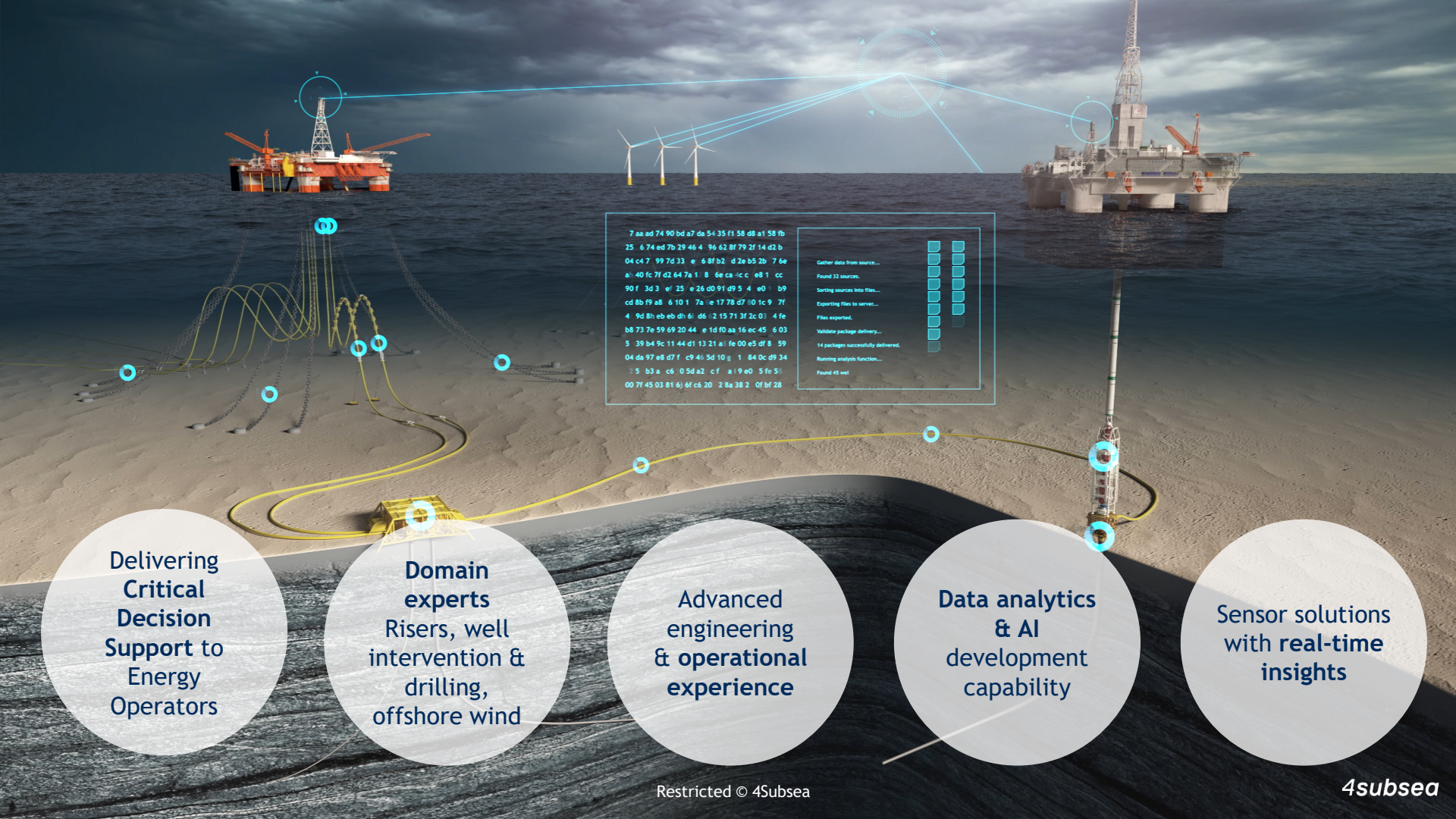
 # People
80

 # Offices
6

Founded in
2007

Global market reach

Delivering Critical Decision Support to Energy Operators



Delivering **Critical Decision Support** to Energy Operators

Domain experts Risers, well intervention & drilling, offshore wind

Advanced engineering & **operational experience**

Data analytics & AI development capability

Sensor solutions with **real-time insights**

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A bit of background

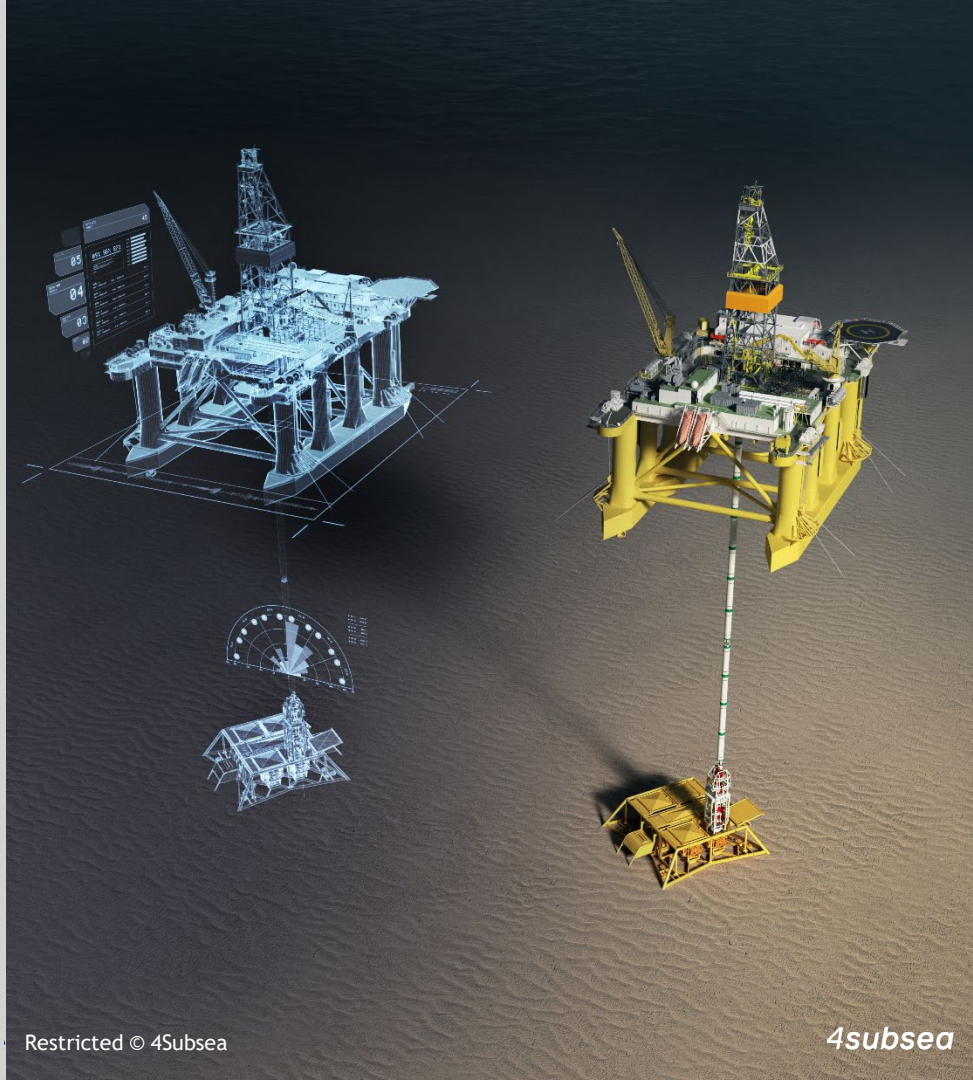
Offshore wind engineering

- “Pioneers” in FOWT coupled analysis
- **Hywind Scotland** coupled analysis, design support, and cable analysis (Concept, FEED, Detailed design)
- **Hywind Tampen** coupled analysis, mooring design, and cable analysis (Concept, FEED, Detailed design)
- Several **concept studies** (Semi, SPAR)
- Several **bottom fixed** cable dynamics and cable protection studies

A bit of background

Monitoring and asset management

- Subsea well / rig monitoring
  - Strain, motions, well integrity, operational decision support
  - > 3000 campaign days pr year
- Monitoring of Subsea7 vessel fleet
  - Motions, weather window optimization
  - Operational on 4 vessels (so far)
- 4insight - Asset management/analytics
  - > 200 external users
  - > 2000 subsea assets (risers, wells)
- Monitoring of Lista onshore wind farm
  - Lifetime extension pilot



Why lifetime extension

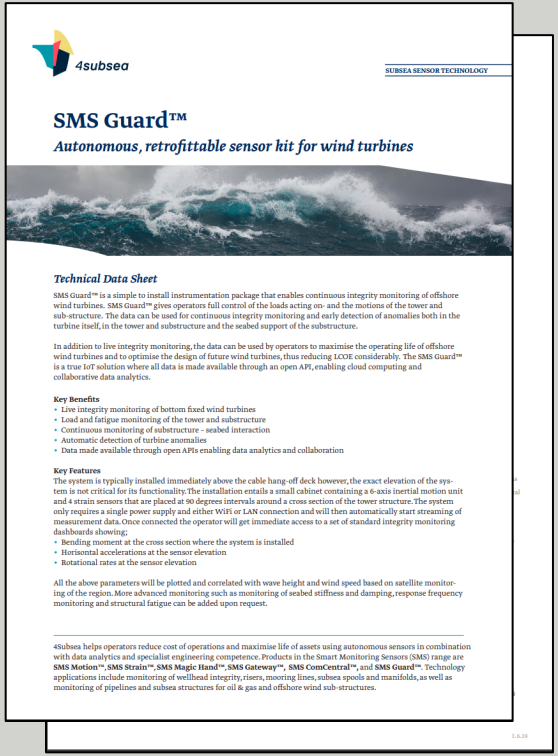
- Actual asset long-term loads will deviate from design assumptions
- In either case (more loads/less loads) there is economic incentive for optimization of asset operation to meet or exceed design lifetime
- In case of more loads: Mitigating actions to reduce loss
  - Insurance claims (?), controller tuning, selective turbine derating, etc.
- In case of less loads: Potential lifetime extension to increase yield
  - Requires documentation, certification (?), regulations, permits, insurance, etc.
- Direct monitoring of loads and motions is basis for either path

Case study: Zefyros

- Pilot measurement campaign at Zefyros (Hywind Demo)
  - Test of sensor kit for offshore wind application
    - Sensors repurposed from subsea well and vessel monitoring
  - Test of operational support service (live data access / dashboards)
  - Test of lifetime extension service (strain measurement and prediction)
  - Digital twin for floating wind (damage extrapolation / other locations)
  - Practical campaign limits (duration and quality of prediction)
  - Validation and general understanding of floating wind turbine behaviour
- Ongoing since April 2020

Equipment

- 4Subsea SMS Guard kit with
  - 4 x SMS Strain sensors (retrofit, magnetic attachment)
    - 10 Hz, +/- 2700 µStrain range, <0.5 µStrain resolution
  - 1 x SMS Gateway
    - Processing and Communication unit
    - 6-DoF Motion sensor (accelerations / gyro)
    - Pressure and temperature sensor
    - 10 Hz – 125 Hz
- In-house developed and fully commercialized
- Designed for reliability and ease of installation
  - Installation by operators own personnel on a single visit
  - Requires only electrical connection and LAN/WiFi



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SUBSEA SENSOR TECHNOLOGY

SMS Guard™

Autonomous, retrofittable sensor kit for wind turbines

Technical Data Sheet

SMS Guard™ is a simple to install instrumentation package that enables continuous integrity monitoring of offshore wind turbines. SMS Guard™ gives operators full control of the loads acting on- and the motions of the tower and sub-structure. The data can be used for continuous integrity monitoring and early detection of anomalies both in the turbine itself, in the tower and substructure and the seabed support of the substructure.

In addition to live integrity monitoring, the data can be used by operators to maximise the operating life of offshore wind turbines and to optimise the design of future wind turbines, thus reducing LCOE considerably. The SMS Guard™ is a true IoT solution where all data is made available through an open API, enabling cloud computing and collaborative data analytics.

Key Benefits

- Live integrity monitoring of bottom fixed wind turbines
- Load and fatigue monitoring of the tower and substructure
- Continuous monitoring of substructure - seabed interaction
- Automatic detection of turbine anomalies
- Data made available through open APIs enabling data analytics and collaboration

Key Features

The system is typically installed immediately above the cable hang-off deck however, the exact elevation of the system is not critical for its functionality. The installation entails a small cabinet containing a 6-axis inertial motion unit and 4 strain sensors that are placed at 90 degrees intervals around a cross section of the tower structure. The system only requires a single power supply and either WiFi or LAN connection and will then automatically start streaming of measurement data. Once connected the operator will get immediate access to a set of standard integrity monitoring dashboards showing;

- Bending moment at the cross section where the system is installed
- Horisontal accelerations at the sensor elevation
- Rotational rates at the sensor elevation

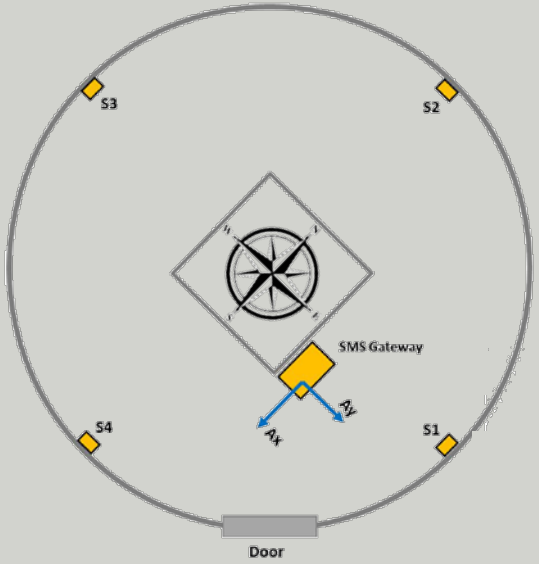
All the above parameters will be plotted and correlated with wave height and wind speed based on satellite monitoring of the region. More advanced monitoring such as monitoring of seabed stiffness and damping, response frequency monitoring and structural fatigue can be added upon request.

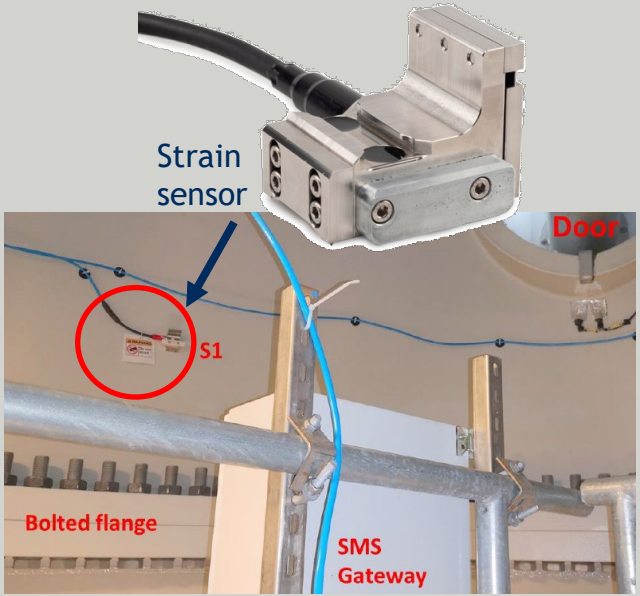
4Subsea helps operators reduce cost of operations and maximise life of assets using autonomous sensors in combination with data analytics and specialist engineering competence. Products in the Smart Monitoring Sensors (SMS) range are **SMS Motion™**, **SMS Strain™**, **SMS Magic Hand™**, **SMS Gateway™**, **SMS ComCentral™**, and **SMS Guard™**. Technology applications include monitoring of wellhead integrity, risers, mooring lines, subsea spools and manifolds, as well as monitoring of pipelines and subsea structures for oil & gas and offshore wind sub-structures.

Link: https://www.4subsea.com/wp-content/uploads/2019/06/SIM_SMS-Guard_data-sheet-I.6.19.pdf

Measurement setup

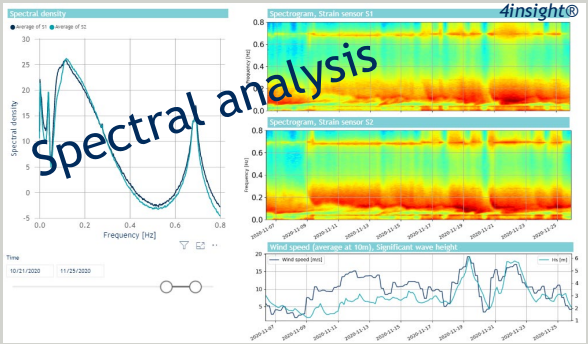
- Sensor kit located with easy access near flange

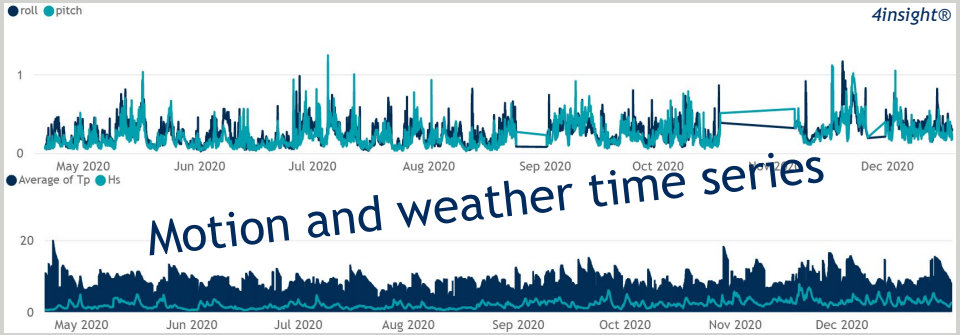


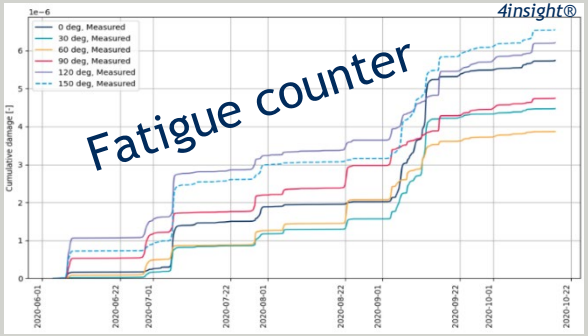


Data analytics

- SMS Gateway online with data link
- “Live” dashboards on 4insight.io
- Motions and weather, spectral analysis, cumulative damage calculation, etc.







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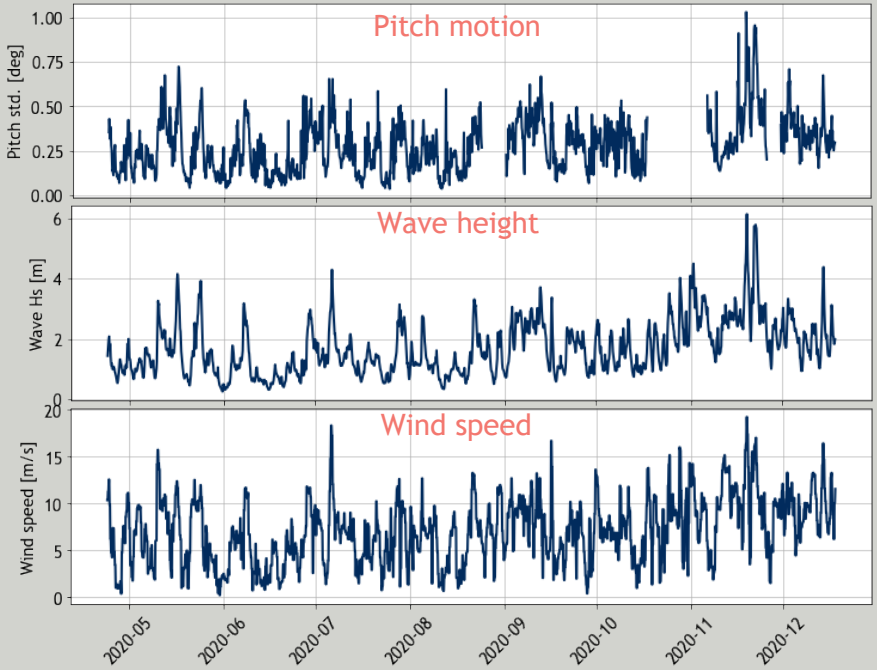
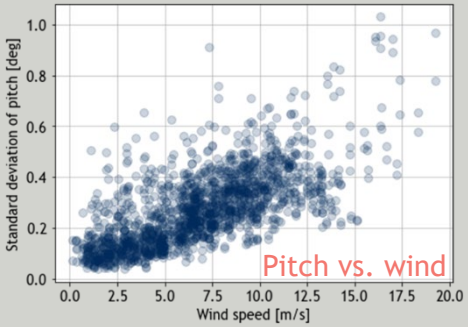
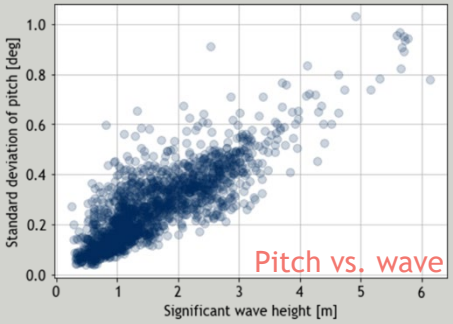
Measured results

Motion vs. wind and wave

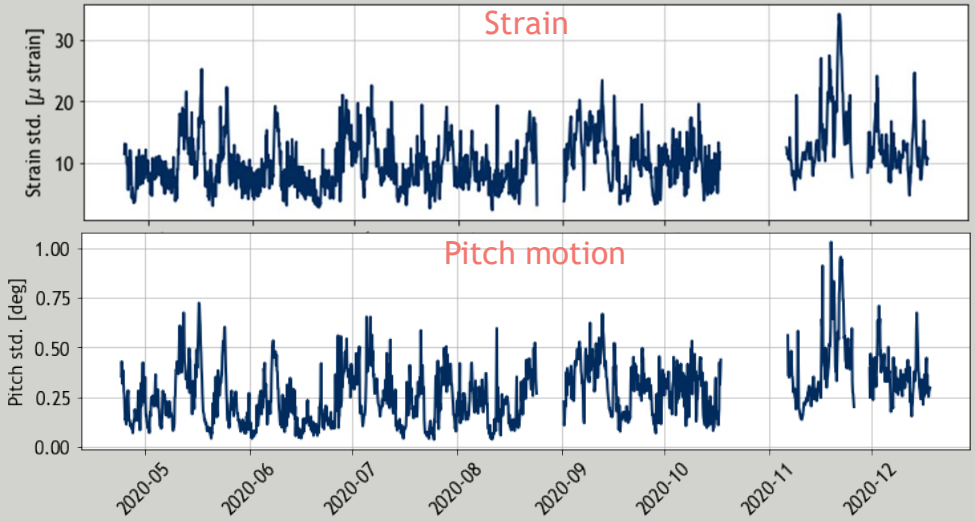


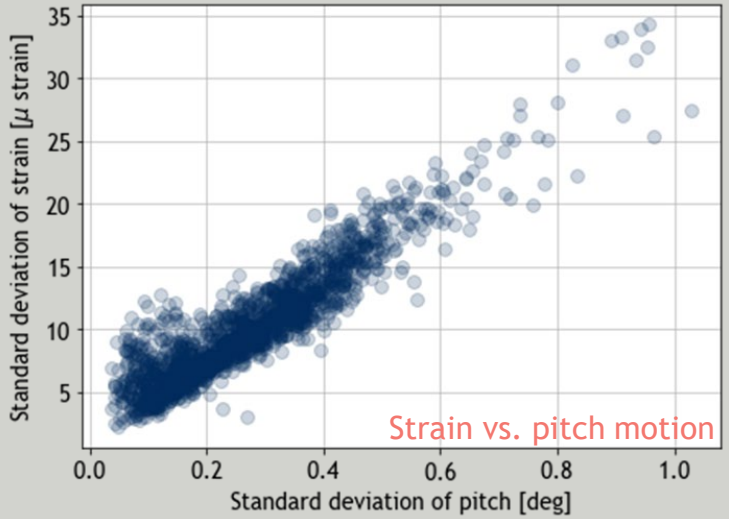




Measured results

Strain vs. motion





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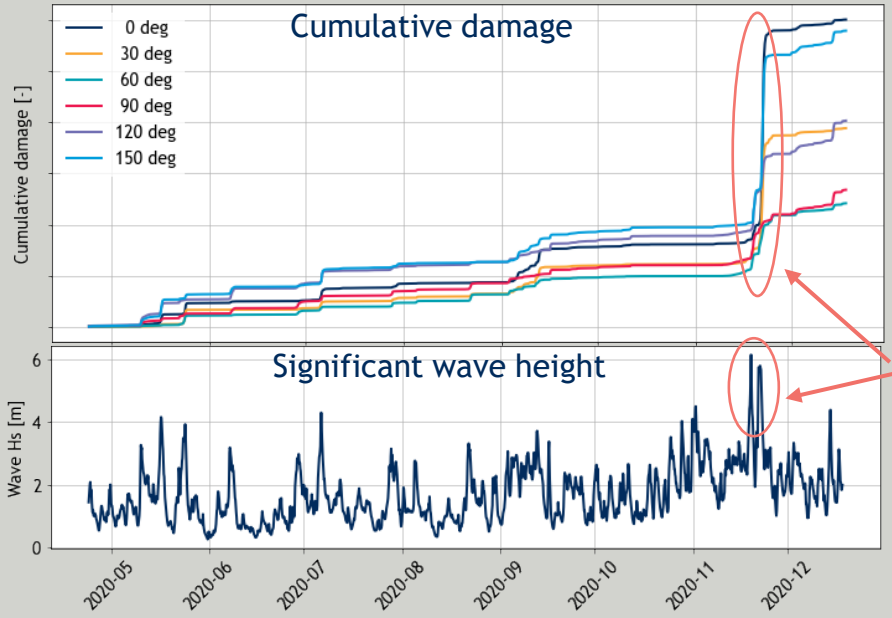
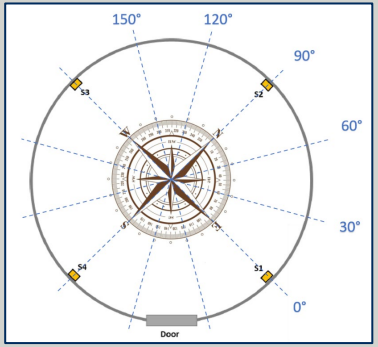
Calculated damage

Cumulative damage vs. wave height



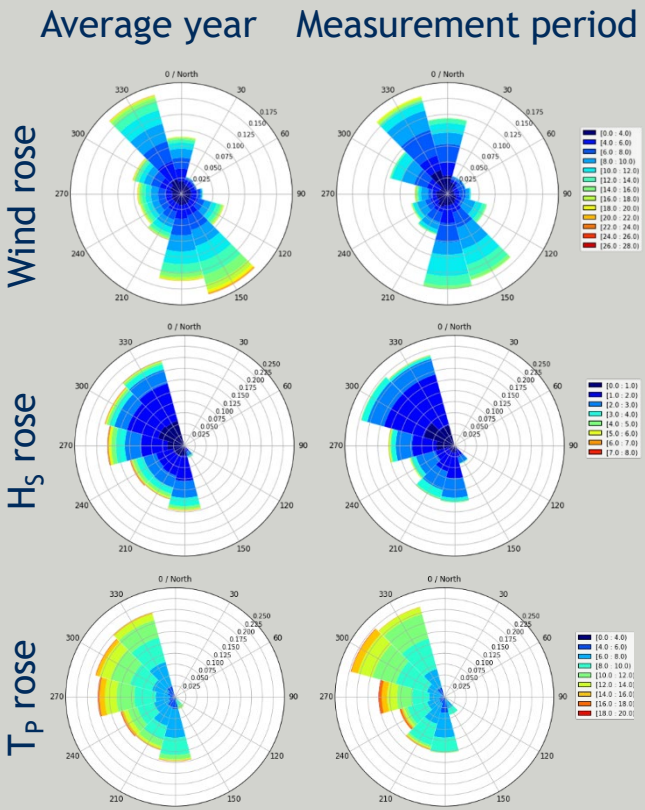


Large damage from a few severe weather events

Weather

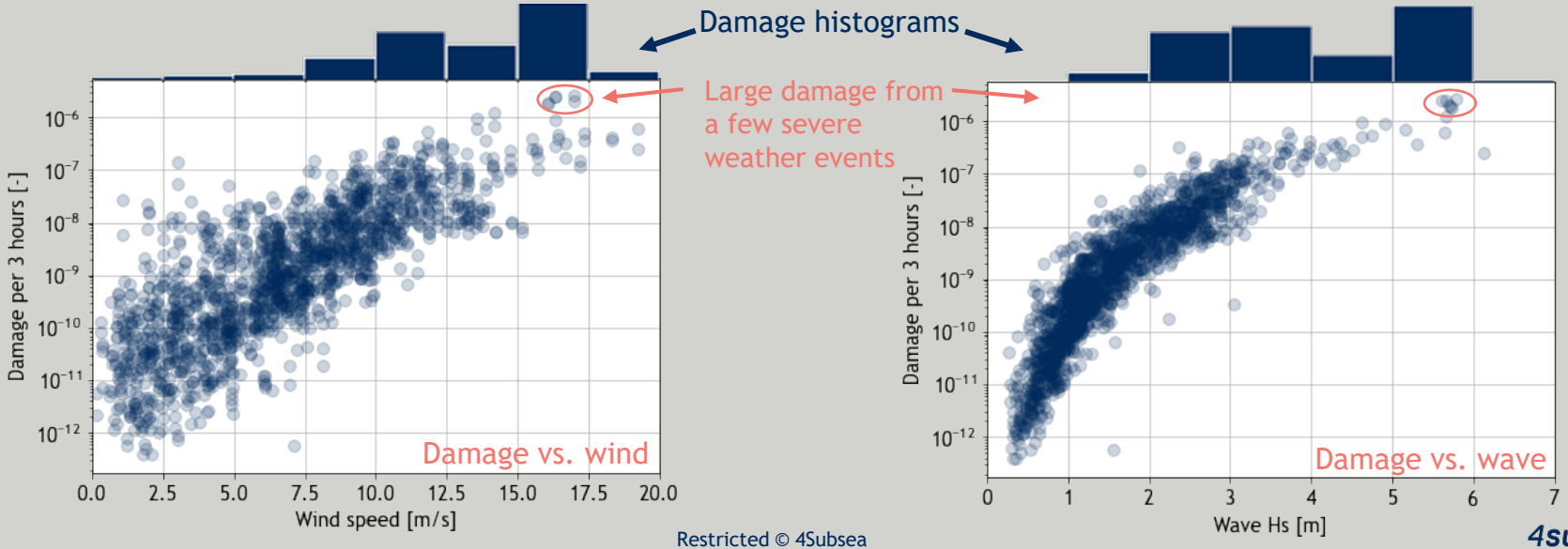
Measurement period vs. average year

- Similar directional distributions
- However, lacking severe weather
  - Measurement period is not including January and February, normally the months with worst weather
- Expect good measurements and prediction models from relatively short campaign (1-2 years)



Fatigue correlation

- Strong correlation with wave height – promising for machine learning
- Uncertainty due to limited number of severe weather events



Lifetime estimates

Direct damage calculation and extrapolation

- Lifetime estimates uncertain due to importance of severe events
- Direct extrapolation based on measured period > 1000 years life
- Improved estimates to be made based on machine learning methods when more data is available

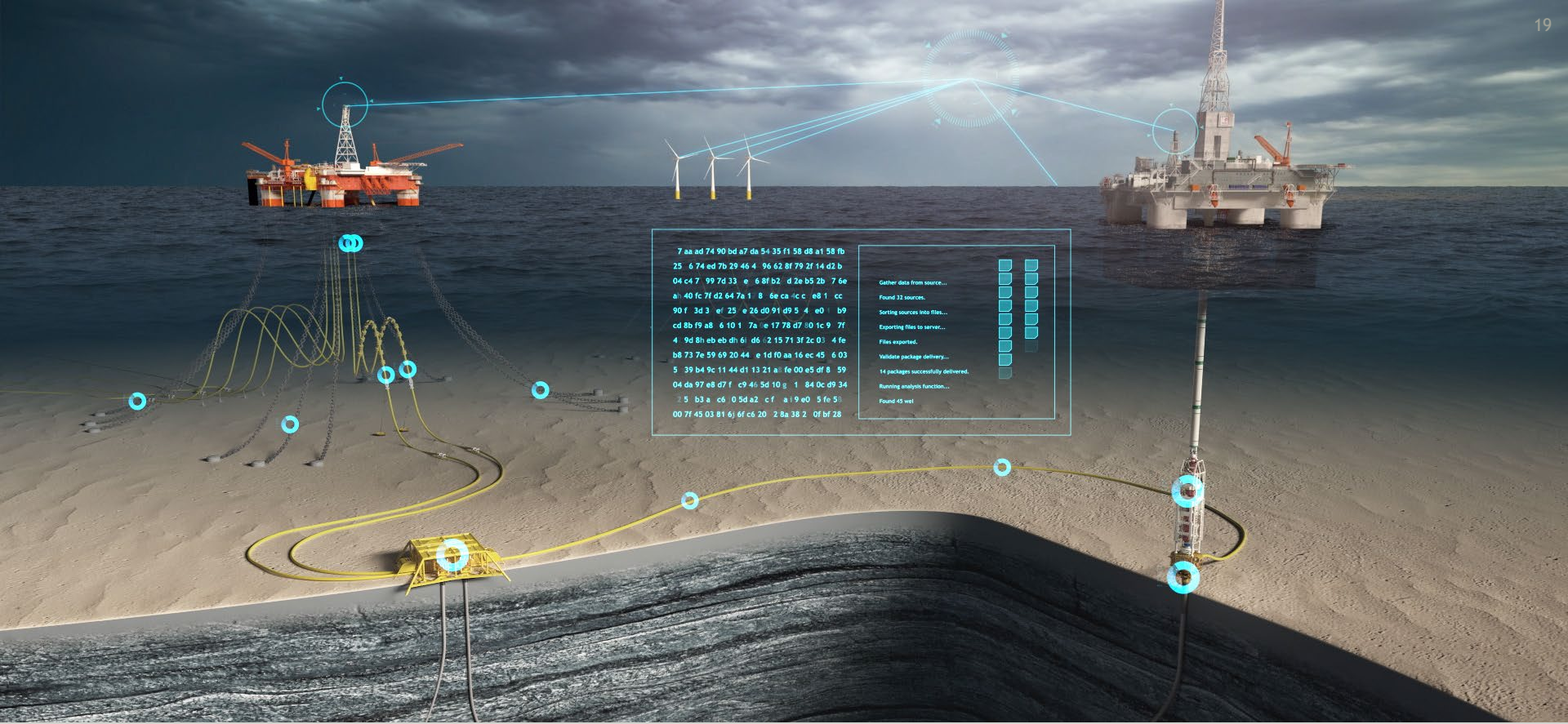
Further work

Continuation of Zefyros campaign and beyond

- Improvements from higher resolution wind and wave data?
  - E.g., 1-hour wind and wave hindcast and high resolution (1Hz?) wind data from SCADA
- Machine learning (ML) models for damage prediction (historic/future)
  - Requires more severe weather data for model training
- Digital twin (DT) for damage prediciton at other locations than flange
  - And several other potential use cases for such model
- Mooring lines? No sensor data available at Zefyros, retrofit is complicated
  - Other turbines where this is available?
- Park management => how many turbines should be monitored?

Acknowledgements

Thanks to Unitech for kindly granting access to Zefyros for this pilot project



Thank you.

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