International RAVE Workshop 2024: Load estimation using SCADA data for wind turbine blades

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Industrial CDT in Offshore Renewable Energy (IDCORE)

- Probabilistic structural integrity assessment of offshore wind turbine rotor blades for lifetime extension
- EPSRC and NERC funded industrial CDT for offshore renewable energy (IDCORE)
- University of Edinburgh, Exeter, Strathclyde, and the Scottish association for marine science (SAMS)
- Frazer-Nash Consultancy are sponsoring the EngD project

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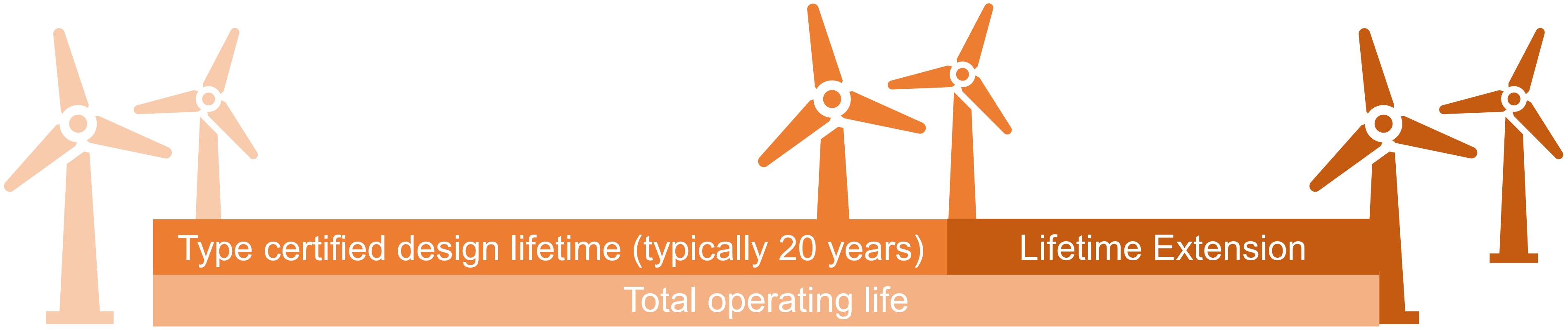
Lifetime Extension of Offshore Wind Turbines

- ORE Catapult estimate around 600 offshore WTs reaching end of life (EoL) by 2030 (in UK) [1]
- UK net zero targets 50 GW of offshore wind deployment by 2030 [2]
- Probabilistic methods to better understand uncertainties associated with RUL assessments



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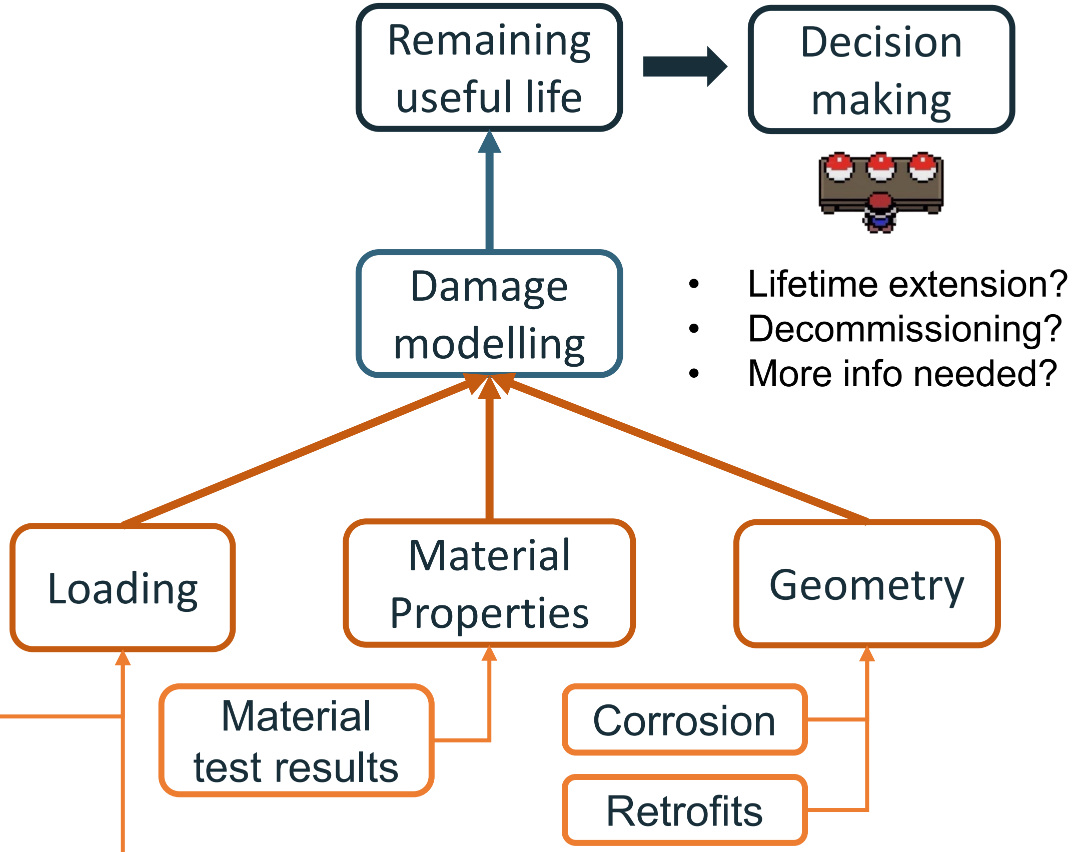
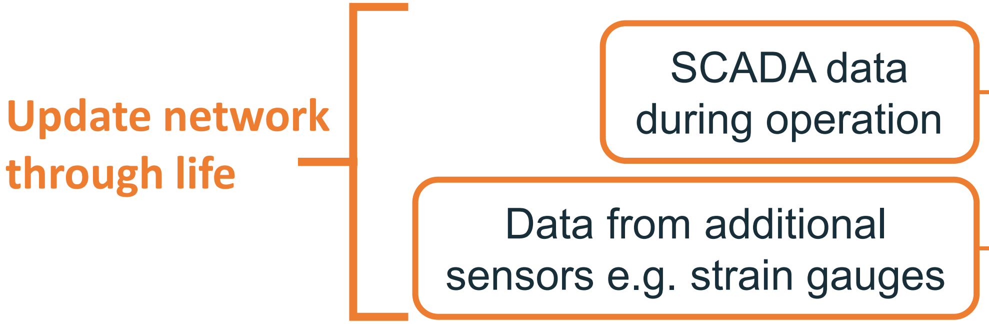
Probabilistic modelling with Bayesian networks (BNs)

- Bayes theorem:

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}$$

- Advantages of BNs:
  - Variables represented as uncertain probability distributions
  - Work well with very limited data
  - Uses prior beliefs which can be updated through time





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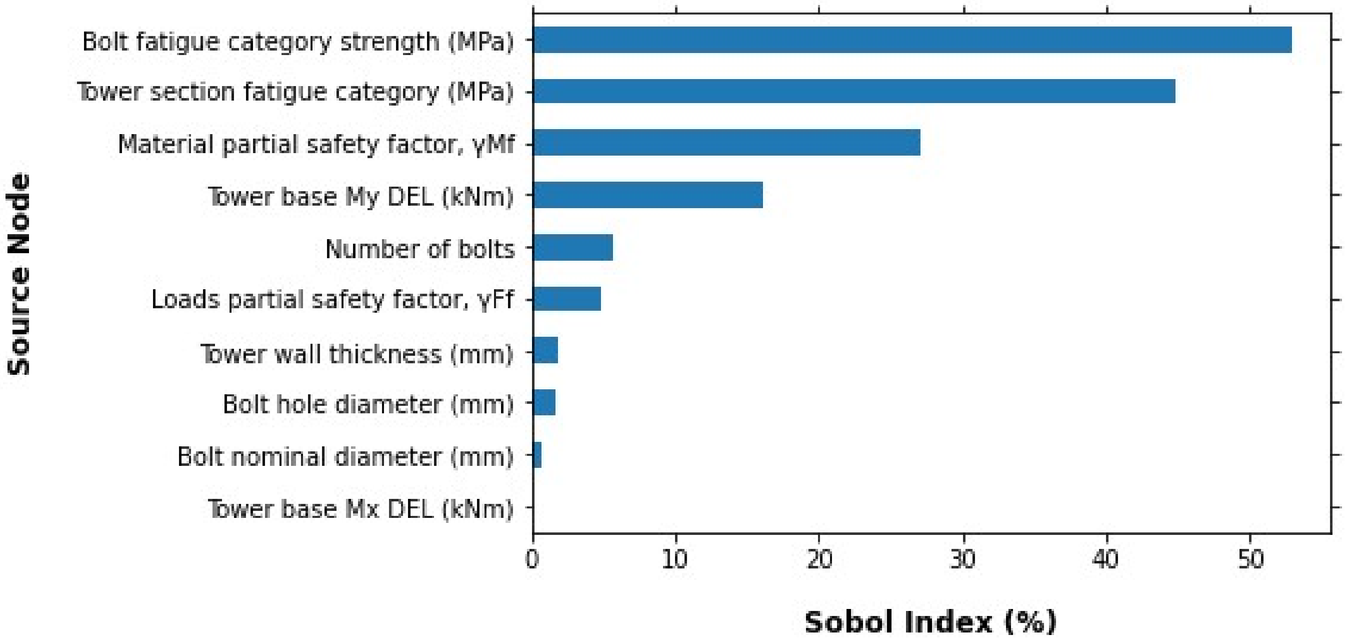
Sensitivity Analysis

Sobol Variance Analysis

- Sobol indices can be used to highlight which parameters contribute the most to the uncertainty in the output
- This can be used to identify where to focus effort to increase confidence in the component life assessment, for example through the addition of more data



Higher Sobol index = greater the contribution of that node to result uncertainty

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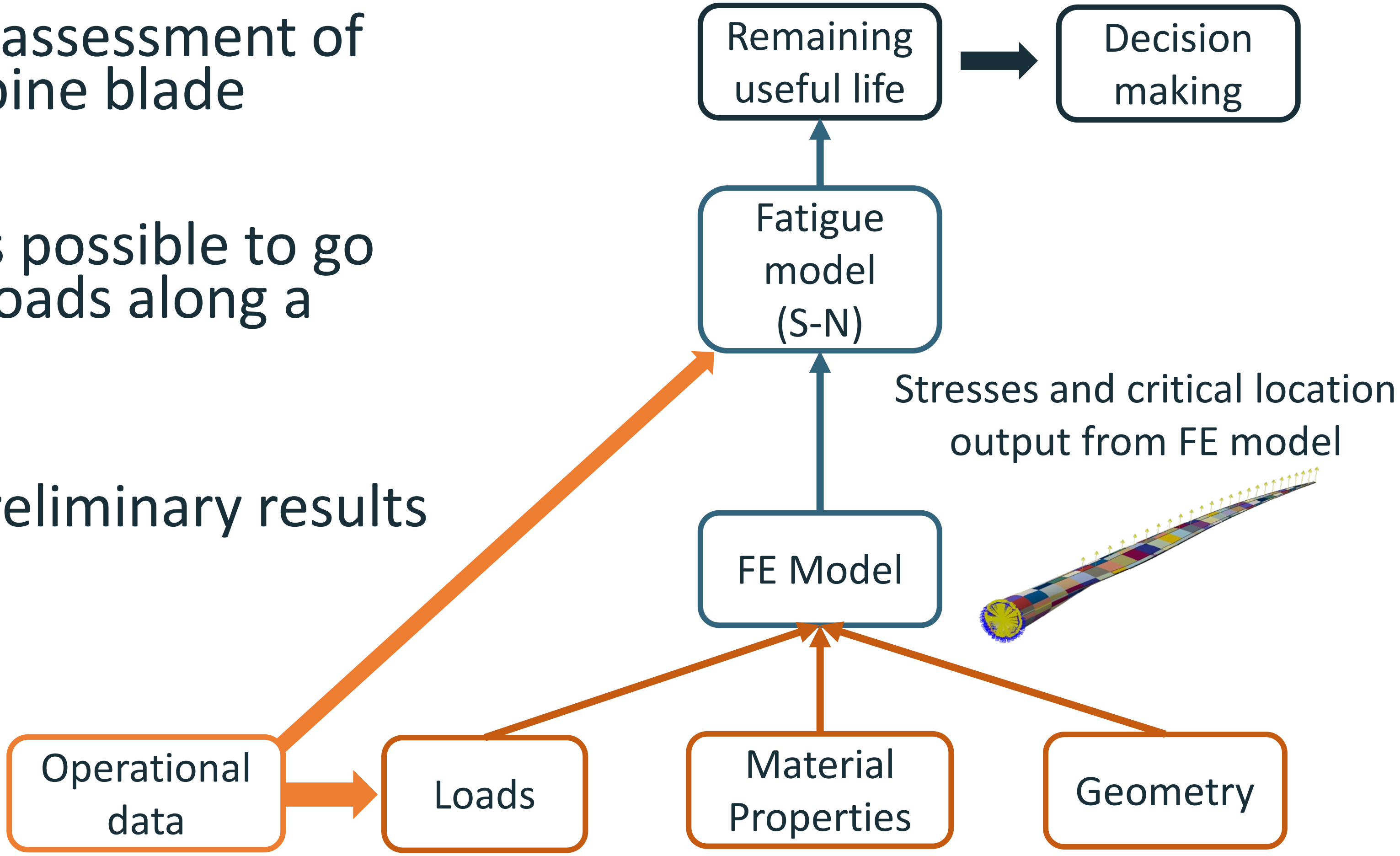
Probabilistic RUL Assessment for Wind Turbine Blades

- Remaining useful life assessment of an offshore wind turbine blade
- Evaluate whether it is possible to go from SCADA data to loads along a wind turbine blade
- Work in progress – preliminary results

➢ Work so far
➢ Results



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Alpha Ventus Data

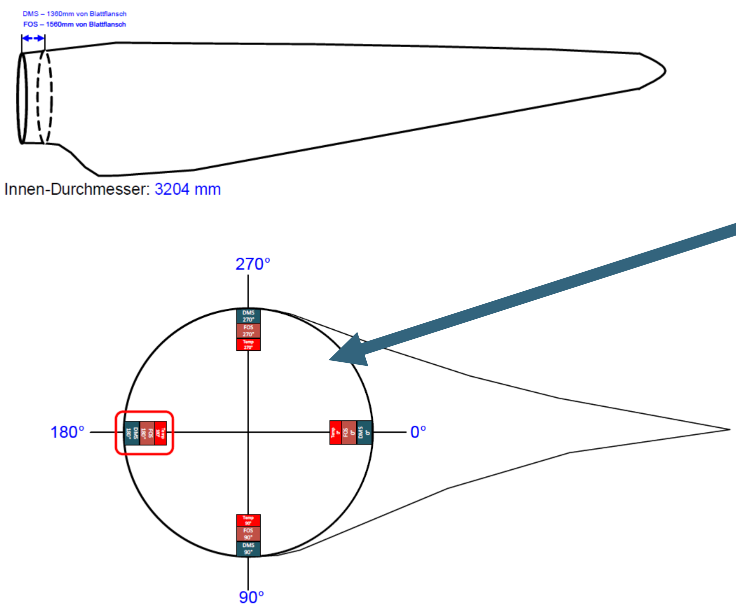
Turbine: **AV4, Senvion 5M**

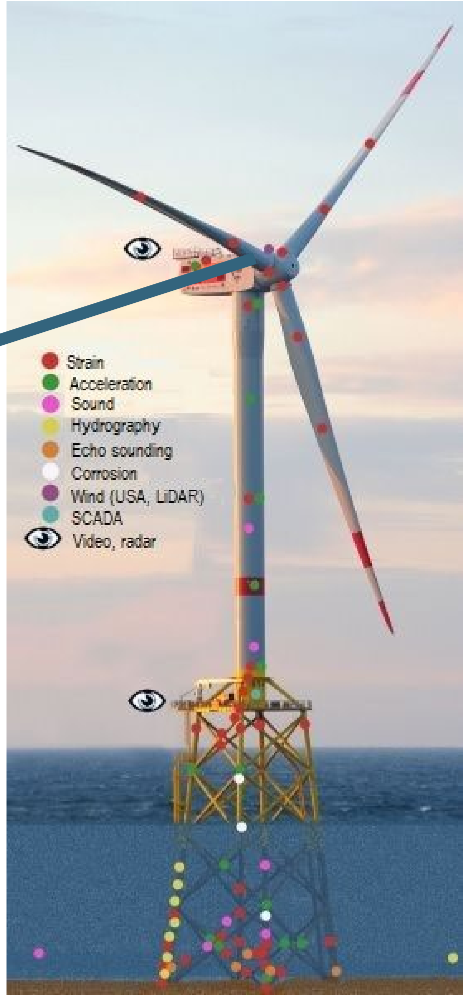
Where: **Blade root**

Sensors: **Strain gauges and "SCADA"**

- AV-04_Nacelle and rotor, hub Blade connection
  - R4_D-B5b1a1 – Rotor blade bending edgewise (kNm)
  - R4_D-B5b1a2 – Rotor blade bending flapwise (kNm)
- AV-04_Nacelle and rotor, nacelle
  - R4_Generatordrehzahl_B4_50Hz (rpm)
  - R4_Pitchwinkel_Ist_B4_50Hz (◦)
  - R4_elektrische_Leistung_B4_50Hz (kW)
  - R4_Windgeschwindigkeit_B4_1Hz (m/s)

Time period: **2020-11-03 – 2023-03-31**





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Load Evaluation: Method

Pre-process data

- Cleaned data by removing any data points not representative of "normal" operation
- Binned data by wind speed
- Calculated mean and standard deviation of wind speed and turbulence intensity within each bin

OpenFAST simulations with NREL 5MW offshore wind turbine model

- 10-min simulated response of wind turbine using mean wind speed within bins
- NREL 5MW offshore wind turbine is the closest model to AV04 turbine

Compare results from OpenFAST to time series from strain gauges

- Compare mean, min, max values for wind speed and blade root bending moments
- Compare DELs calculated from simulated and measured data

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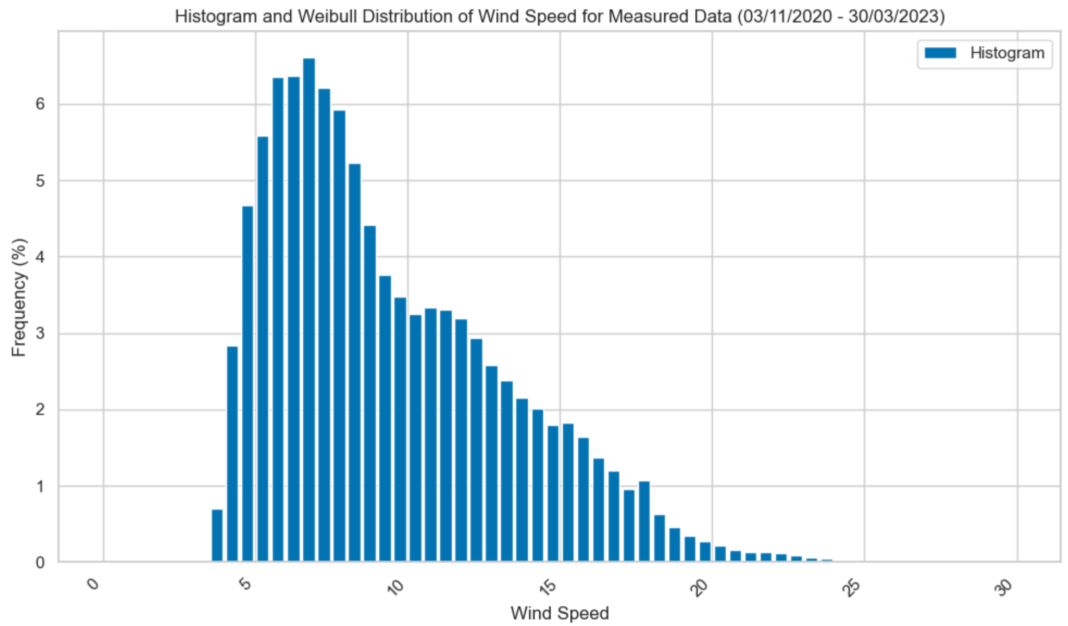

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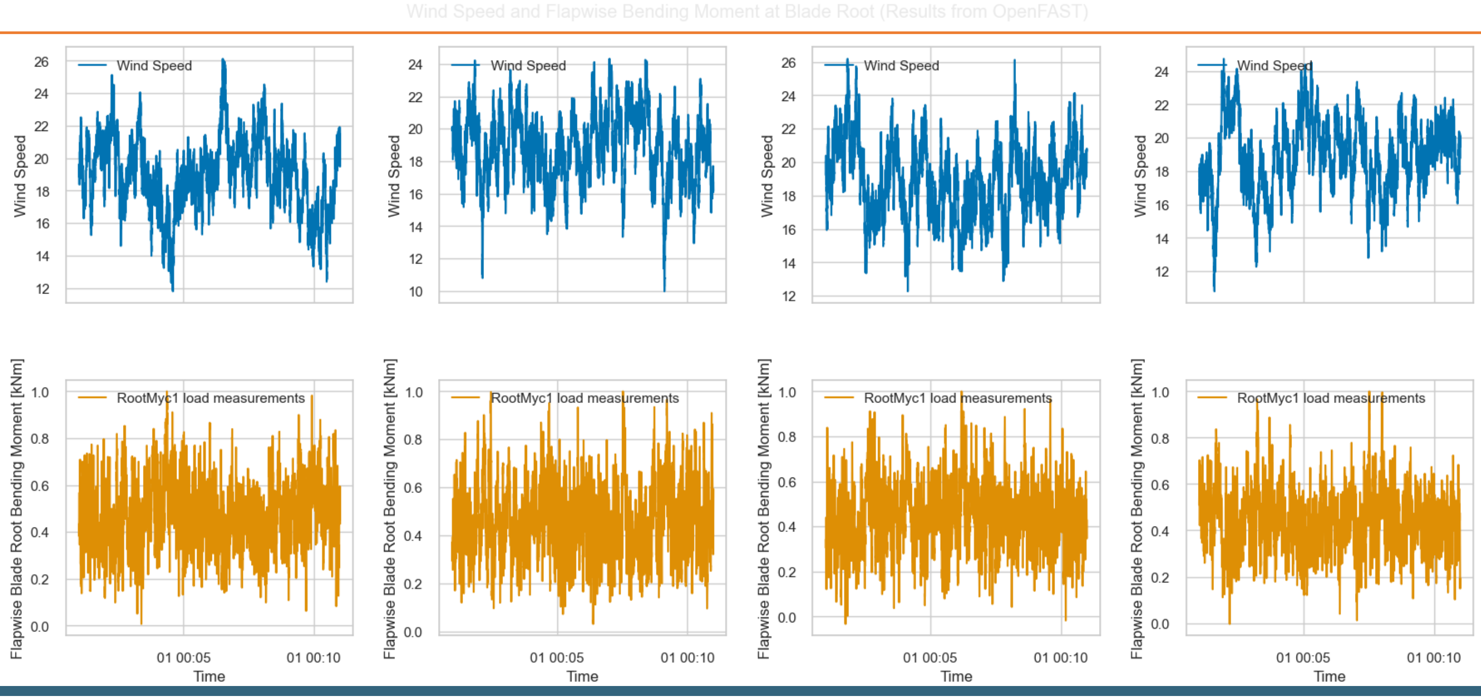
- Mean wind speed: 18.8 m/s
- IEC turbulence class C
- 6 random wind seeds used



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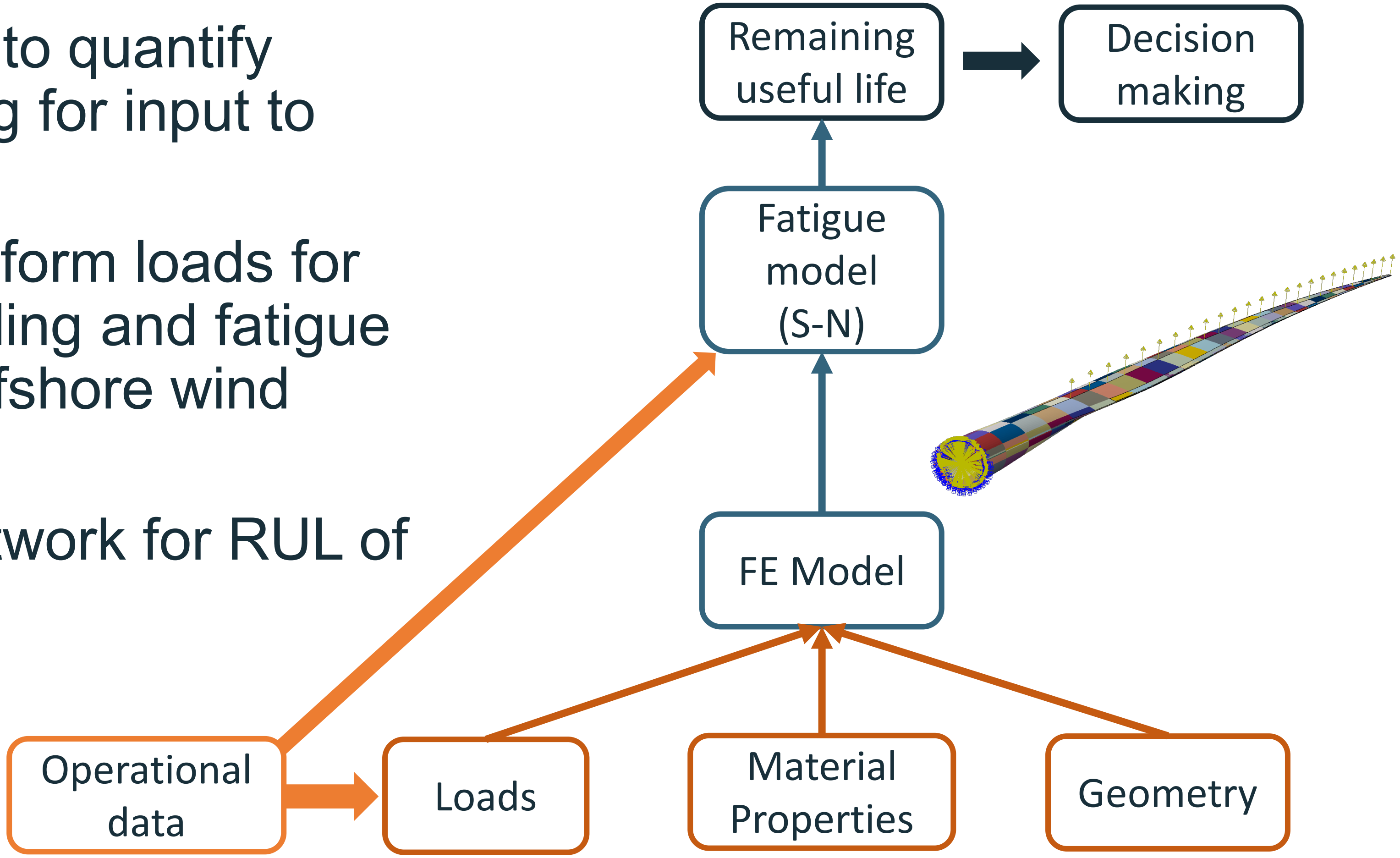
Conclusion and Next Steps

- Results will be used to quantify uncertainty in loading for input to Bayesian network
- Use RAVE data to inform loads for finite element modelling and fatigue assessment of an offshore wind turbine blade
- Build a Bayesian network for RUL of wind turbine blades



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Thank you!

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References

1. Spyroudi, Angeliki. “End-of-life planning in offshore wind.” Tech report. ORE Catapult, Glasgow, UK. 2021.
2. HM Government, “Offshore Wind Net Zero Investment Roadmap.” Tech report. HM Government, UK. 2023.