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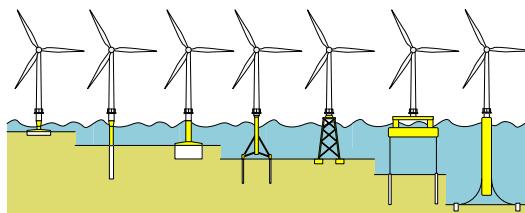


## Wind Europe Bilbao 3 April 2019

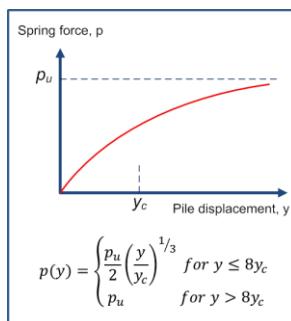
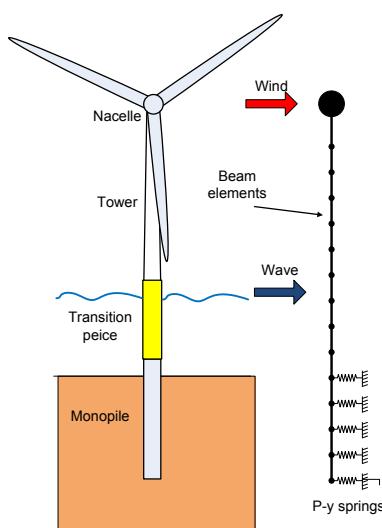


### Integrated Structural and Foundation Monitoring for Offshore Wind Turbines

Byron Byrne and Anela Bajric-Hodzic



### Monopile Design



Simplified soil-structure interaction models allow for the many calculations needed to optimise wind farm foundations



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## PISA Project – 2.5 years and £3.5m

The diagram illustrates the PISA Project workflow. It starts with a 3D Finite Element (FE) model of a wind turbine foundation, which is used for 'Design'. This leads to 'Validate' through 'Field Tests - 2 Test Sites' (shown as two large yellow cylindrical structures in a field). The process then moves to a 'Simplified 1D Model' (represented by two schematic diagrams showing vertical force and moment distributions), followed by 'Apply' to an 'Accurate Response Prediction' graph. The graph plots response height  $H$  (m) against ground displacement  $v_g$  (m), comparing 3D FE (red line), 1D (parametric) (green line), and API/DNV (blue line) models. A vertical dashed line at  $v_g = 0.1D$  indicates the first lateral displacement.

**3D FE**

**Field Tests - 2 Test Sites**

**Simplified 1D Model**

**Accurate Response Prediction**

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## Initiatives from PISA

The diagram highlights several initiatives from the PISA project:

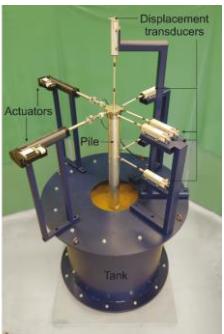
- PISA**: Shows a 3D FE model of a wind turbine foundation and a simplified 1D model.
- Cyclic Modelling**: Compares monotonic (dashed line) and cyclic (solid line) load responses, featuring the **Orsted** logo.
- MoDeTo**: Shows a 3D finite element model of a foundation in soil layers, featuring the **PLAXIS** logo.
- Foundation Scour**: Features the **REMS** (RENEWABLE ENERGY MARINE STRUCTURES) logo and the **e.ON** logo.
- Layered (PISA2) and Other Materials (ALPACA)**: Features the **PISA**, **EPSRC** (Engineering and Physical Sciences Research Council), and **ALPACA** logos.
- Monitoring**: Shows a wind turbine with monitoring equipment, featuring the **PARKWIND** and **Ørsted** logos, and the **EPSRC** logo.

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### Cyclic Loading





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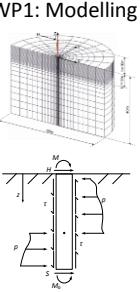


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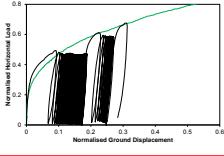


### Oxford-Ørsted Project : 2018 to 2023

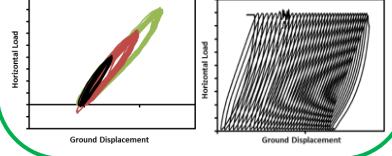
**WP1: Modelling**



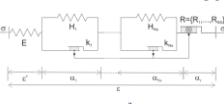
**WP2: Laboratory Testing**

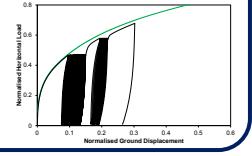



**WP4: Field Testing**

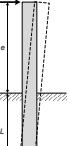



**WP4: Theoretical Methods**



$$f = \frac{H_0}{2} \left( \varepsilon - \sum_{n=1}^{N_t} \alpha_n \right)^2 + \sum_{n=1}^{N_t} \frac{H_n}{2} \alpha_n^2$$


**WP5: Application to Design**






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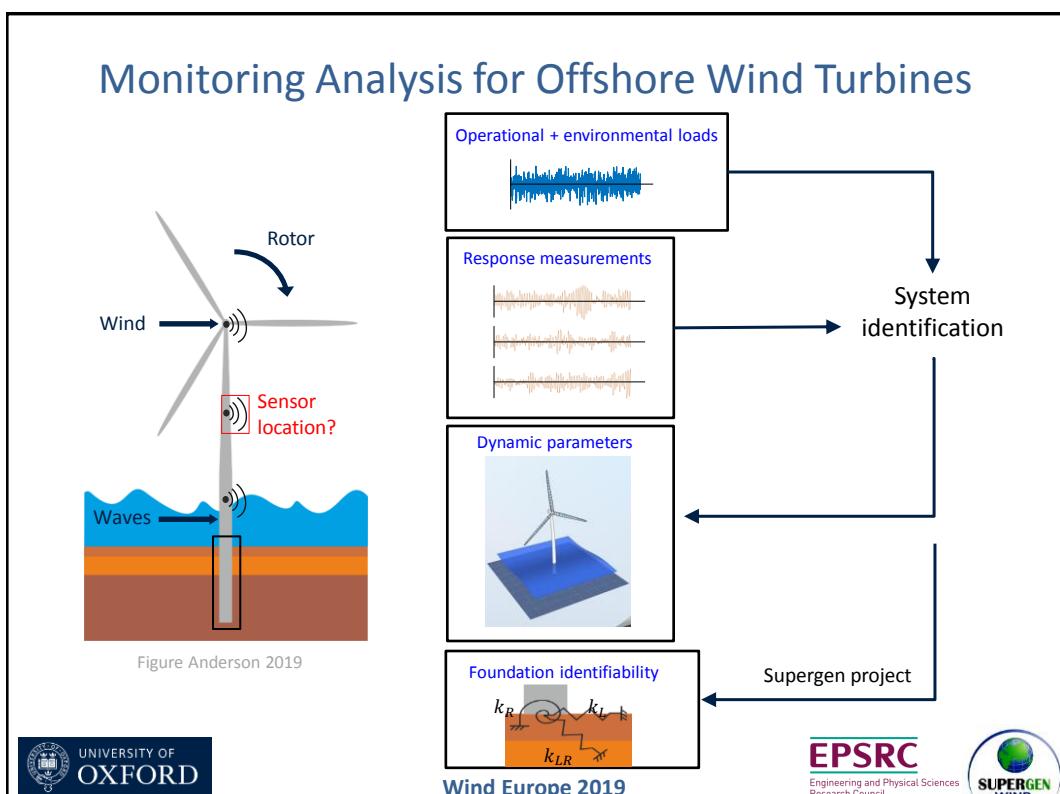
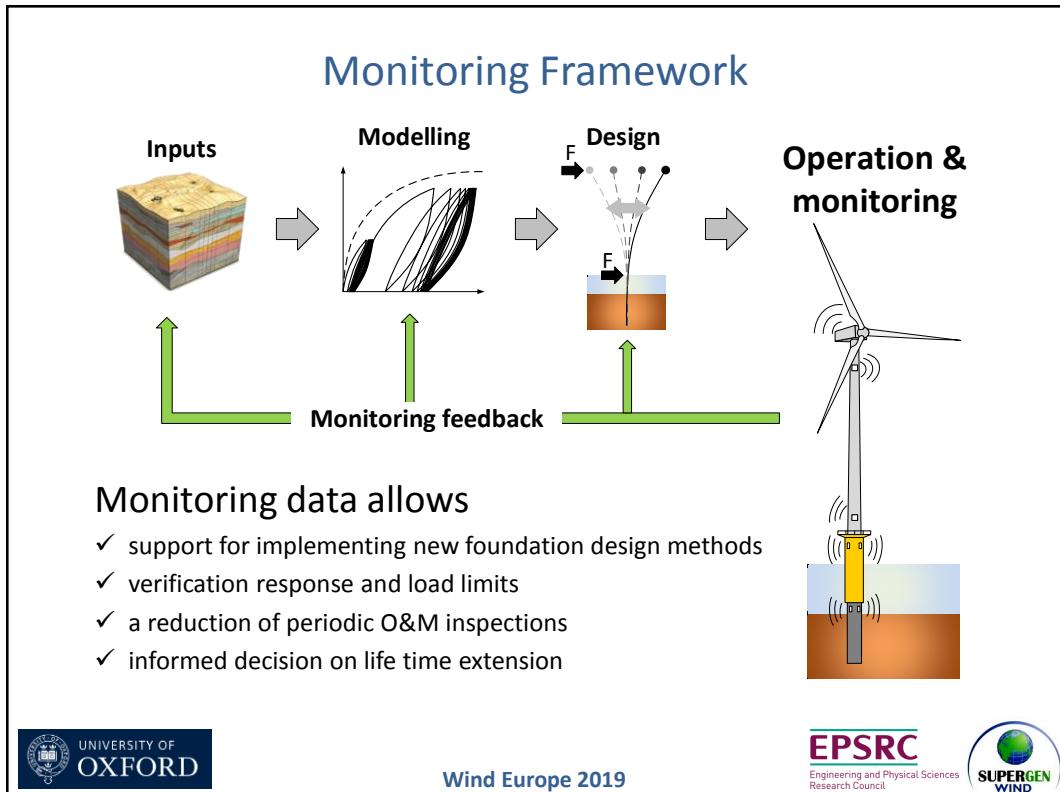
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## Example Data From Wind Farm

Typically few wind turbines in a farm monitored

Monitoring above sea:	Monitoring below sea:
<ul style="list-style-type: none"> <li>Metocan data</li> <li>SCADA data</li> <li>Accelerometers</li> <li>Strain gauges</li> </ul>	<ul style="list-style-type: none"> <li>Strain gauges</li> <li>Power and earth pressure</li> <li>Water temperature</li> </ul>

**Data summary at Nobel Wind:**  
100Hz sampling frequency  
More than 50 channels  
1TB/year

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## Analysis of Monitoring Data - Examples

Algorithm applicability to field data:

- Acceleration measurements at two locations (>10Hz sampling)
- Standstill conditions during monitoring period
- Known mass of nacelle-rotor assembly, structure and damper

Unique estimation of macro-element foundation

$\Delta \omega/\omega_{\text{fix}} [-]$

$k_u/k_\theta/k_{u\theta}$

$M$

$EI, m$

$k_u$

$k_\theta$

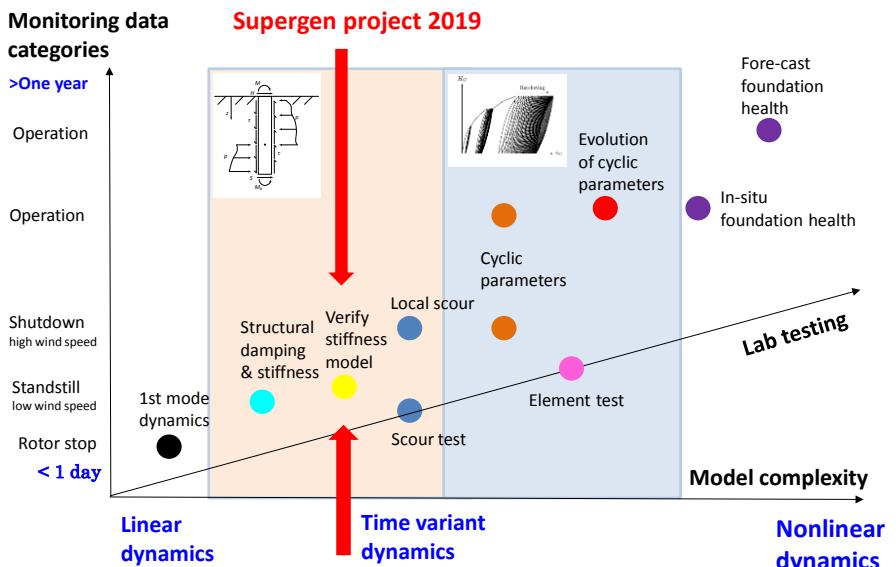
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## Future data assessed foundations



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## Summary and Conclusions

### Context:

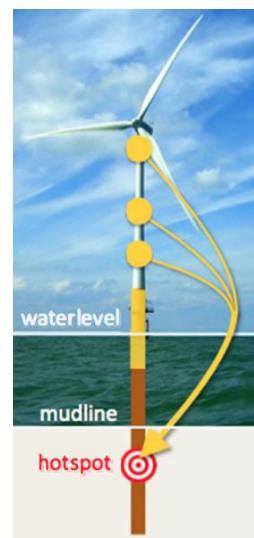
- New advanced site specific foundation design methods enable structural optimisation

### Output of Supergen Project:

- novel algorithm for monitoring analysis of offshore wind turbine foundations.
- data-driven assessment of installed monopile foundations

### Impact:

- Support for implementing new foundation design methods into engineering practice.
- a reduction of periodic O&M inspections
- informed decision on life time extension



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