ROMEO H2020 PROJECT

DIGITAL TWINS IN OFFSHORE WIND

RAMBØLL Bright ideas. Sustainable change.

Photo: Iberdrola

Wind Energy Science Conference
18th June 2019
University College Cork, Ireland

WHERE DO DIGITAL TWINS COME FROM?

APOLLO 13 MISSION

NASA

1970

DITGITAL TWIN TERMINOLOGY

Michael Grieves, U of Michigan

2002

FIRST IMPLEMENTATION AT OFFSHORE PLATFORM

Ramboll established first Digital Twin for Lifetime Extension

2006

ROMEO PILOT PROJECT

Ramboll established first Digital Twin of an offshore wind jacket

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2017

Similar challenge faced in different industries:

Remote asset to be maintained and operated over entire lifetime, whereas the physical access is difficult.

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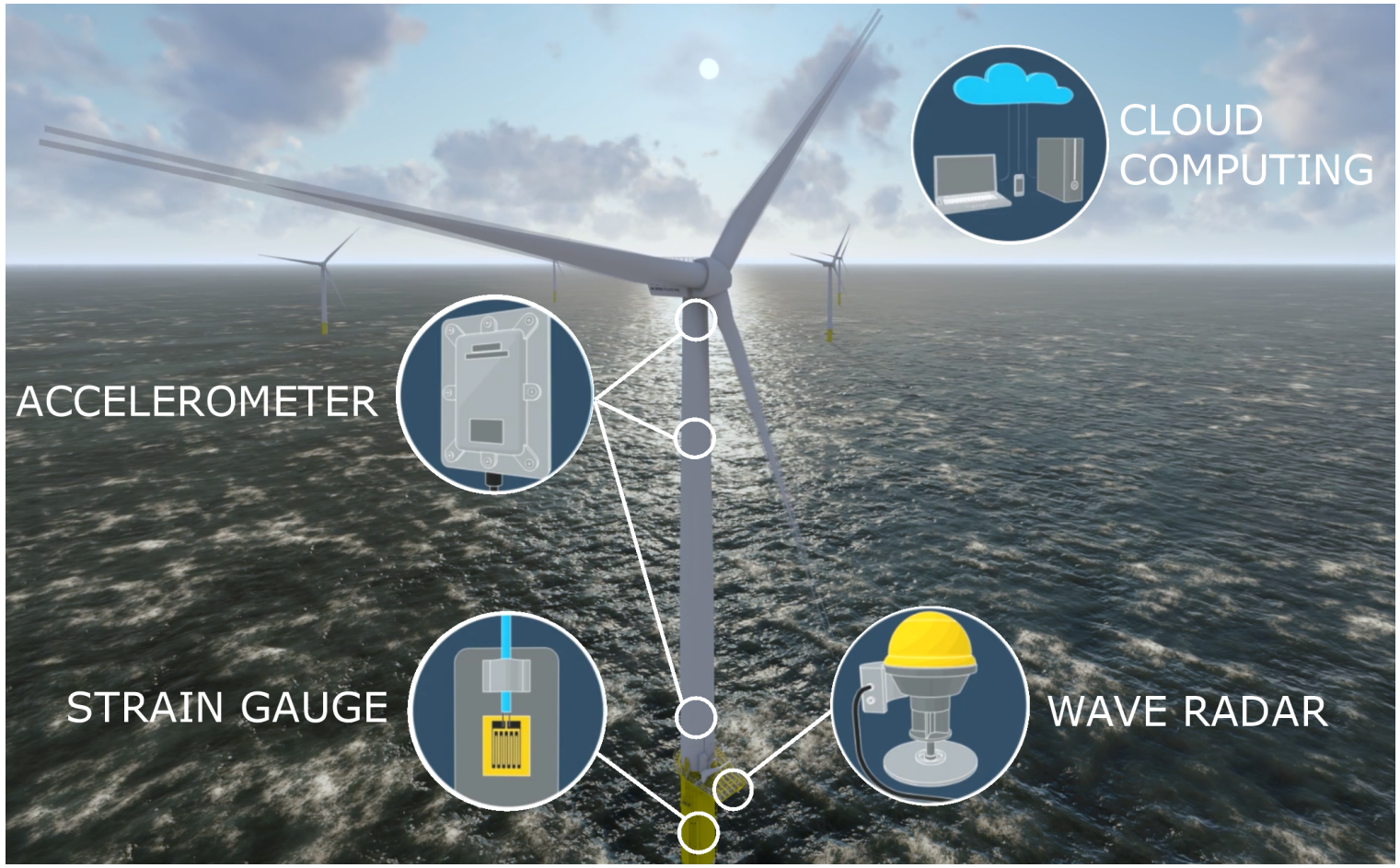
MOTIVATION OF DIGITAL TWINS

- Measurements show deviations in structural dynamics between installed WTG and their corresponding FE model
- Design process & assumptions are governed by certification standards
- Timeline of projects does not allow for thorough site investigations
  - conservative design decisions for the foundation structure are taken



→ **Measurement data justifies to deviate from common practice**

AGENDA - DIGITAL TWIN ROADMAP

01

Optimal sensor placement

- Cost effective and purpose specific sensor layout

02

FE Model Updating

- Updated model parameter
- Structural behaviour as installed

03

Wave & wind load calibration

- Updated wave load coefficients

04

Reduction of uncertainties

- Extended fatigue life
- Reduced inspection costs

05

Damage detection

- Evaluation of real time data
- Warnings based on trends and predictions

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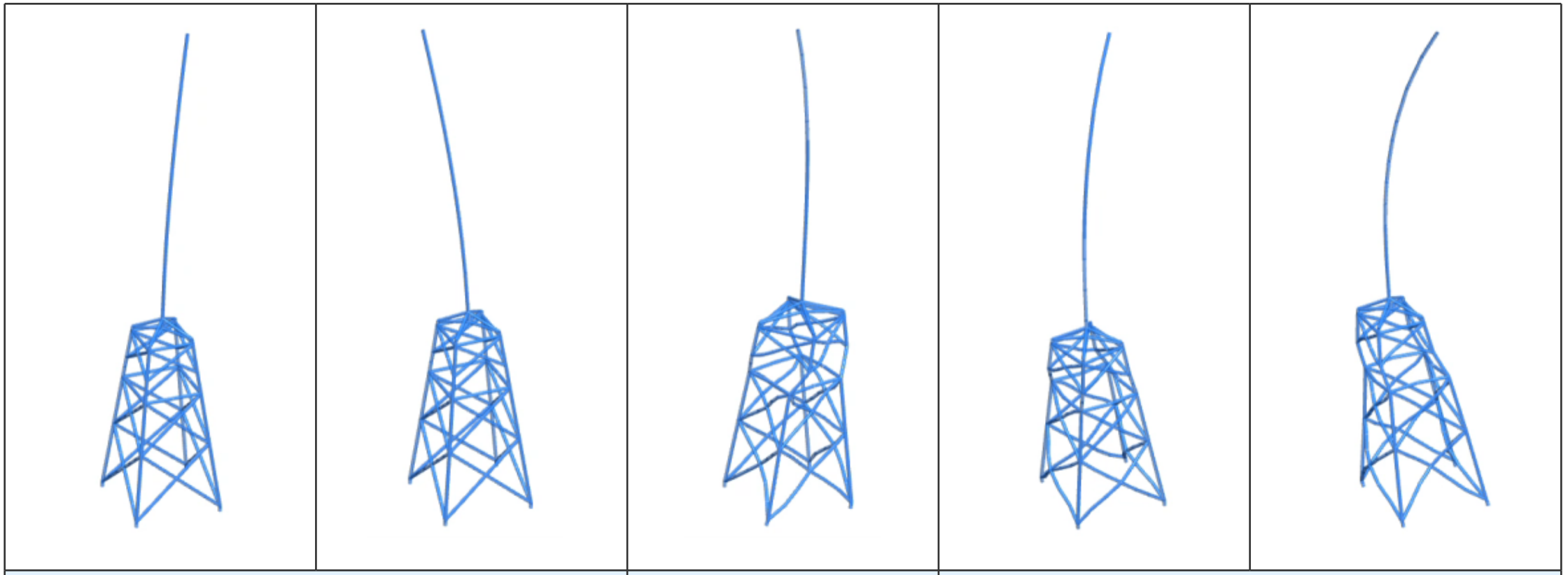
DYNAMICS OF WIKINGER WTG



1st bending		1st torsional	2nd bending	
fore-aft	side-side		fore-aft	side-side

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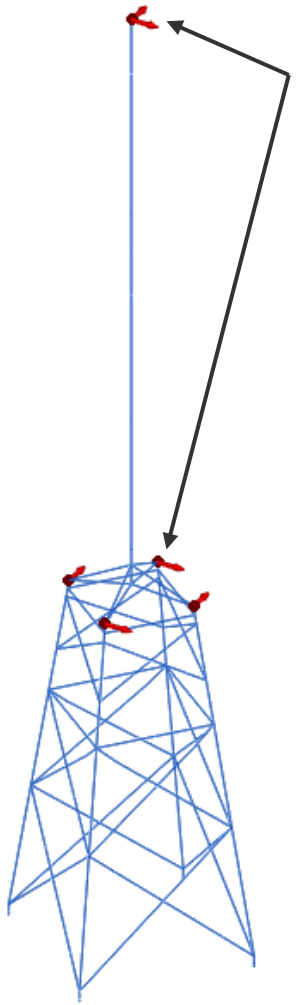
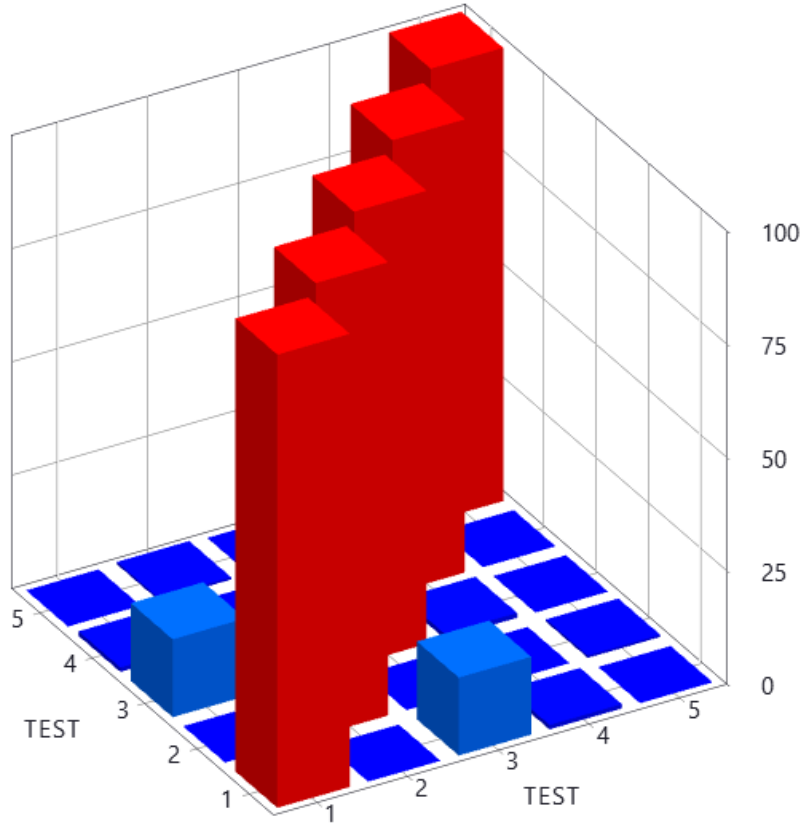
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 745625.

01 OPTIMAL SENSOR PLACEMENT – ROMEO PROJECT

- Optimal placement is defined by:
  - Minimum amount of hardware
  - Best accessible locations
  - Accurate observability of mode shapes dependent on chosen level of detectability (monitoring strategy)
- Support structure and wind farm location specific sensor placement
- Ensures best value of CMS for at least 25 years of operation



WIKINGER WTG



Modal assurance criterion (MAC-matrix)

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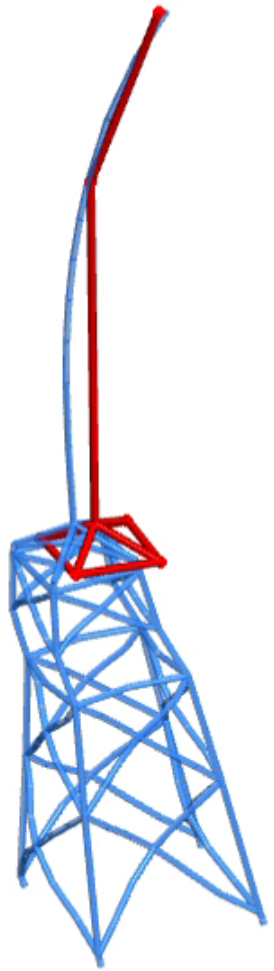
02 FE MODEL UPDATE

- Goal:
  - Update modal parameters of the FE model so that it better represents the installed structure
- Updating process:
  1. FE model parameter selection
  2. Sensitivity analysis on parameters
  3. Bayesian updating of parameters
     - weighting coefficients
     - realistic boundaries



FE model

Measurement model

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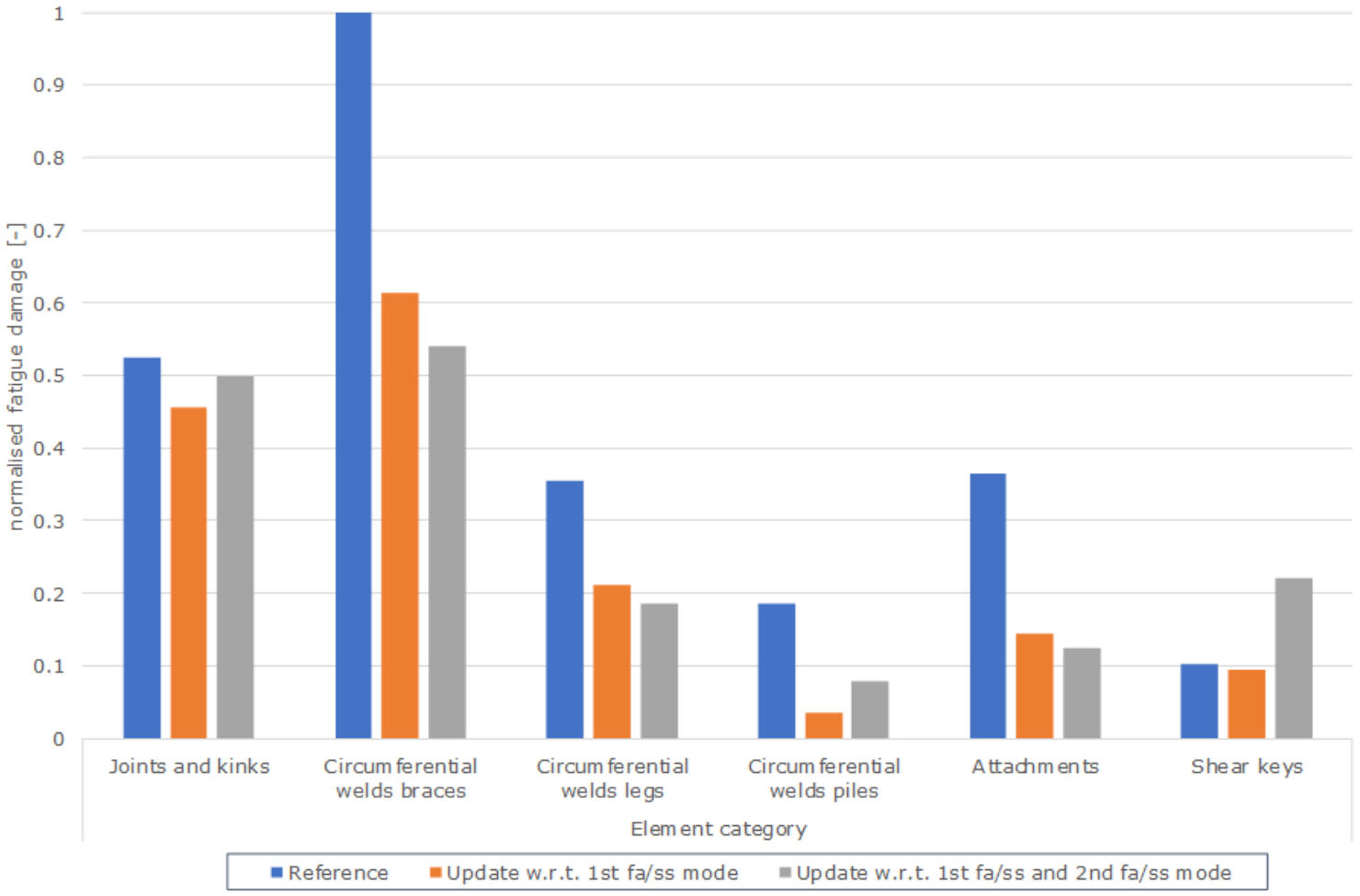
03 WAVE LOAD CALIBRATION

- Identification of real loads
  - Access to entire load history
- Update of the FE model loads based on measurement data
  - 3 wave radars needed to capture the directional sea state
- Recalculation of ULS and FLS

Wave Radar REX

04 EXTENDED FATIGUE LIFE

- Recalculation of fatigue limit state (FLS) using:
  - Modally updated FE model
  - Load updated FE model
- Shifting of fatigue hot spots
- Extension of fatigue life



05 DAMAGE DETECTION

FE model

Measurement model

- Continuous monitoring through real time data analysis algorithm
  - Confidence in known structural behaviour allows for modal tracking of healthy structure
  - Deviation in mode shape & natural frequency from the virgin model indicates change of the system -> damage
  - Type of deviation leads to damage localisation
  - Predictive warnings based on patterns and trends

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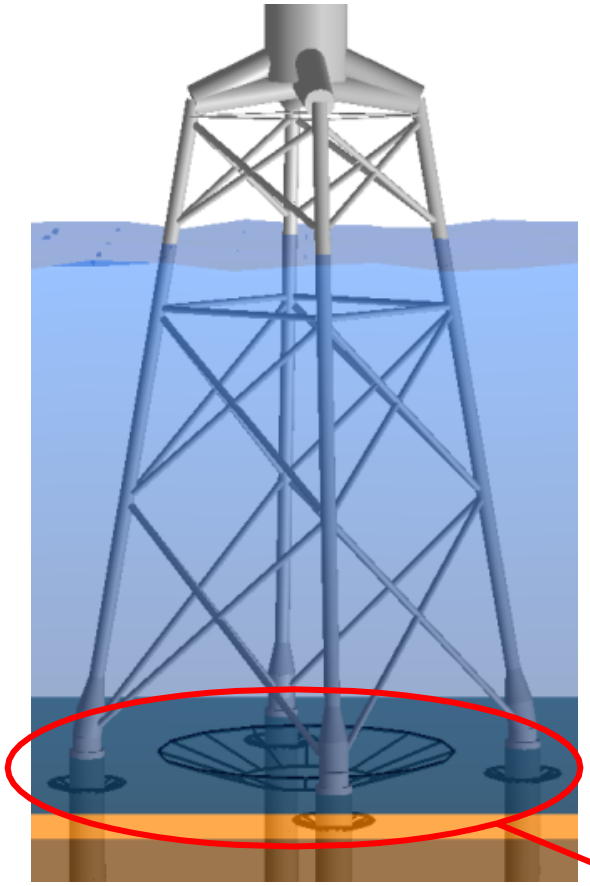
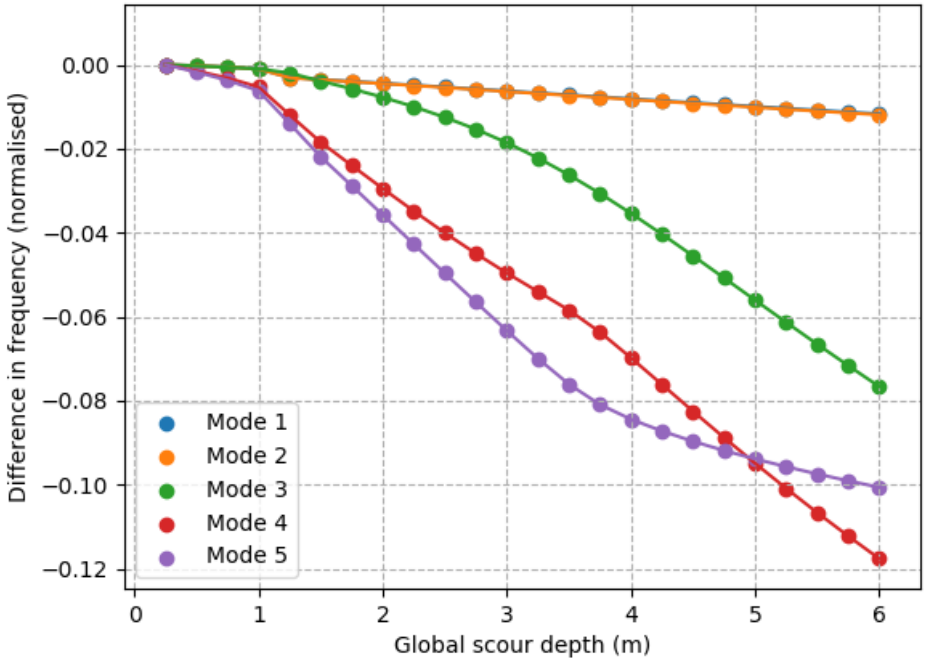
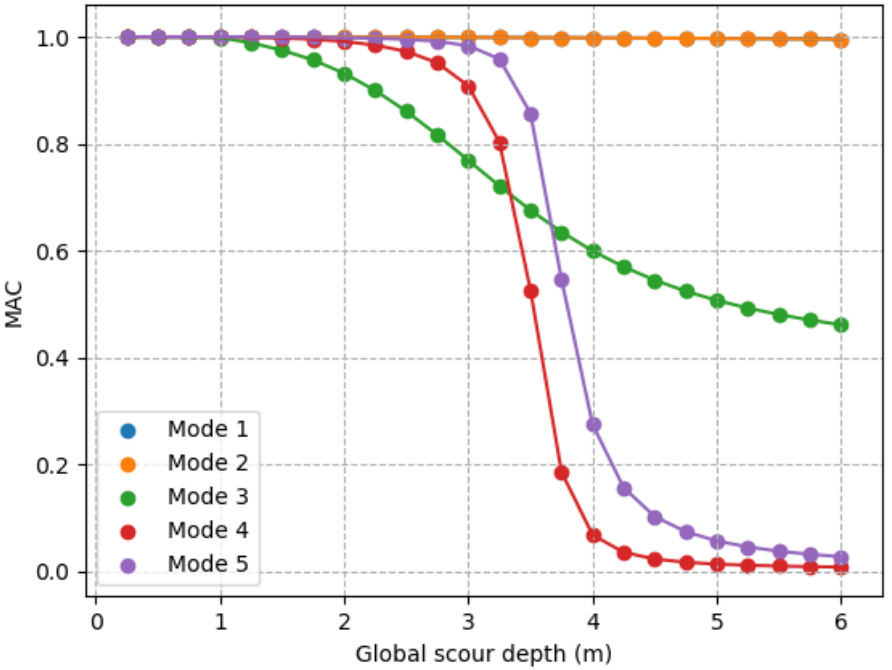
05 DAMAGE DETECTION
EXAMPLE: SCOUR

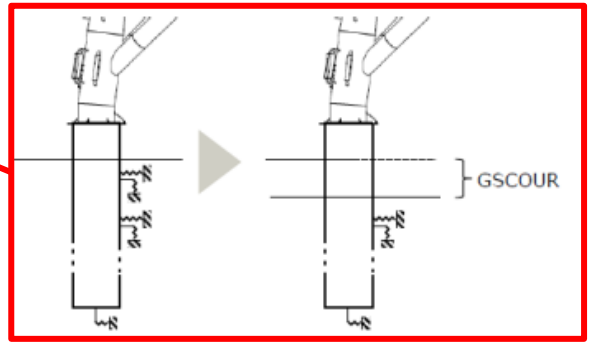


Natural frequency



Mode shape





- Virgin model of healthy structure can be tested for anticipated damages
- Localisation of damages possible

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SUMMARY

- A digital twin is a model that represents the behaviour of the structure **as-installed**
- It gives access to the structural behaviour of the entire lifecycle
- Leading to:
  - Lifetime extension of existing wind farms through updated fatigue calculation
  - Exact planning of O&M activities through continuous monitoring algorithms
  - Optimisation of new foundation designs, e.g. inclusion of more realistic soil profile through the transfer of findings

THANKS FOR YOUR ATTENTION!

Contact

Simon Siedler – Project Engineer Ramboll Offshore Wind
simon.siedler@ramboll.com

Ursula Smolka – Chief Consultant Ramboll Offshore Wind
ursula.smolka@ramboll.com

Tim Fischer – Vice Director Ramboll Wind
tim.fischer@ramboll.com

www.ramboll.com/wind

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