ROMEO H2020 PROJECT

DIGITAL TWINS FOR STRUCTURAL PARTS IN OFFSHORE WIND TURBINES: REQUIREMENTS, CHALLENGES AND OPPORTUNITIES

RAMBØLL Bright ideas. Sustainable change.

Wind Europe Offshore Conference
Copenhagen, Denmark

Photo: Iberdrola

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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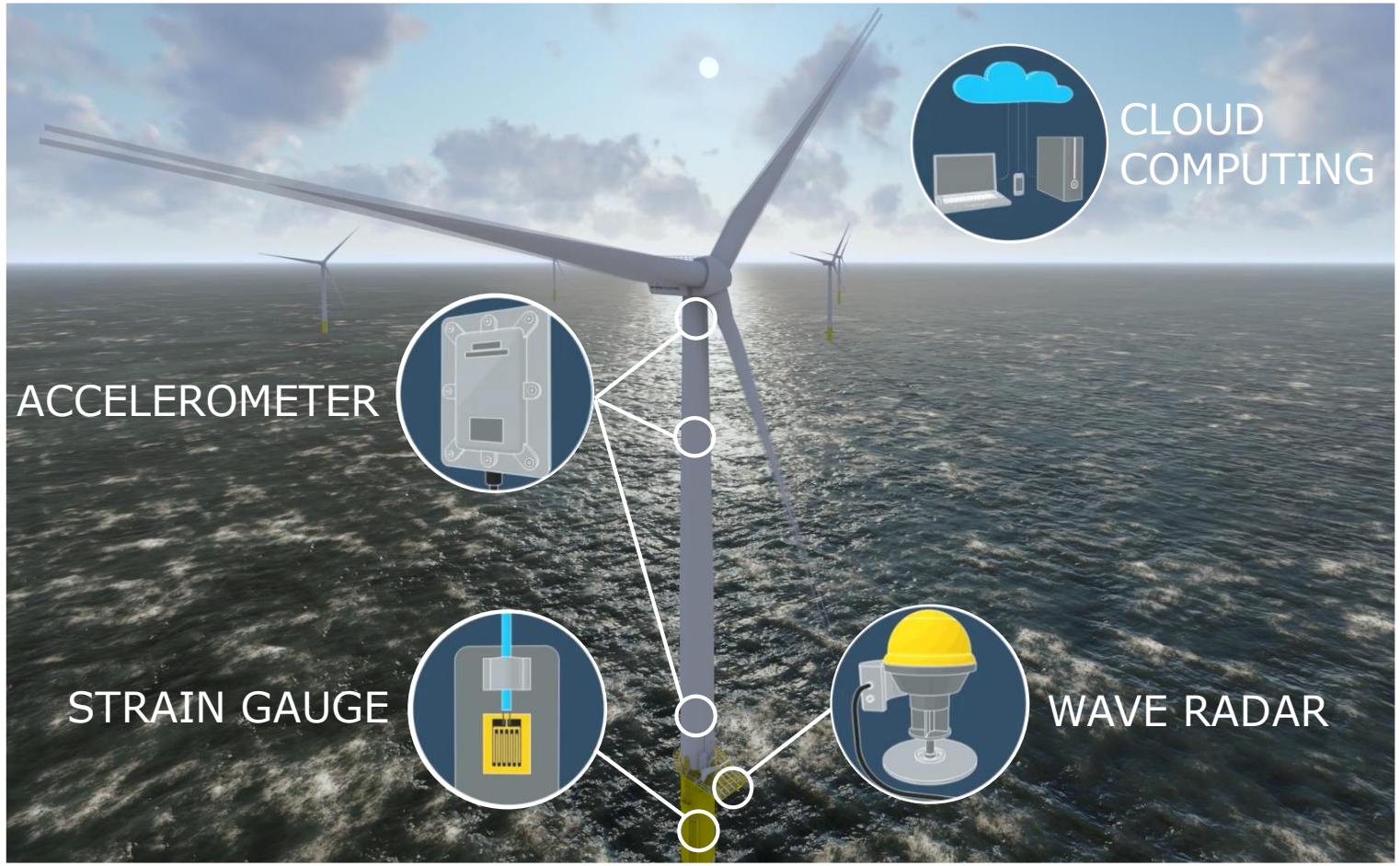
MOTIVATION

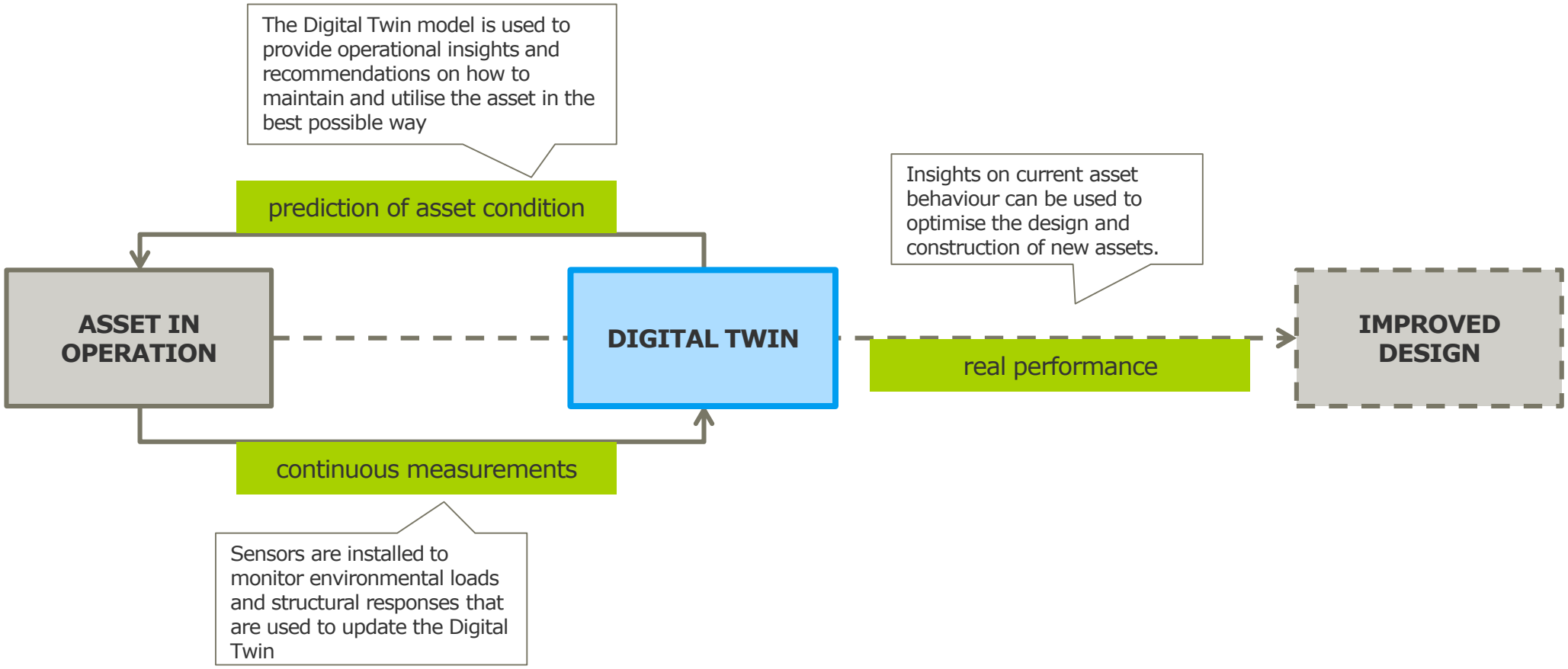
- Measurements show deviations in structural dynamics between installed WTG and their corresponding FE model
- Design process & assumptions are governed by certification standards
- Timeline of projects does not allow for thorough site investigations
  - conservative design decisions for the foundation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



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

A **digital twin** is a **digital replica** of a **physical asset**, where **sensor data in real-time** are used for **monitoring and assess the current performance** of the **asset** and **predict its future behaviour**

A DIGITAL TWIN CAN BE USED TO ENHANCE THE ENTIRE ASSET VALUE CHAIN



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



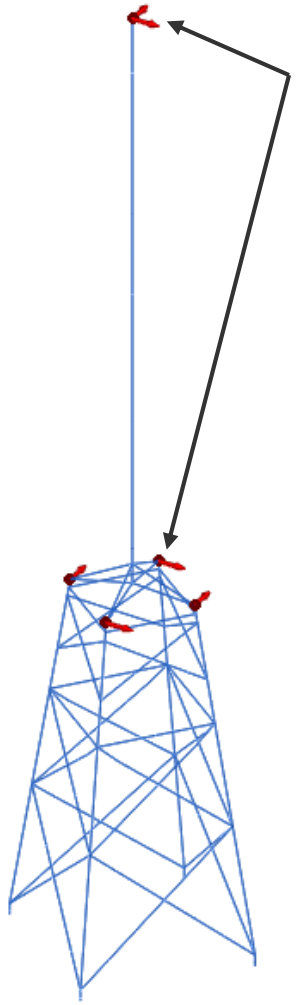


1st bending		1st torsional	2nd bending	
fore-aft	side-side		fore-aft	side-side

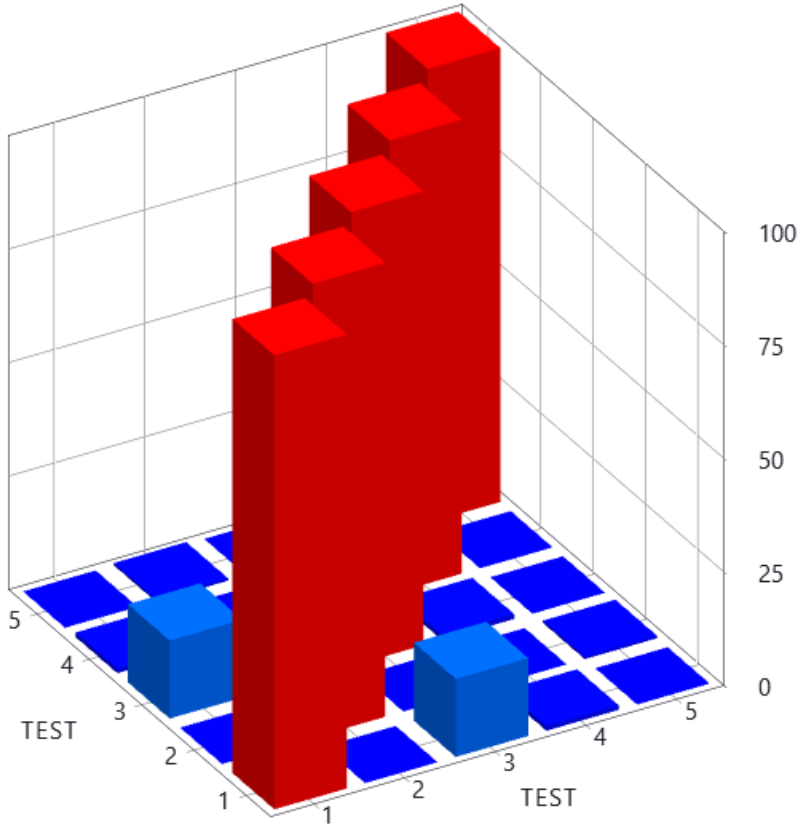
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 745625.

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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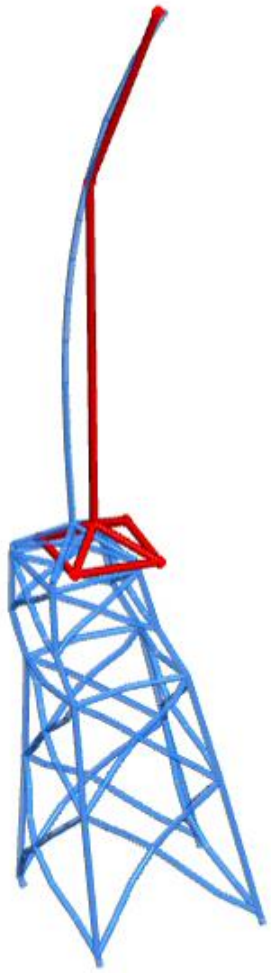
02 FE MODEL UPDATE

- 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

Photo: RS Aqua. Copyright 2019

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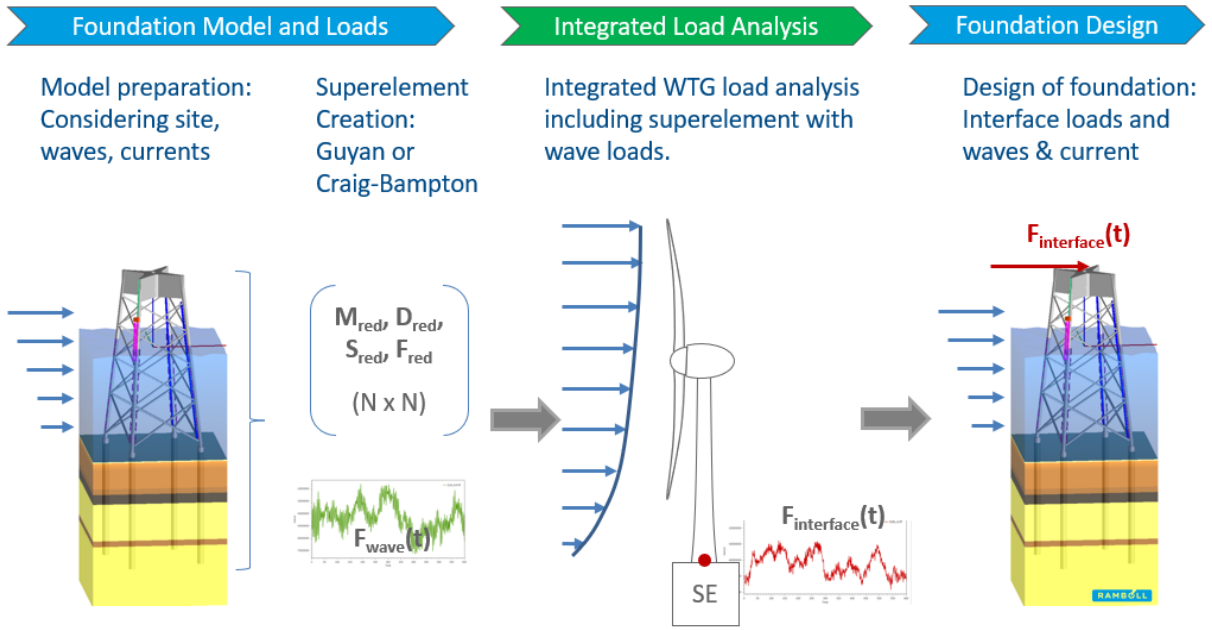
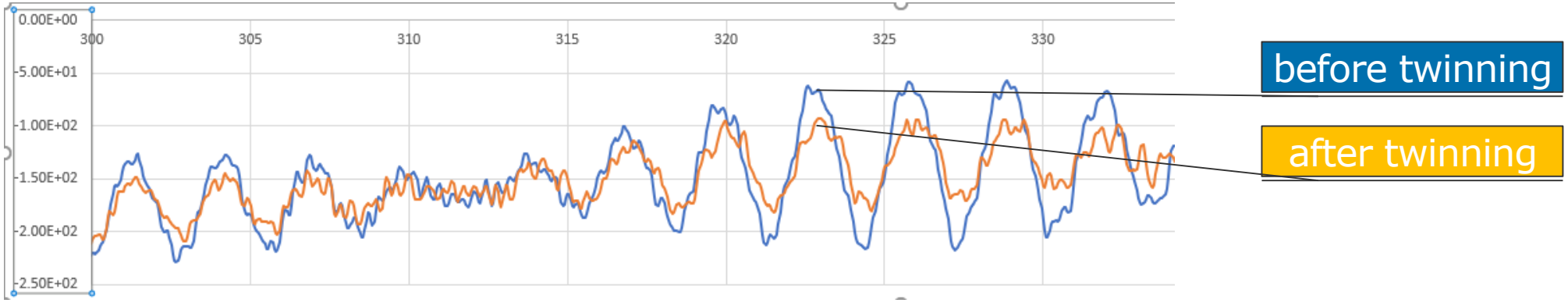
04 EXTENDED FATIGUE LIFE





- Calculation of fatigue limit state using:
  - Modally updated FE model
  - Load updated FE model
- Shifting of fatigue hot spots
- Extension of fatigue life due to reduced load amplitudes

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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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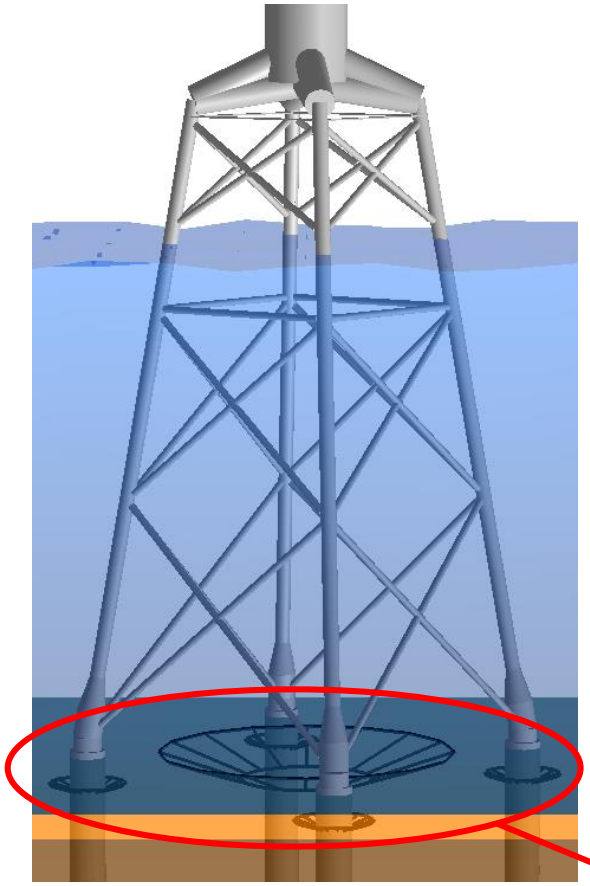
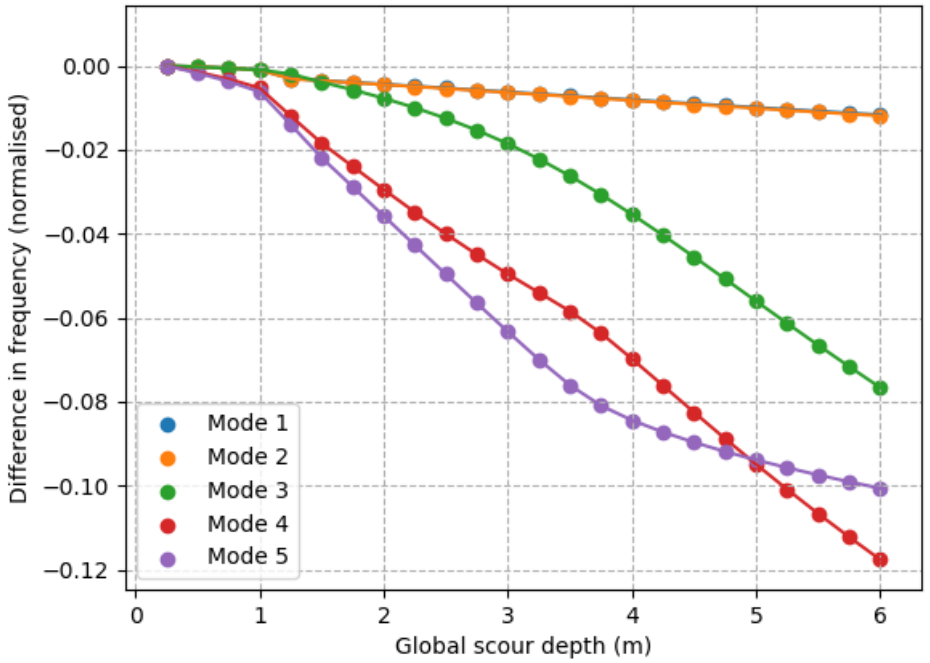
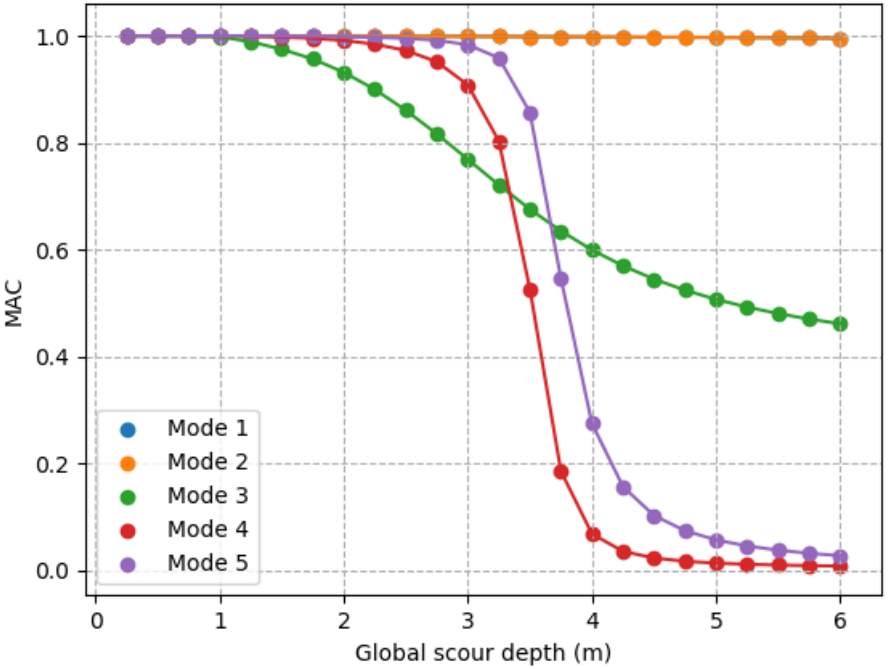
05 DAMAGE DETECTION
EXAMPLE: SCOUR

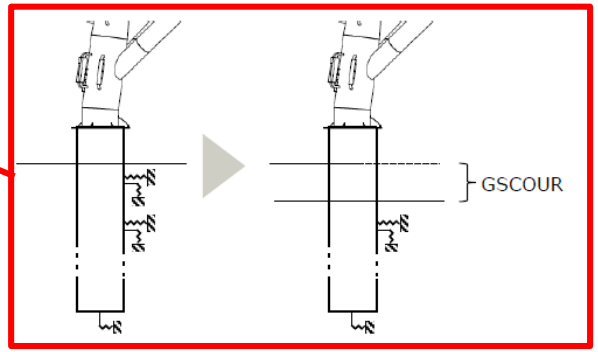


Natural frequency



Mode shape





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

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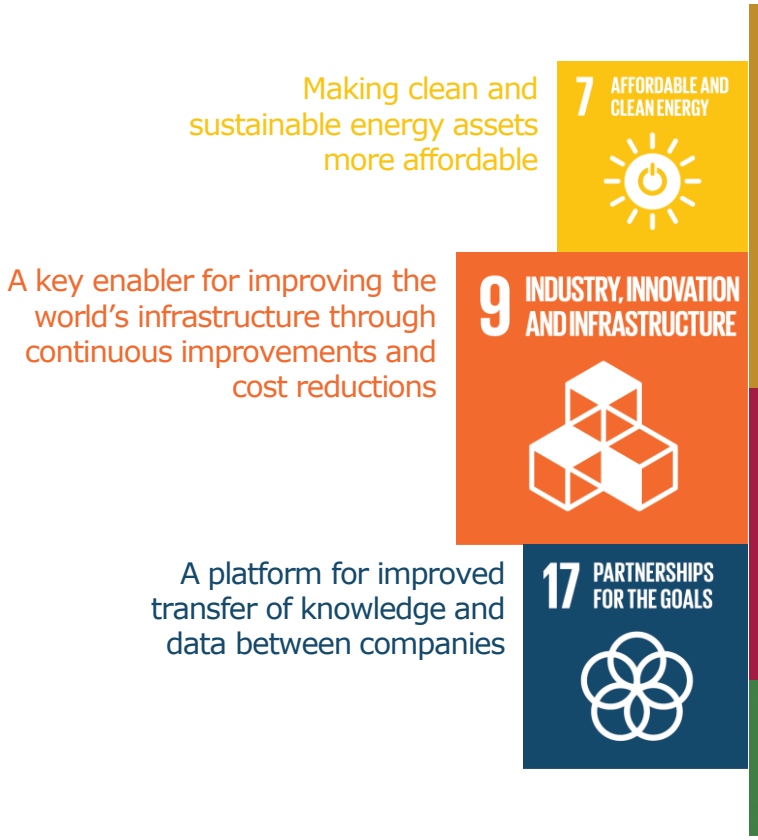
A DIGITAL TWIN CAN BE A KEY ENABLER FOR ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS



Making clean and sustainable energy assets more affordable

A key enabler for improving the world's infrastructure through continuous improvements and cost reductions

A platform for improved transfer of knowledge and data between companies

Reduced consumption of materials enabled by:

- Life-time extension of current assets
- Less frequent change of components due to better knowledge about their current state
- Opportunities for reducing the materials used in new designs based on new knowledge from monitorisation

Better working conditions – less hours in hazardous environment

Increased productivity of assets empowered by real-time performance data

Reduced carbon-footprint through better utilization of assets

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THANKS FOR YOUR ATTENTION!

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