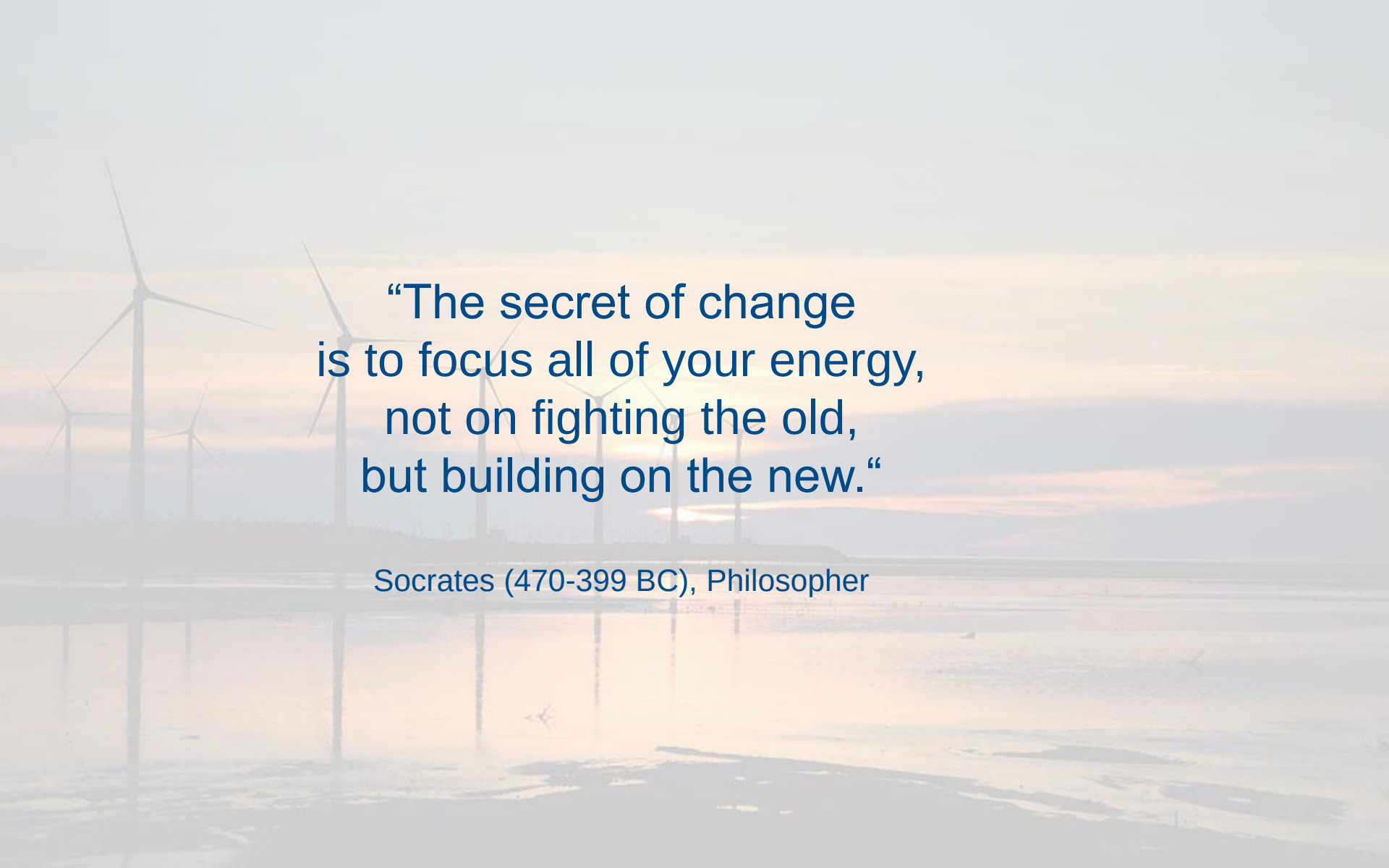
Digital Twin technologies for offshore foundations

Ramboll

Digital Enabled Asset Management (DEAM)

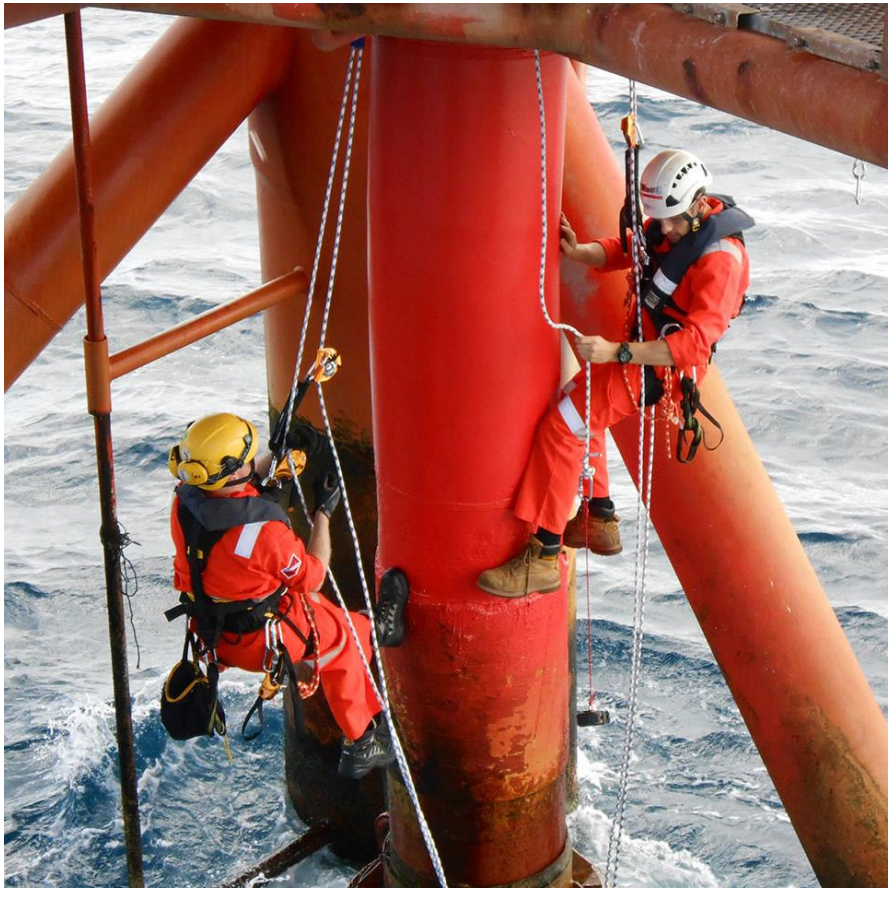
6th April 2022

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Nº 745625.


“The secret of change
is to focus all of your energy,
not on fighting the old,
but building on the new.“
Socrates (470-399 BC), Philosopher

Traditional O&M - with corrosion

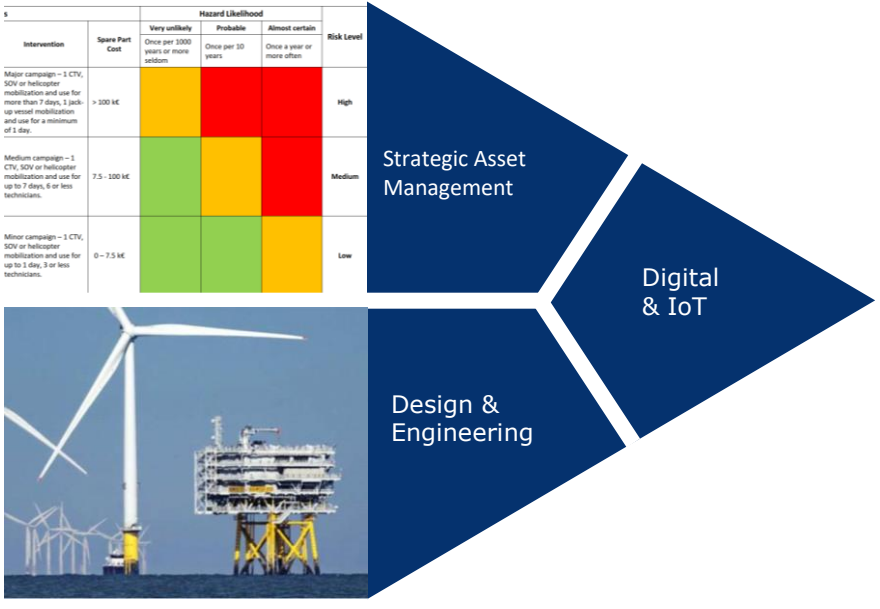
- Corrosion protection and corrosion allowances designed for 25 years of service life
- After 8 years, periodic inspection reveals excessive corrosion
- Derating turbine until malfunctioning ICCP system identified as cause, maintenance planned, and repair executed
- Structural reassessment required to determine impact on structural integrity and service life



*https://www.ndtgsl.co.uk/assets/imgs/jpgs/img1.jpg

Ramboll‘s True Digital Twin for offshore wind on the DEAM Platform

Digital enabled asset management (DEAM)



Digital enabled asset management (DEAM) is a multidisciplinary service that combines

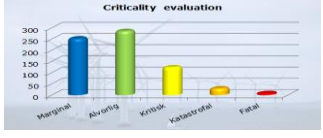
1. deep domain knowledge acquired from 20+ years pioneering work in the offshore business
2. which has been contextualised by asset management principles
3. with digital implementation using Industry 4.0 technology as **digital twins**.

Strategic asset management ensures focus on value generated and prioritization in the long-term business context. Digital delivery brings continuity and automated processes. Domain knowledge provides confidence in decision support.

DEAM is built for asset owners to take informed, timely and confident decisions about utilization, safety, compliance and cost of their assets.

Where Does the Value Generation Come From?
- Planning from a Risk and Consequence Point of View

1 CRITICALITY ASSESSMENT

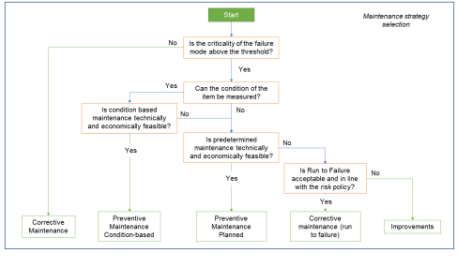


Frequency	Marginal	Serious	Critical	Catastrophic
0<MTBF<1M	M	H	VH	VH
1M<MTBF<6M	M	H	H	VH
6M<MTBF<1Y	M	H	H	VH
1Y<MTBF<5	L	M	M	H
5Y<MTBF<10 Y	L	M	M	H
10<MTBF	VL	L	M	M

Based on a risk evaluation, actions will be prioritized where it provides most value.

Failure Mode Effects & Criticality Analysis (FMECA)

2 DETERMINE TYPE OF MAINTENANCE



Determine type of maintenance based on a consistent decision tree:

- Condition based (digital twin)
- Predetermined
- Corrective
- Other

Selection of the most critical failure modes

3 CREATE PURPOSEFUL MONITORING AND ANALYTICS

Nr.	Category	Purpose	Objective
1.1	Validation (Data for sound arguments in front of certifiers, insurance and other stakeholders)	No bathymetric survey need to assess scour condition	Validate that monitoring of scour protection integrity is feasible and seabed survey can be reduced.
1.2		Re-establish DFF3 for inspection free structure	Operational WTG fatigue validation
2.1	Damage	Prevent critical fatigue crack at jacket lattice structure	Detect excessive fatigue loading from WTG
2.2			Detect excessive scour formation
2.3		Prevent structure from tilting or deformation	Detect ultimate loads
2.4			Detect unexpected movement
2.5			Detect excessive scour formation
2.6		Prevent harmful operation	Detect 1st natural frequency outside WTG specification
2.7		Prevent catastrophic failure	Detect full member loss in jacket lattice structure
3.1	Fatigue Assessment	Extended lifetime / lifetime achieveability	Reassessment of environmental conditions
3.2			Continuous DEL monitoring

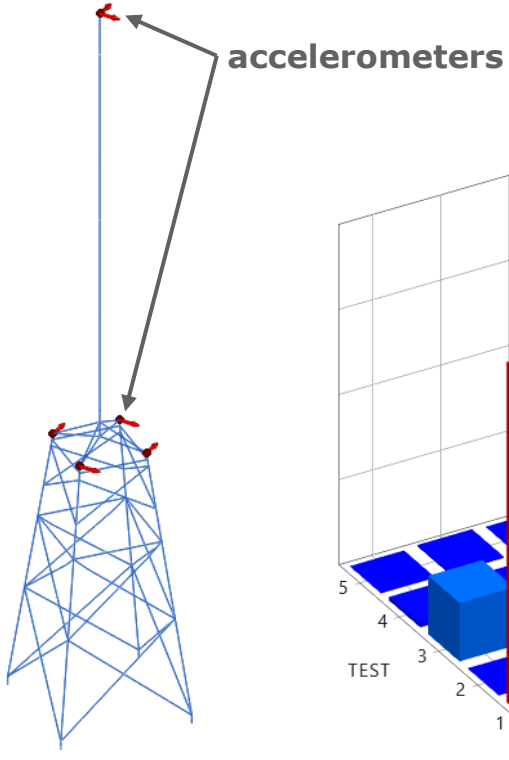
Development and implementation of Digital Twin

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

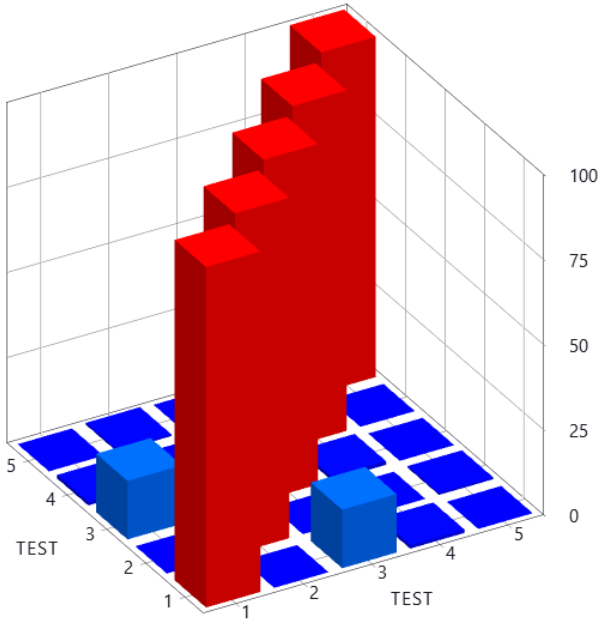
RAMBØLL ROMEO

Optimal sensor placement

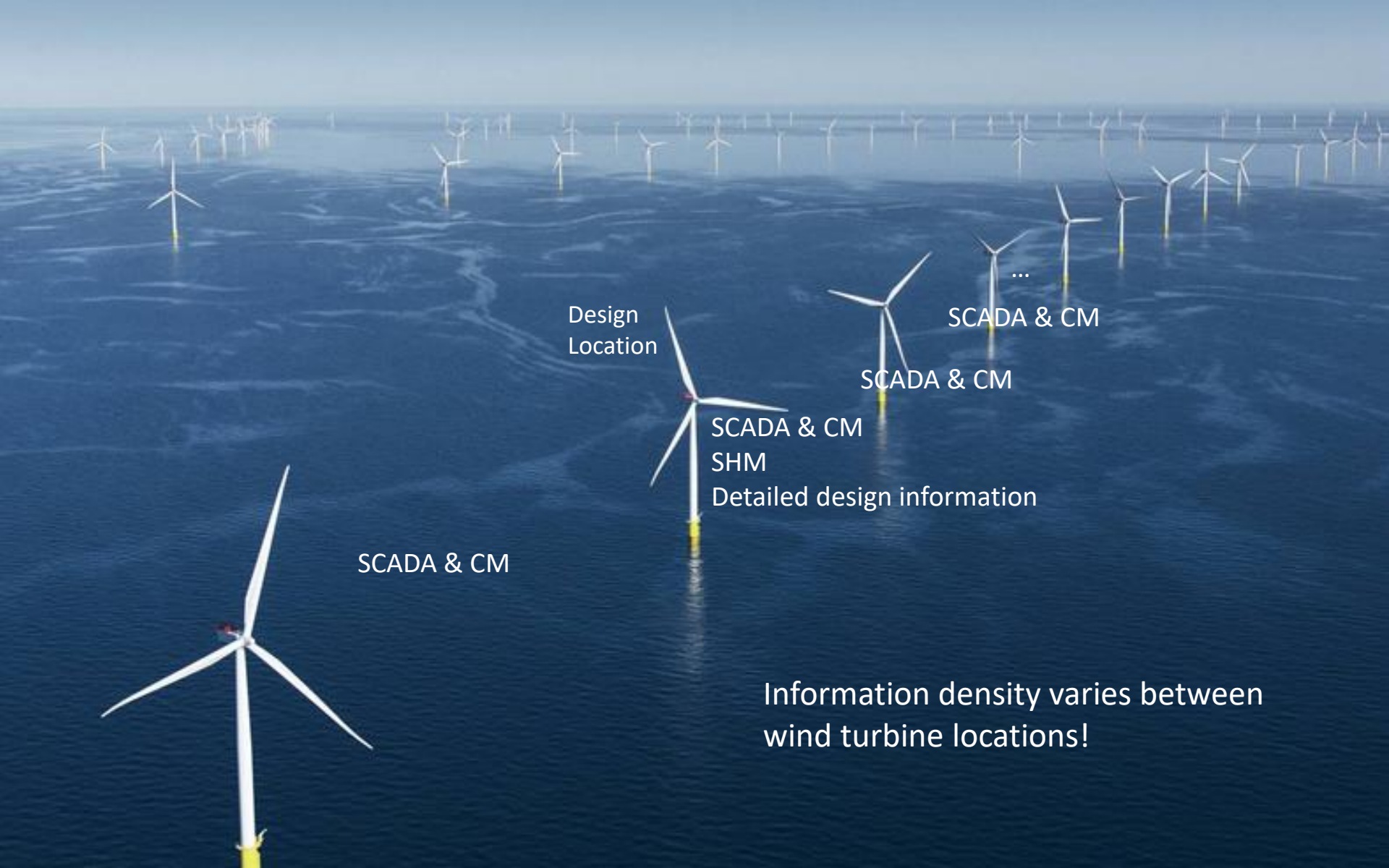
- Optimal placement is defined by:
  - Minimum amount of hardware
  - Best accessible locations
  - Accurate observability of mode shapes dependent on chosen leve of detectability (monitoring strategy)
- Support structure and wind farm location specific sensor placement
- Ensures best value of CMS for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



WIKINGER WTG



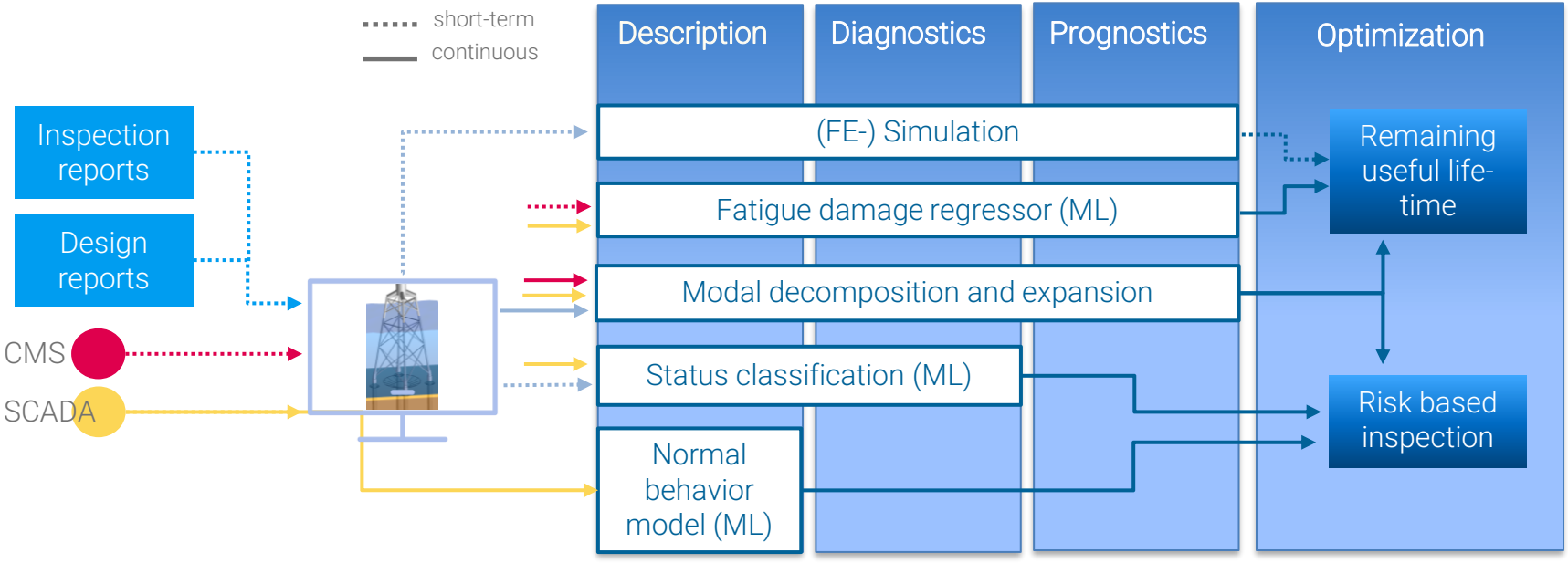
Modal assurance criterion (MAC-matrix)


...
SCADA & CM
Design
Location
SCADA & CM
SCADA & CM
SHM
Detailed design information
SCADA & CM
Information density varies between
wind turbine locations!

Demonstration of ROMEO analytics for low-cost monitoring

Risk assessment of critical failure mechanisms without feasibility of direct sensing:

- Fatigue
- Selection of anomalies:
  - Structural anomalies
  - Environmental conditions beyond expectation



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

RAMBØLL ROMEO

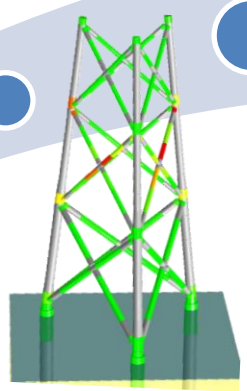
Digital Twin – Model updating levels

L4: Uncertainty assessment
How does the relation between load and response compare? How do measured and simulated internal forces compare under known loads?

L3: Load updating
How do reality and design loads compare? Both environmental and operational loads are considered.

L2: Model updating
Automated model updating by dynamic properties.

L1: Screening & diagnosis
How do model and reality compare?

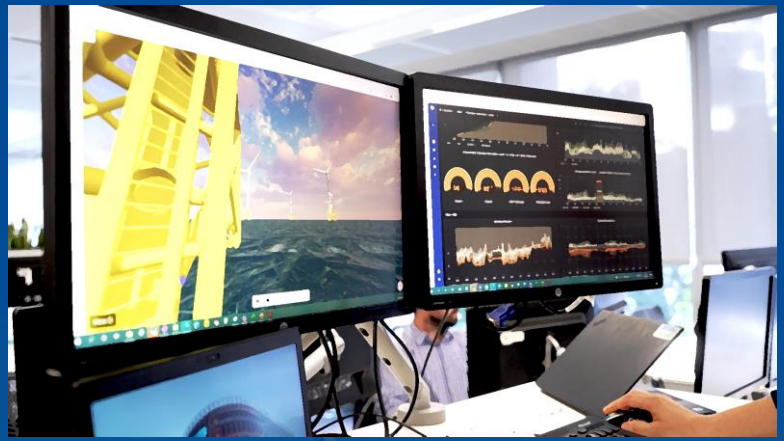


First model updating is executed as early as in the construction phase. Load updating requires typically at least one year of data while the uncertainty assessment focusses on specific relevant load cases. The process is fully integrated in the digital twins' life.

Note: In general, no continuous data acquisition and analysis needed to execute these steps.

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

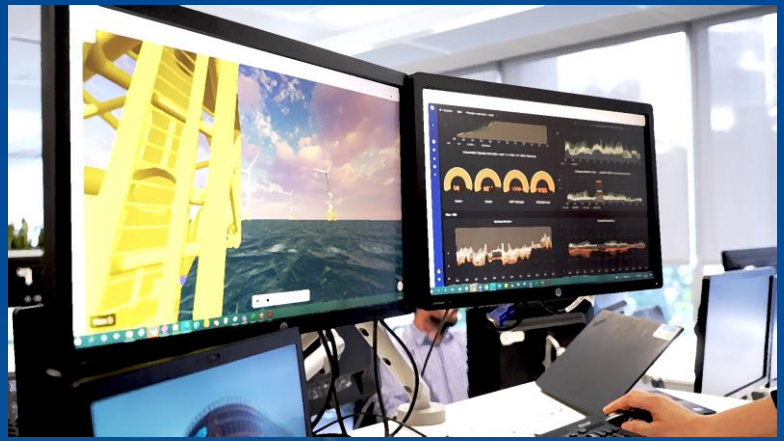
RAMBØLL ROMEO



DEAM - with corrosion

- The wind farm is operating robustly for five years already. Energy production is meeting expectations and the O&M team has mastered the first years of service with a good learning curve.
- In winter, the Digital Twin indicates abnormal behaviour of the ICCP system on two turbines.
- The Digital Twin allows you to run scenario analysis with different severities of malfunctioning ICCP systems to analyse the influence on fatigue life.
- Furthermore, the team can check the installation documentation of the ICCP system of all turbines in detail. This reveals an abnormality in the material and installation process for the indicated locations.

RAMBØLL ROMEO



DEAM - with corrosion

- **Reduced expenditure:** A condition-based inspection of the two ICCP systems and structure can be planned well ahead, and the right retrofit, material and tools can be anticipated.
- The data and analytics from the wind farm together with a clear strategy to deal with the abnormalities convince shareholders, partners and authorities that you are in full **control**.
- **Increased revenue:** Through scenario analysis, you are always confident in the achievability of the target lifetime and avoid an over consumption of fatigue life over extended periods by taking the right measures preventing secondary effects to take place.

RAMBØLL ROMEO

Thank you for your kind attention!

April 2022

Ramboll Deutschland GmbH
Jürgen-Töpfer-Straße 48, 22763
Hamburg, Germany
ramboll.com

Carolin Wendelborn
carolin.wendelborn@ramboll.com

Ursula Smolka
ursula.smolka@ramboll.com

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