Monitoring et estimation de la durée de vie d'éoliennes offshore

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SERCEL at a glance

A VIRIDIEN company

Established in 1956

Headquarters in Nantes, France

Leader on its core market

Leverages on its expertise to bring innovative solutions to the Infrastructure world

Sercel is the worldwide leader **in the design and manufacture of high-tech solutions** for subsurface exploration and infrastructure monitoring.

1,500 EMPLOYEES WORLDWIDE

800 ENGINEERS & TECHNICIANS

300 M$ REVENUE IN 2023 (15% re-invest in R&D)

See Inside the Earth & Infrastructure

NATURAL RESOURCES

ENERGY TRANSITION

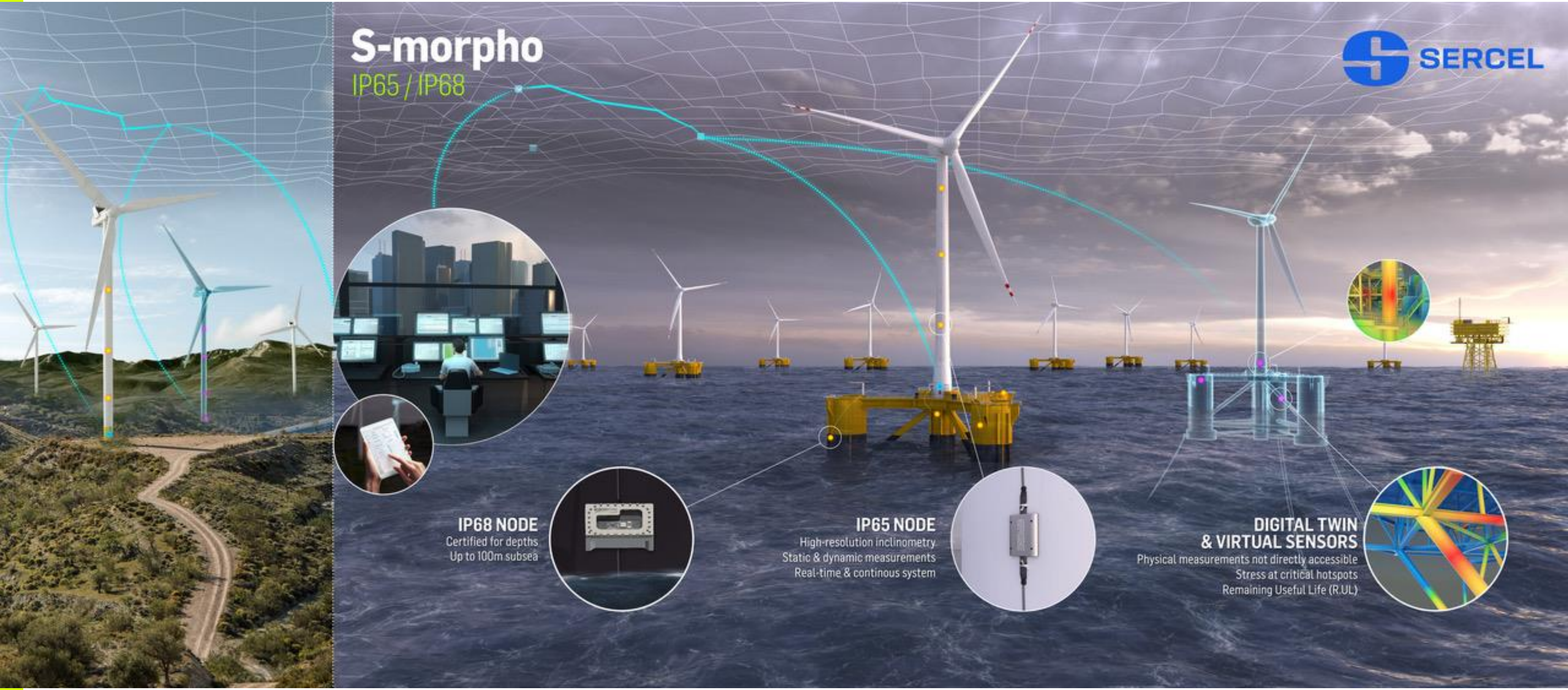
INFRASTRUCTURE MONITORING

DEFENSE

MARINE LOGISTICS & PORTS

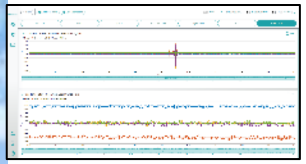
EARTH & OCEAN MONITORING

Global Wind Solution Overview



SHM-France precend
SERCEL

Context & Objectives



Offshore Wind Turbine at sea with embedded measurements:

- SCADA (Supervisory Control And Data Acquisition)
- Vibration structural monitoring system (Sercel solutions : S-lynks or S-morpho)

➔ **What is the health of the turbine?**

Structural Health Monitoring in Offshore Wind
What does it mean?

Does the structure behave as expected (design) under the environmental & operational loads conditions (wave, current and wind)?

1-The objectives of health measurement is to:

- Follow product life cycle
- Estimate Fatigue with regards to real loads

2-In order to:

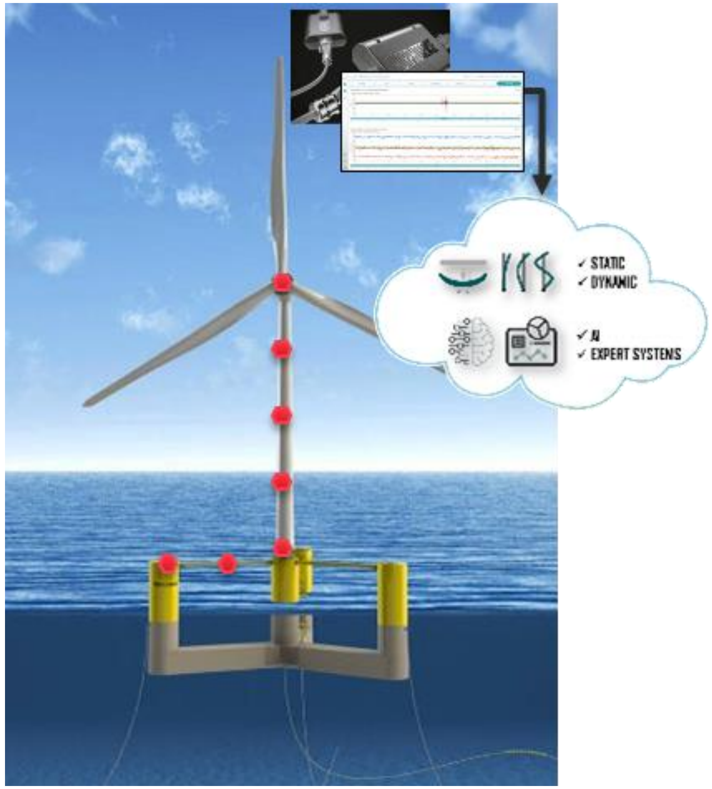
- Prevent Failure
- Extend operating lifetime

3-With the final target to:

- Ensure the continuity and efficiency of operations
- Reduce Operational and Maintenance (O&M) costs
- Increase Profitability
- Improve future design

Existing solutions to assess the health of a turbine

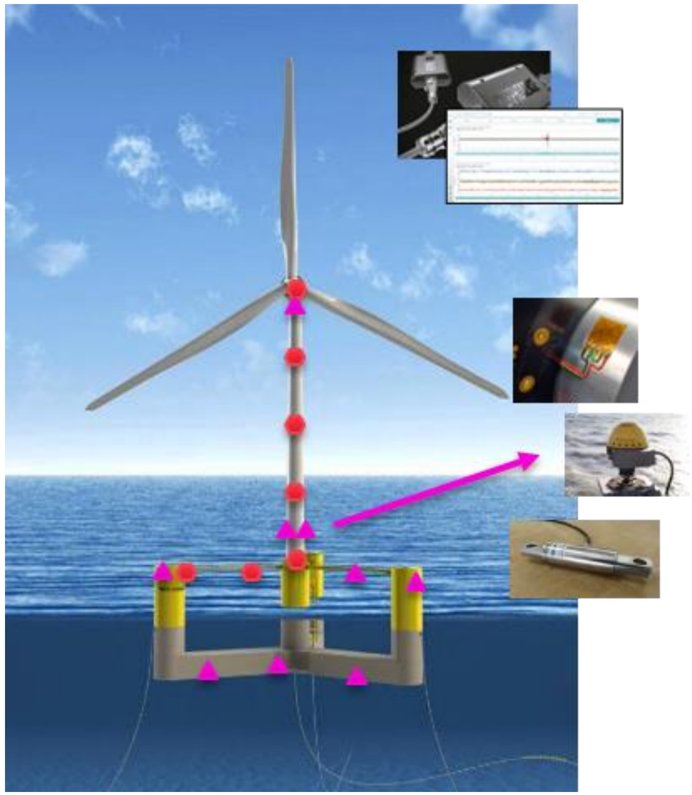
Solution 1 – Process Measurements



- Measurement processing (OMA, Static, …)
- Added rules on component failures
- Expert system or A.I. (data-driven approach)

➔ Limited by sensor's number & performance

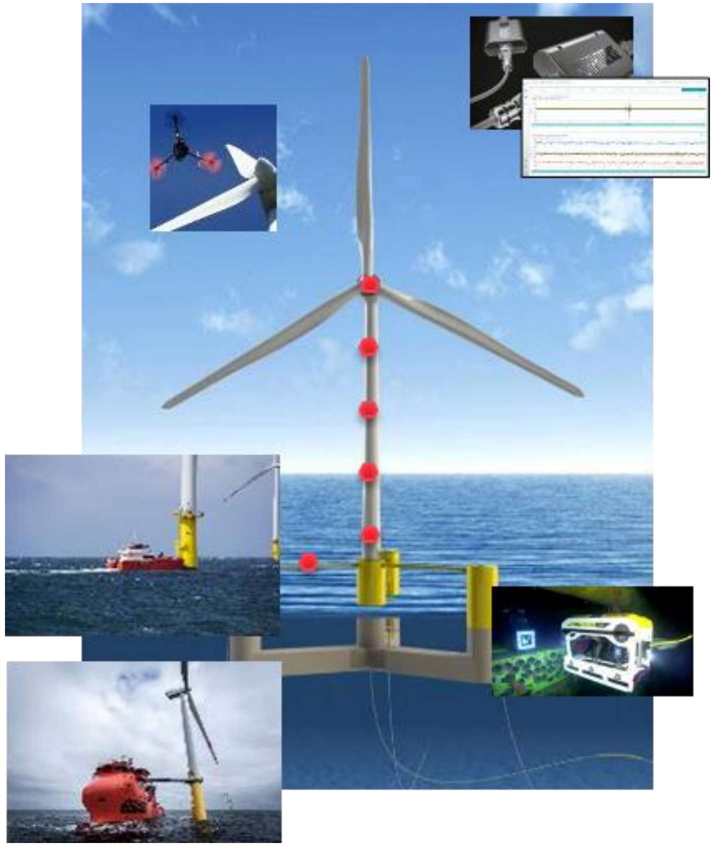
Solution 2 – More Measurements



Third party sensors : Strain gauges, Tension line gauges, Corrosion sensor

➔ Limited by :
- Costs & robustness of sensors
- Commissioning procedure costs & complexity
- Transmission of a huge amount of data

Solution 3 – More Visual Inspections



- Vessels or Helicopters for crew transfer
- ROV (underwater) & Drones (tower & blades)

➔ Limited by costs & access condition

Towards 4th solution - a Digital Twin

*Can we use **modeling solutions & expertise** to provide tangible information for the Operation & Maintenance ?*

1. With a limited set of sensors
   (Using only accelerometers & SCADA)

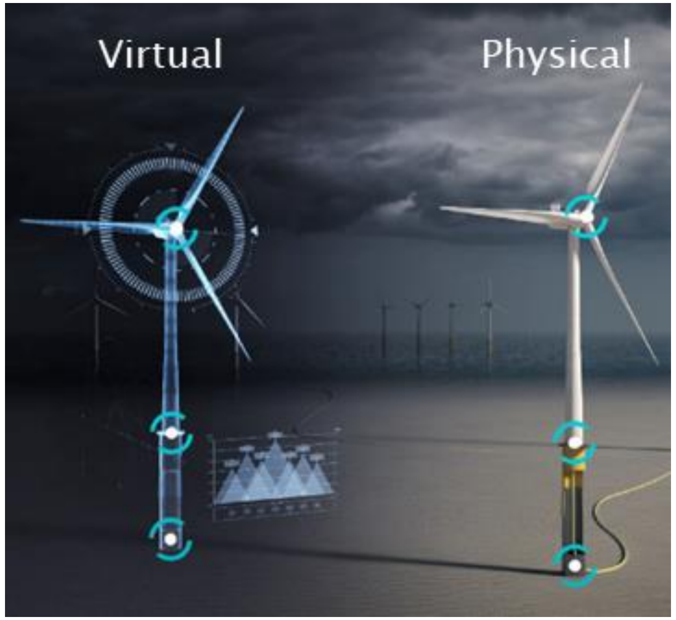
2. Without having to go on-site
   (Limiting on-site trips to legal value)

3. Continuously & In Real time
   (Limiting intervention delay and costs)

The Digital Twin – Definition and Main Principles

*The Digital Twin is a virtual representation of a physical asset that **calculates performance and makes system information available**, to provide decision support, based on:*

- *An accurate and reliable physics-based model (virtual),*
- *A high-fidelity sensor data streaming to mirror the life of its corresponding physical asset (physical)*



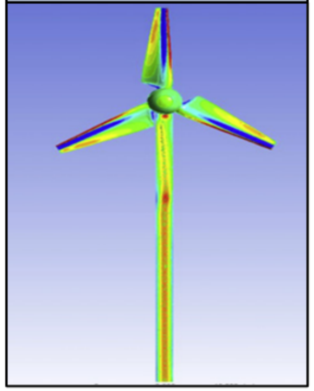
- Fei Tao et al. – 2018- Digital twin-driven product design, manufacturing and service with big data
- DNV – 2014- Fatigue design of offshore steel structures

Our Physics-based solution – Fatigue estimation

MEASUREMENTS

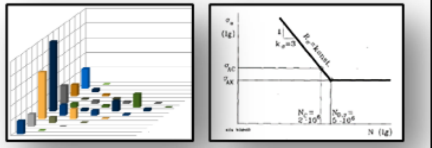
MODELS

DIGITAL TWIN



Stress

FATIGUE TOOLBOX



Rainflow counting

Miner's Rule

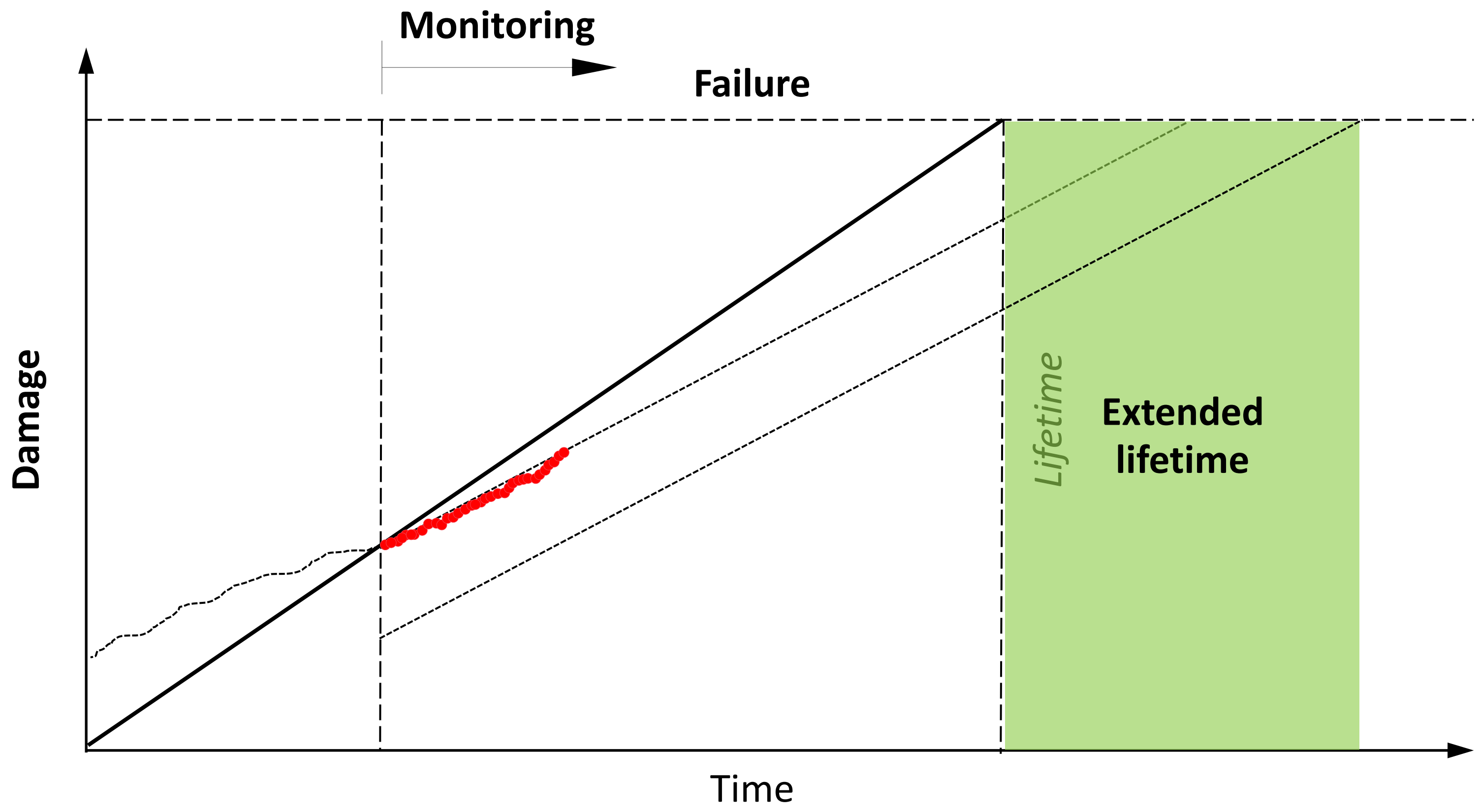
Damage, Fatigue, R.U.L.

O&M DECISION SUPPORT

Digital Twin applications :

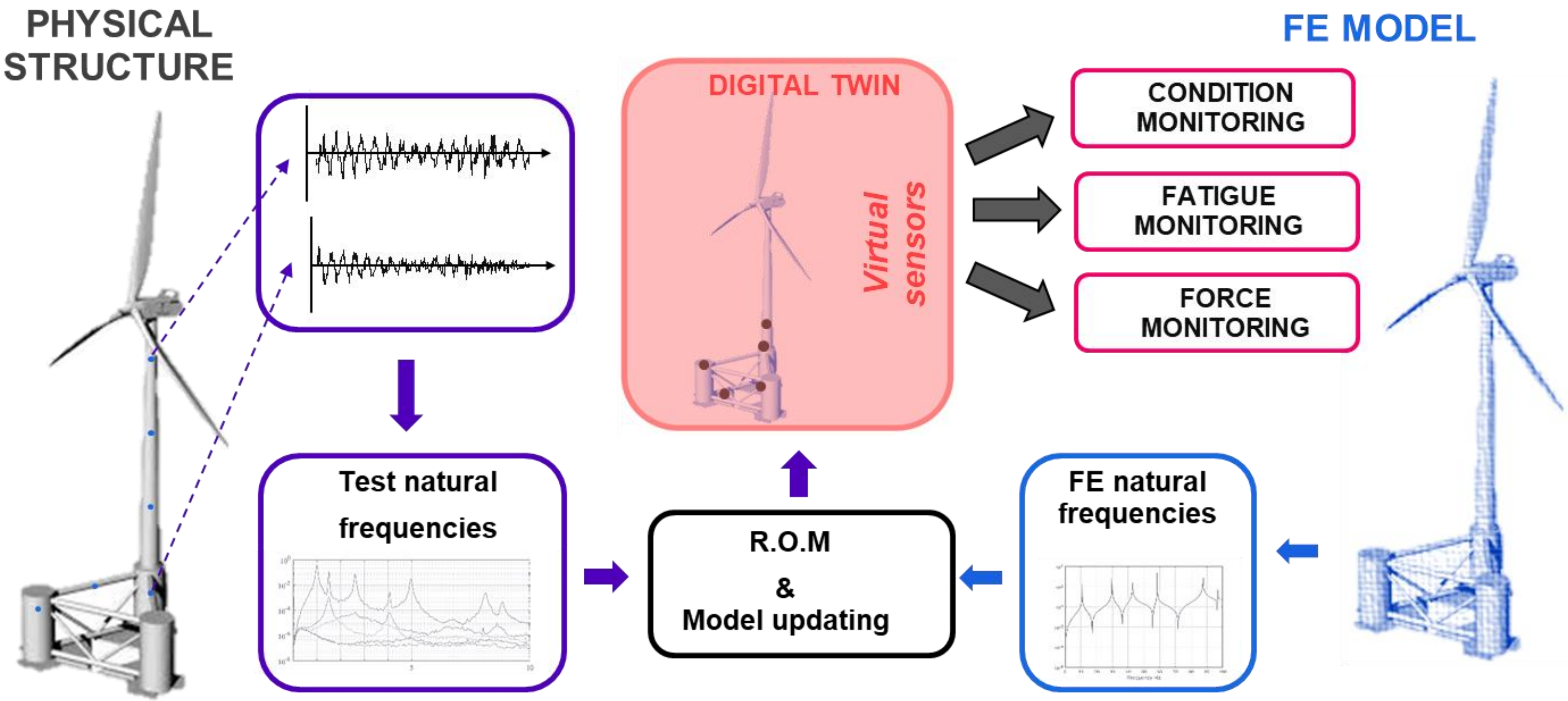
- Virtual sensors
- Fatigue & remaining useful life (R.U.L.) estimation
- Mechanical parameters tracking
- Design feedbacks

Fatigue Monitoring ➔ lifetime extension

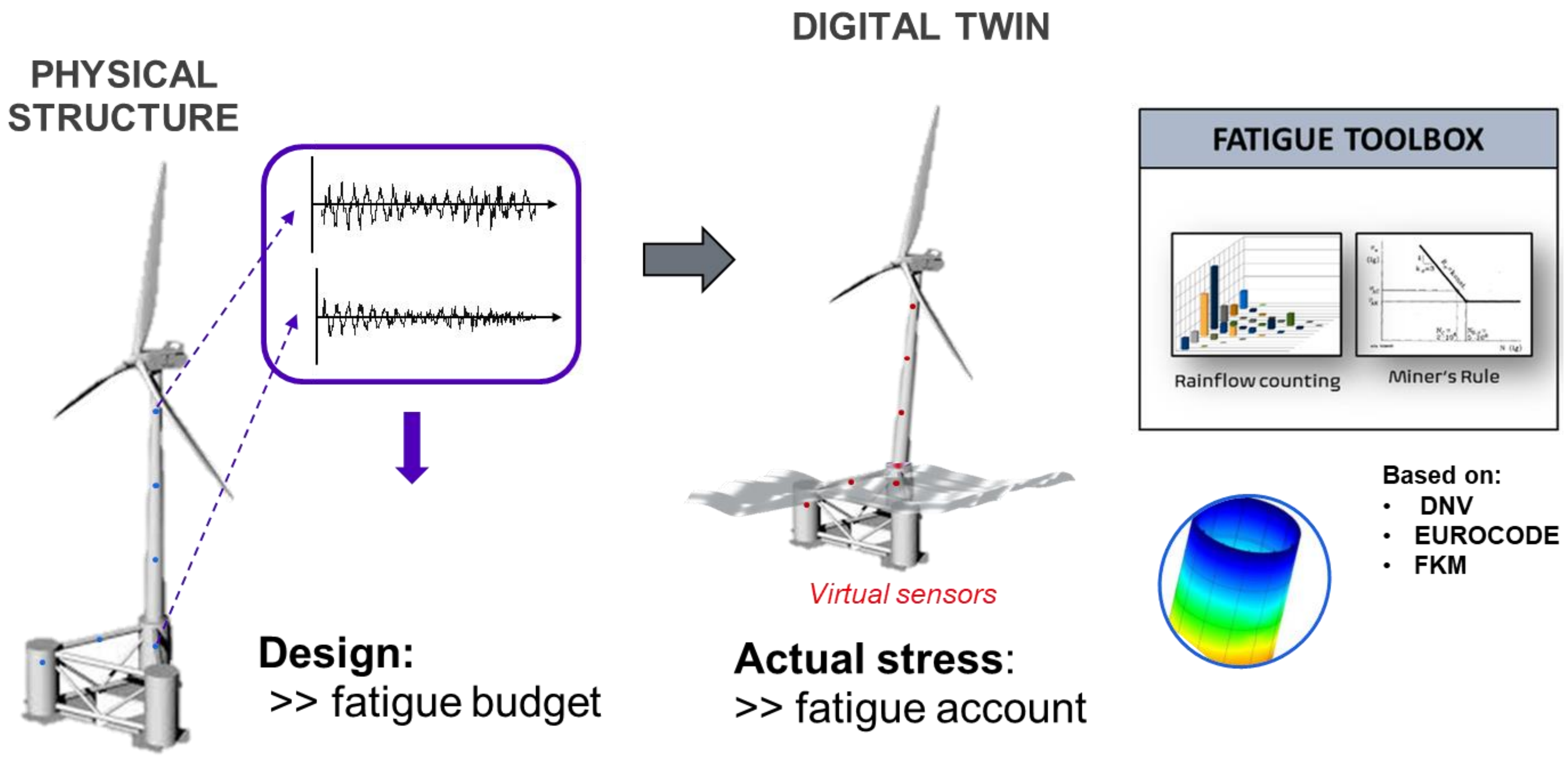


Nabuco et al:Fatigue Stress Estimation of an Offshore Jacket Structure Based on Operational Modal Analysis. Journal of Shock and Vibration, 2020

FOWT Digital Twin use case



Fatigue Monitoring stress account

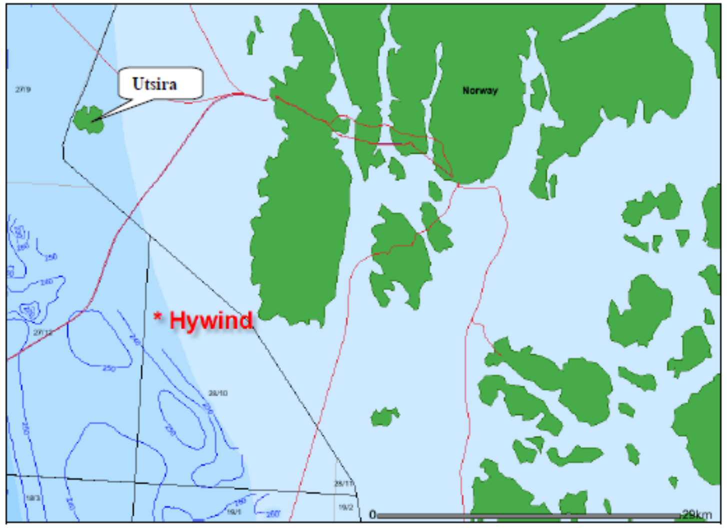


Zefyros Floating Offshore Wind Turbine

DIONYSOS Project

[Digital Intelligent Operational Network using hYbrid SensOrs / Simulations approach]

FRANCE ENERGIES MARINES



Zefyros location (ex-Hywind)
59°N-5°E

Hywind Main dimensions and Data	
Wind Turbine Generator	2.3 [MW]
Turbine weight	138 [Tons]
Height of Nacelle	65 [m]
Rotor diameter	82.4 [m]
Hull draft	100 [m]
Displacement	5388 [m^3]
Diameter water line	6 [m]
Maximum diameter under water	8.3 [m]
Pitch Control	Dynamic

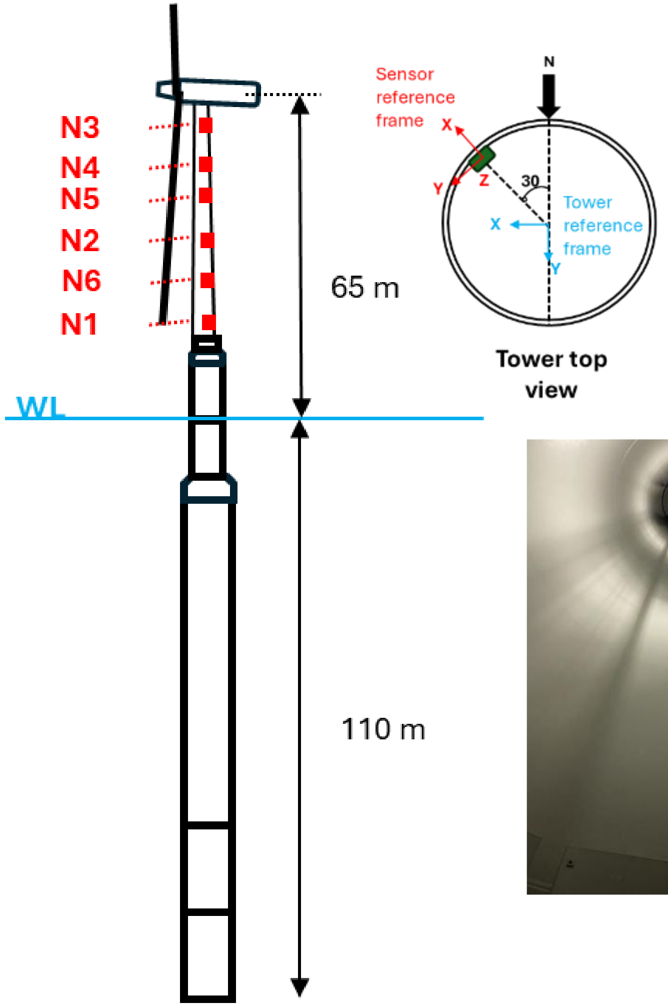
SHM-France precend

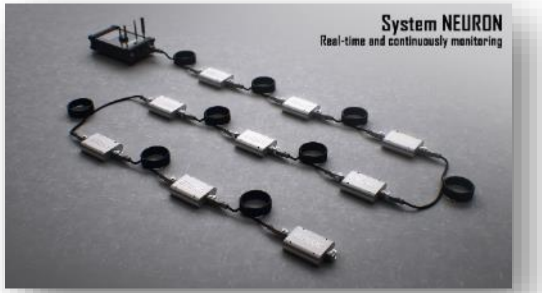
SERCEL A Viridien Business

Data collection as Digital Twin inputs

Structural data : S-morpho monitoring system:

- ✓ One cable hard-wired sensor network
- ✓ 6 nodes including 3D accelerometers, 3D magnetometers and temperature sensor. (Fs= 40Hz)
- ✓ A secured cloud architecture for fast processing and provision of a single dashboard, highlighting strategic data.
- ✓ Quick & easy to install (magnets)
- ✓ Low power consumption: 50W for a 10-node network

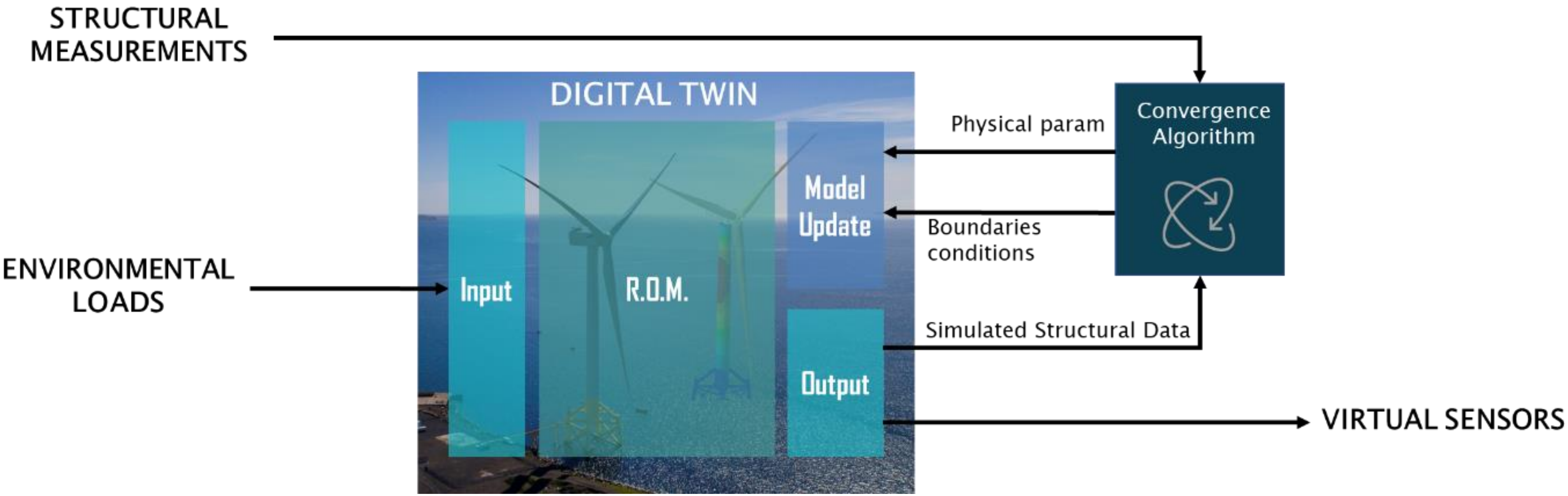




Environmental Data (loads):

- ✓ MeteoFrance Data (FEM)
- ✓ Scada Data
- ✓ Wind, Wave, Current (Fs= 1hour)

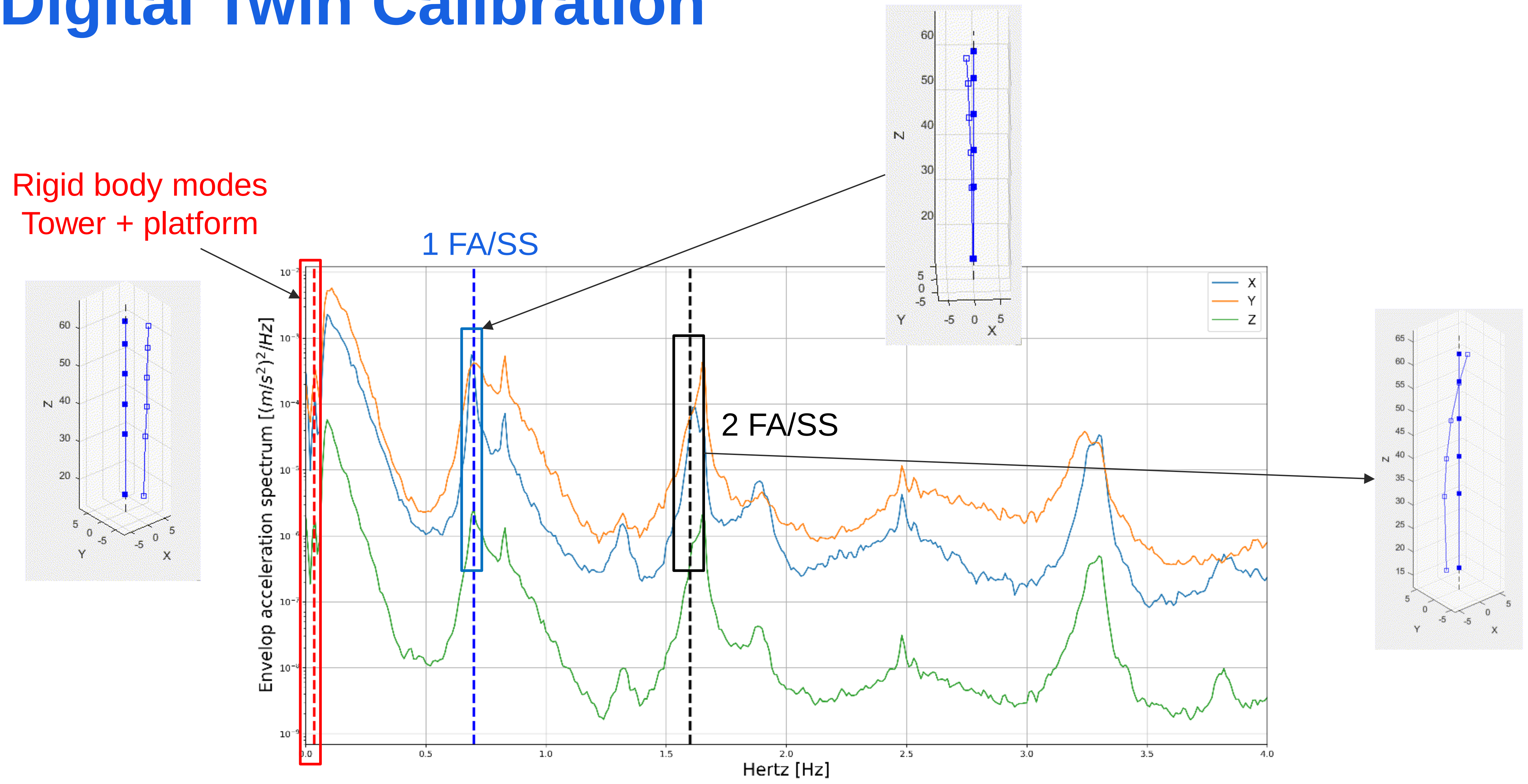
Digital Twin Operations



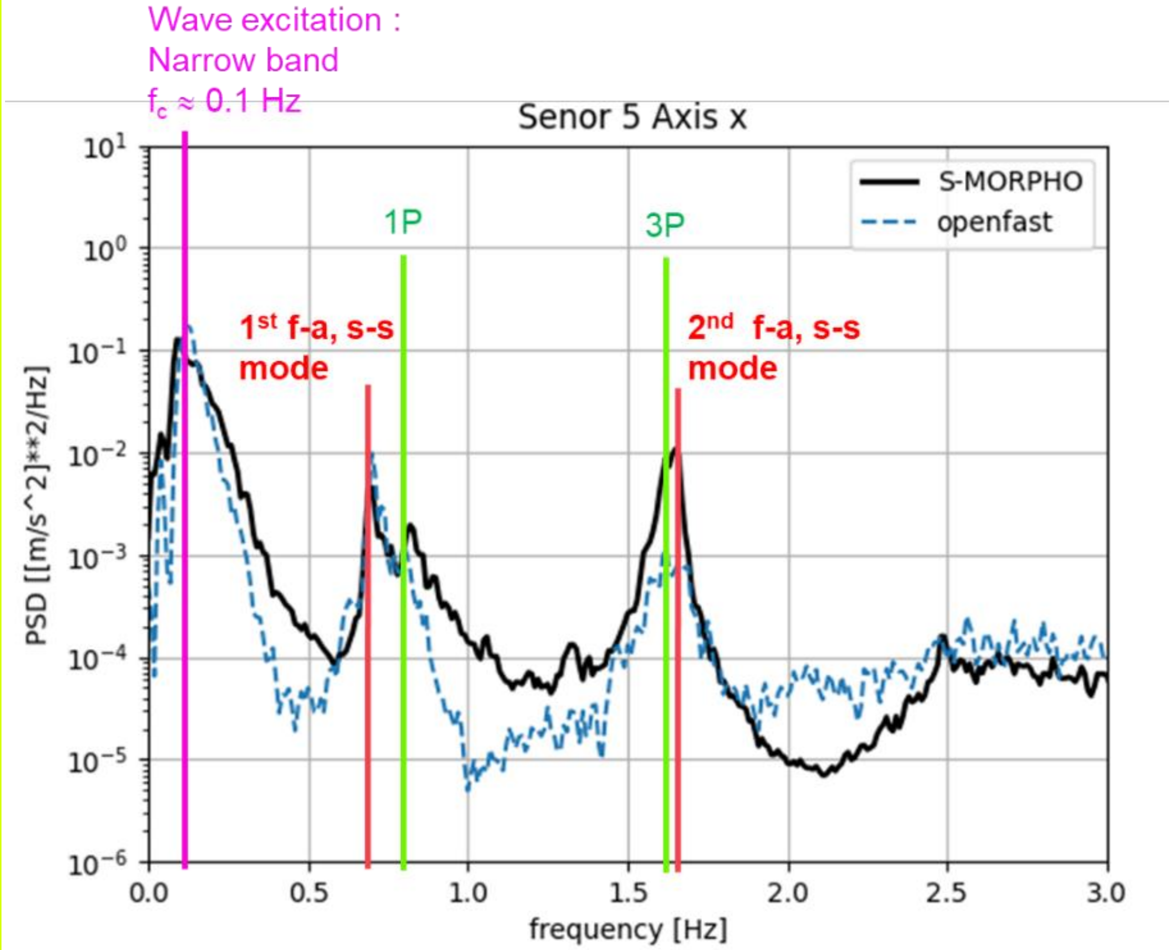
Tested with differents physical simulator:

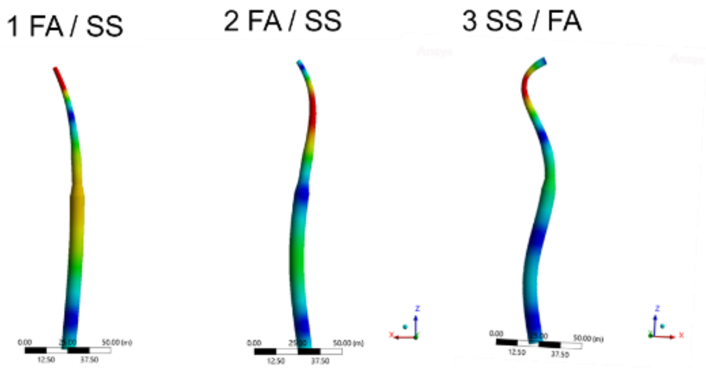
- ANSYS (as reference, SERCEL)
- OPENFAST (as standard option, SERCEL+FEM)
- HOMER (BV specific SW)

Digital Twin Calibration



Digital Twin model Results





		DT Calibration	DT Operation
Tower modes	**Measure [Hz]**	**Ansys [Hz]**	**OpenFast [Hz]**
Mode 1 FA	0.69	0.72	0.72
Mode 1 SS	0.69	0.72	0.70
Mode 2 FA	1.62	1.69	1.73
Mode 2 SS	1.65	1.69	1.70

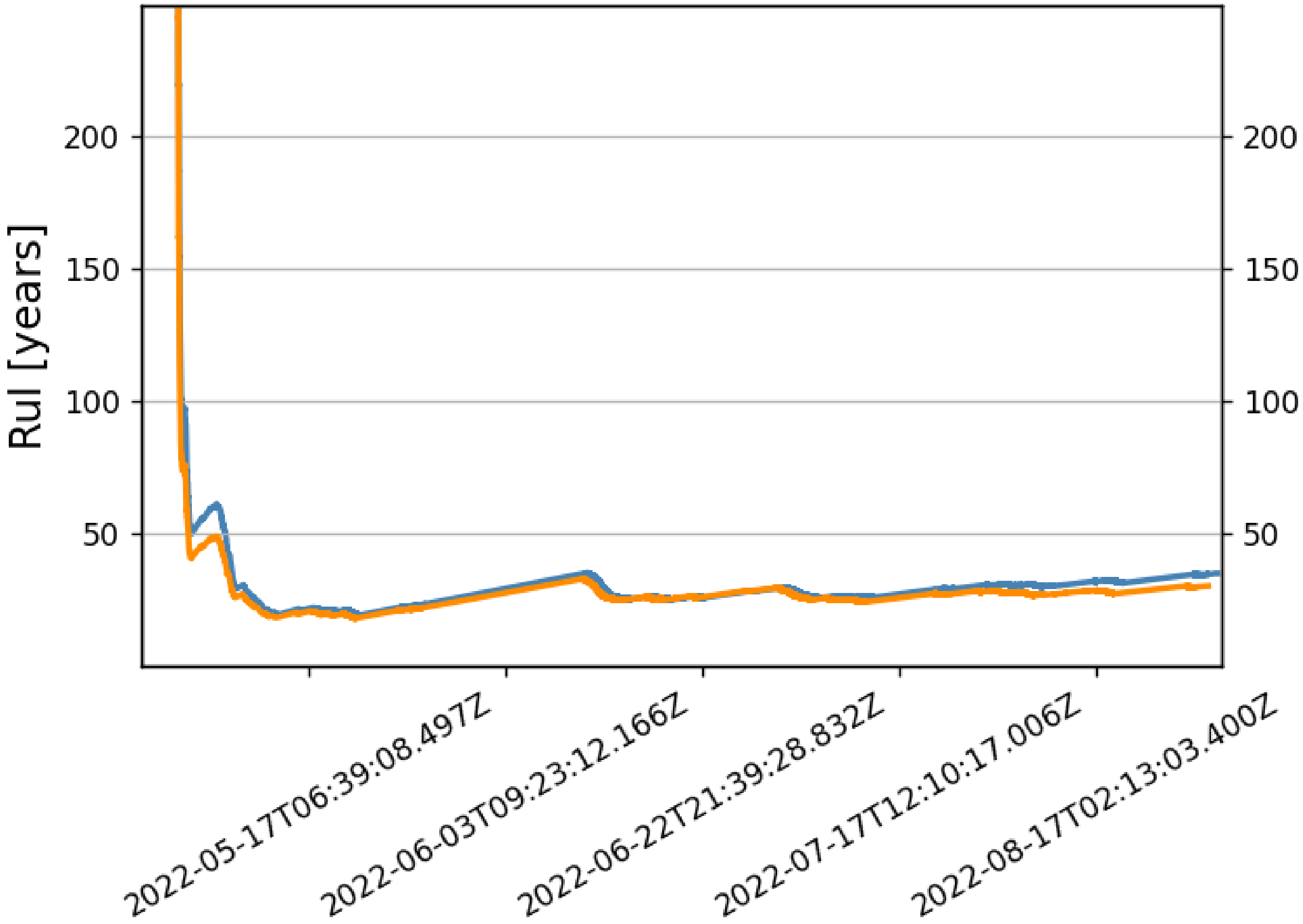
Fatigue & R.U.L. Estimation

Fatigue estimation parameters:

- Transition piece : 8 hotspots
- Beam stress

First results:

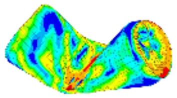
- Load history integration
- In progress



DIGITAL TWIN BENEFITS
Operational, financial and other benefits

Operational benefits

- ✓ **STRUCTURAL INTEGRITY** management in continuous mode
- ✓ In-depth **STRUCTURAL INSIGHTS**
- ✓ **PREDICTIVE MAINTENANCE**
- ✓ In-depth structural insights : **RISK** management enhancement



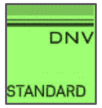
- ✓ **STRESS** & **FATIGUE** analysis in real-time
- ✓ **R.U.L (*)** estimation
- ✓ **LIFESPAN EXTENSION** validation

- ✓ **UNIQUE DASHBOARD** for all available measurements
- ✓ **3rd PARTY SENSORS** integration
- ✓ **ONE STOP SHOP** solution

(*) Remaining Useful Life

Financial & other benefits

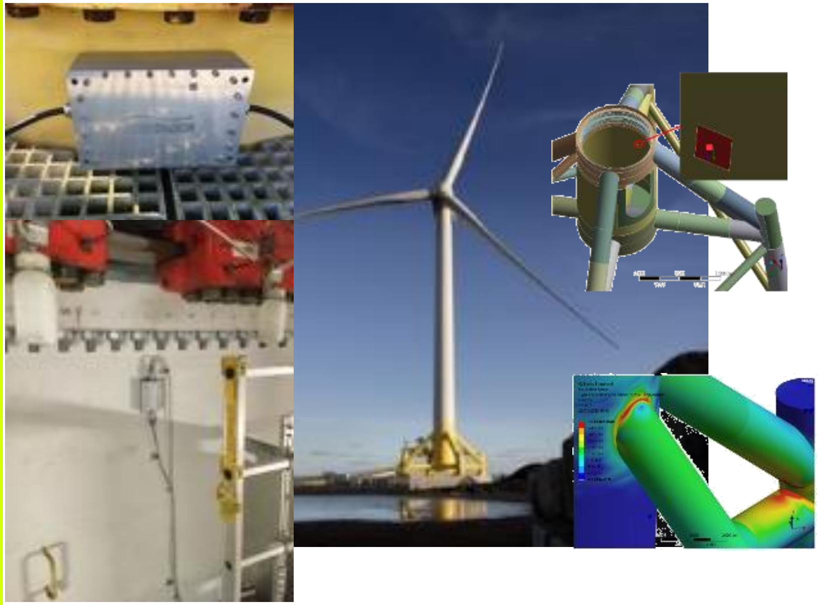
- ✓ **EARLY DETECTION OF ANOMALIES**
  - Avoid excessive & **UNEXPECTED MAINTENANCE COSTS**
  - Plan repairs on time at the **RIGHT COST**
  - **CO_2 footprint reduction** (no useless technical visits)
- ✓ **LESS steel – BETTER design**



- ✓ **COMPLIANCE** with futures **REGULATIONS STANDARDS**

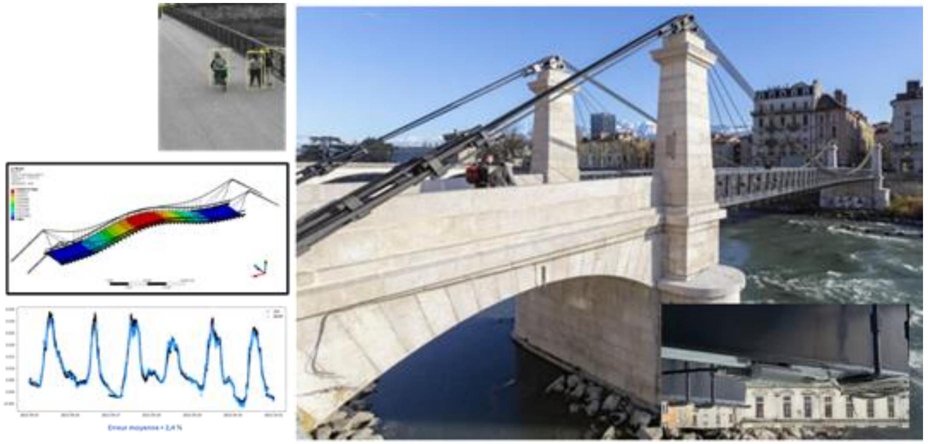
- ✓ **DIGITAL EVIDENCE** to assess regulations compliance
- ✓ Valuation of **OPERATING PROFITS**
- ✓ Contribution to **LCoE OPTIMIZATION**
- ✓ Increase of **PROFITABILITY**
- ✓ **DIGITAL EVIDENCE** for **M&A TRANSACTIONS**

Other DT Use cases



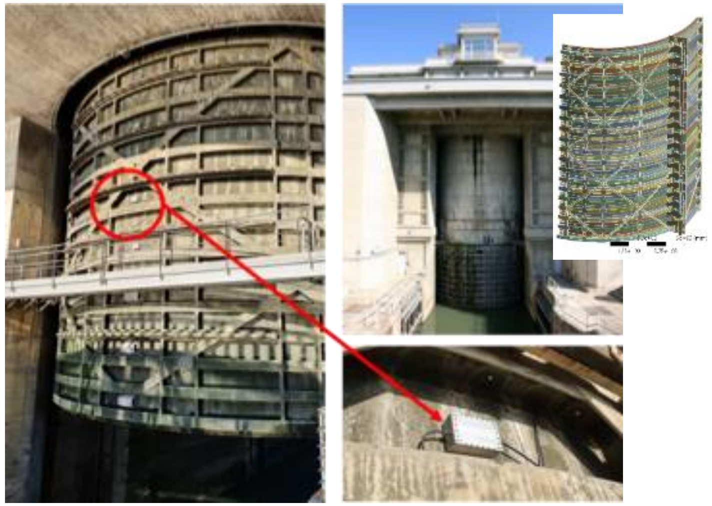
Jacket Bottom-fixed OWT

- Real time structural monitoring (static deformation, Modal analysis)
- Fatigue and Residual lifetime estimation



Footbridge

- RT Structural monitoring (static, dynamic)
- Predictive model of deformation (pedestrian, environmental loads)
- Boundaries conditions tracking (stiffness, friction)



Rhone River Water Lock Gate

- RT Structural monitoring (static structural indicators)
- Specific Hotspots local fatigue estimation
- Critical hotspots identification for predictive maintenance

THANK YOU

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Main Failures in Floating Offshore Wind Turbine

52% of failures in a FOWT are due to Support Structure.

- 36% - Tower and Transition Piece Failures
- 34% - Mooring Subsystem
- 30% - Floating Foundations

But, in terms of RPN (Risk Priority Number = Severity * Occurrence * Detection), the ranking of failure is:

1. Floating Foundations.
   The failure modes are : Hitted by dropped objects, Watertight Failure (very hard to detect)
2. Mooring Subsystem :
   Mooring Lines Broken is the main failure mode
3. Tower & Transition Piece Failures:
   Failure modes : Cracks, Abnormal Vibrations, Fault Welding, Deformations, Collapse