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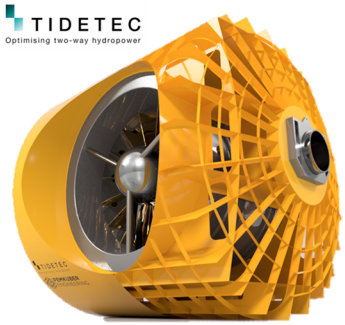
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

Development and validation of models for material degradation, strength assessment and structural health monitoring

OVIDI CASALS BOIXADÓS, **COMPASS**

FIBREGY 1st Information Day
2021/07/01 – On-line event

Partners and Workpackages interconnections



WP3

Development and validation of models for material degradation, strength assessment and structural health monitoring

WP2

Fibre-based materials, coatings and connection solutions for OWTP platforms

WP4

Design, engineering and development of guidelines

WP6

Technology validation and demonstration

- Experimental information from **WP2** and **WP6** will be used to validate the numerical results and for the preparation of basic benchmark cases
- Demonstration of the numerical analysis tools developed in **WP3** will be done by applying them in the design and engineering tasks of **WP4** and to develop the two complete CAE models of the targeted concepts in **WP6**

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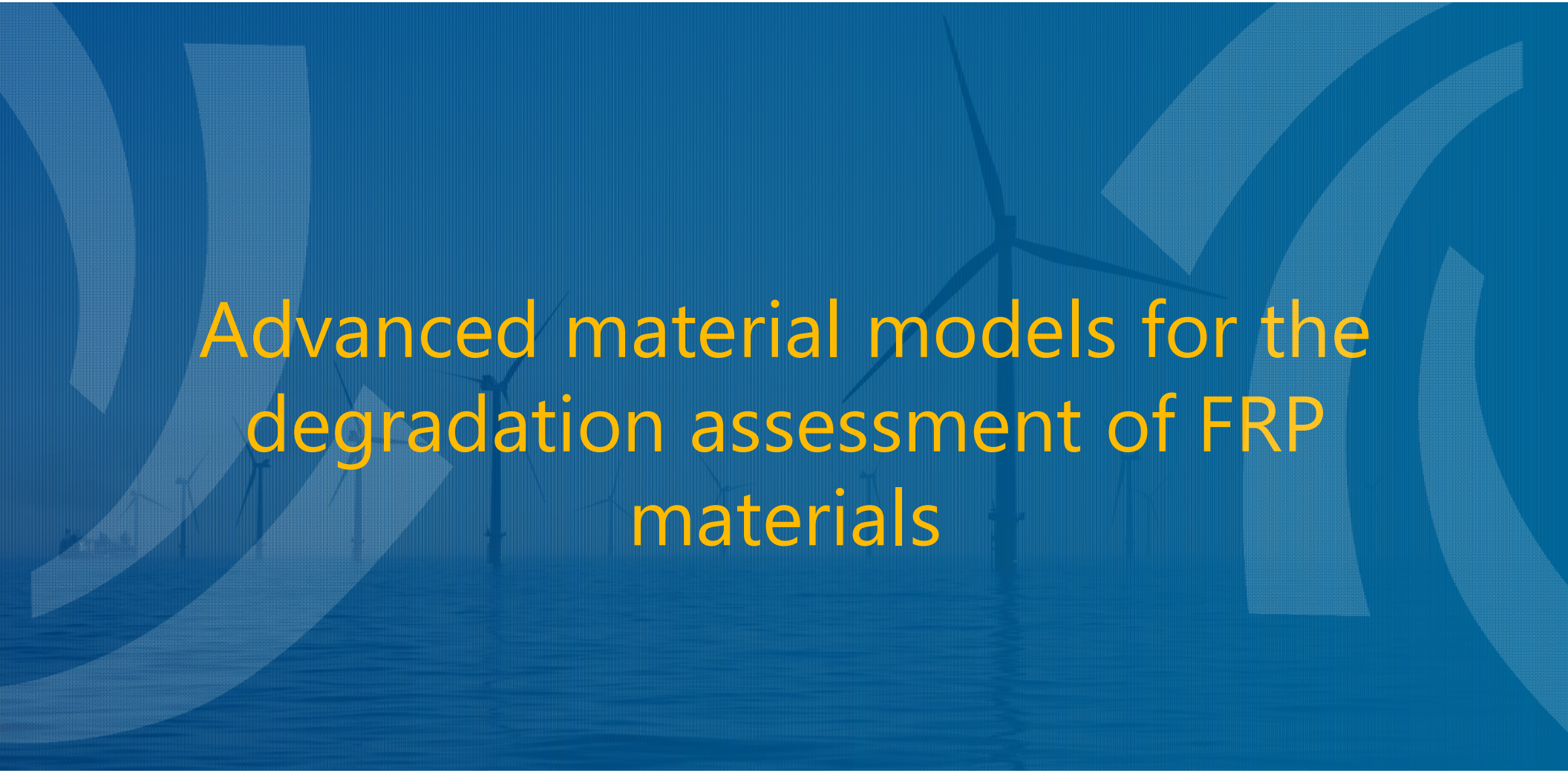

Advanced material models for the degradation assessment of FRP materials

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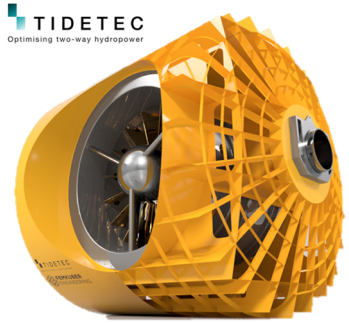
Extension and fine-tuning of a Serial-Parallel RoM-based degradation assessment model

- Extend the advanced **SP-RoM model** to assess the **fatigue life of FRP** structural components and functional elements of large OWTP platforms
- Development of a **constitutive model for thermoplastics**
- Development of a degradation model for the **structural adhesives**



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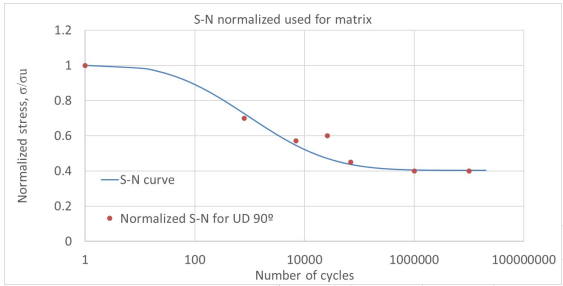
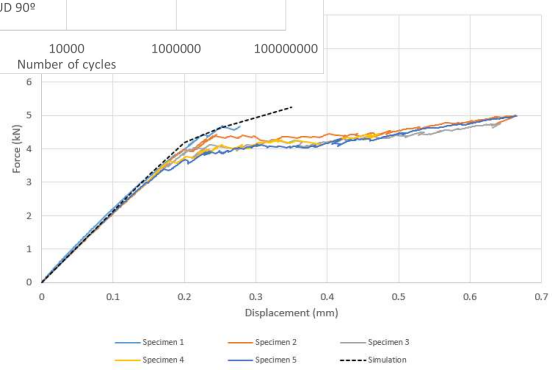
FDA methodology – Relevant information to be obtained from the experimental tests for numerical model validation purposes

WP2 → **WP3**

- **Static tests** for the assessment of the longitudinal, transverse and shear strength of the laminates
- **S-N fatigue tests** of UD0º and UD90º specimens
- Measured force-displacement relations
- **Connection's testing** (single lap, double lap, T-joint …)
- Images and/or continuous recordings of the experiments for the identification of damage initiation and further correlation with the force-displacement curves





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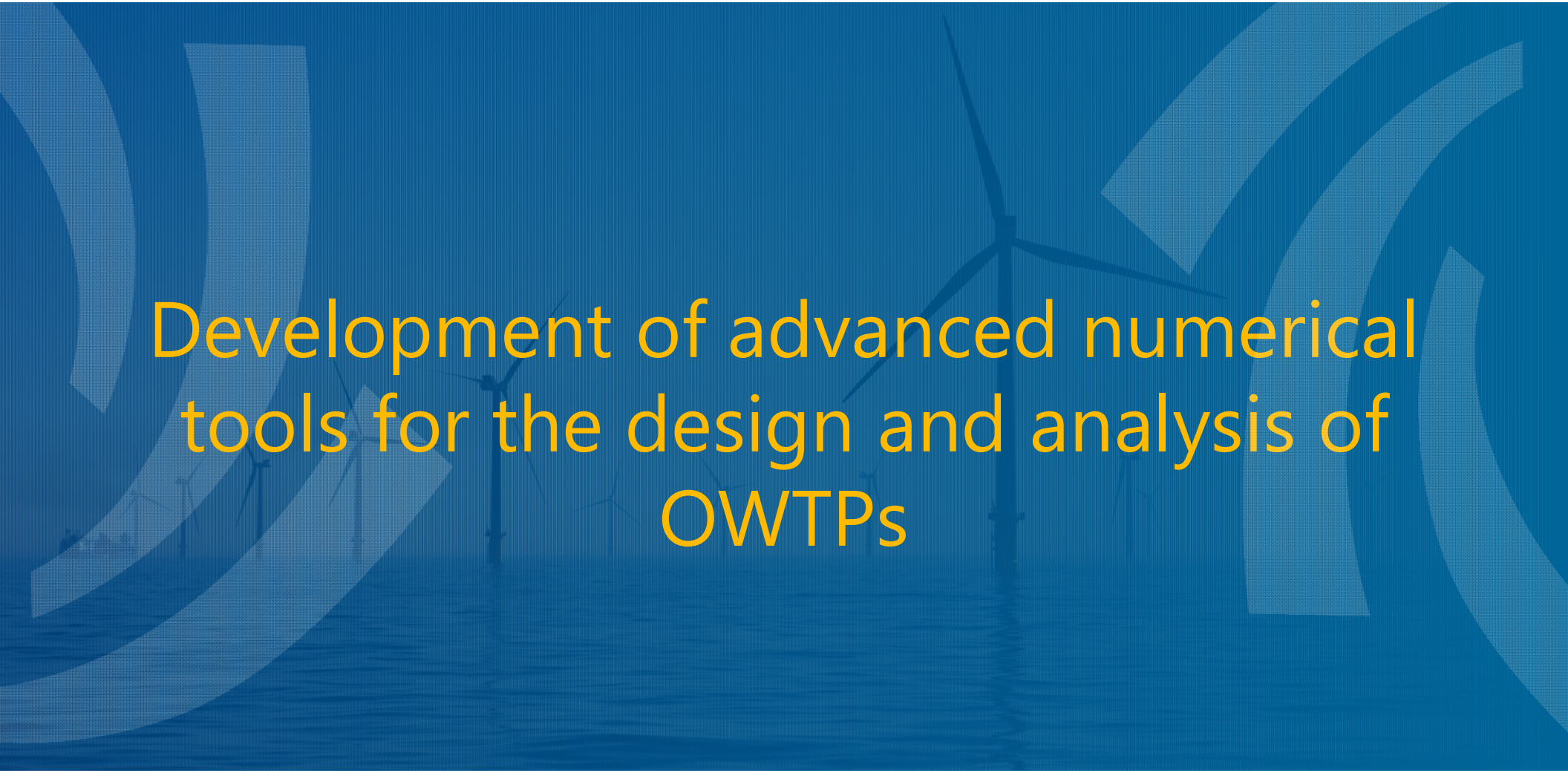
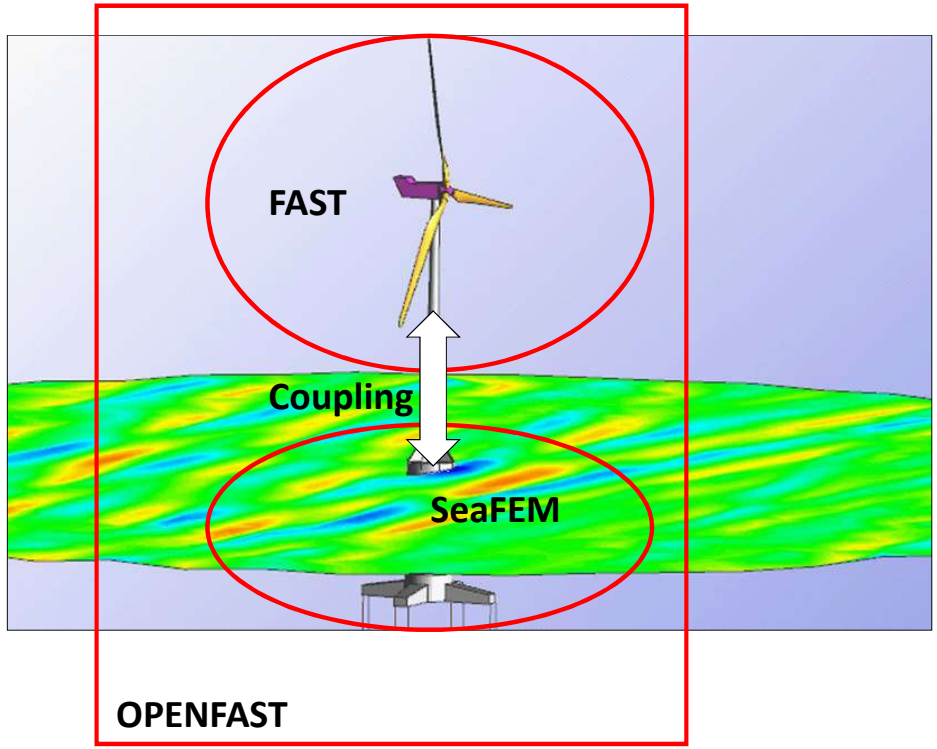


Development of advanced numerical tools for the design and analysis of OWTPs

FIBREGY

Extension of a coupled aero-hydro-servo-elastic solver for multi-wind turbines

- The hydro-elasticity solver **SeaFEM** will be integrated within the modular framework of **OpenFAST**



FIBREGY

Extension of a coupled aero-hydro-servo-elastic solver for multi-wind turbines

- The hydro-elasticity solver **SeaFEM** will be integrated within the modular framework of **OpenFAST**

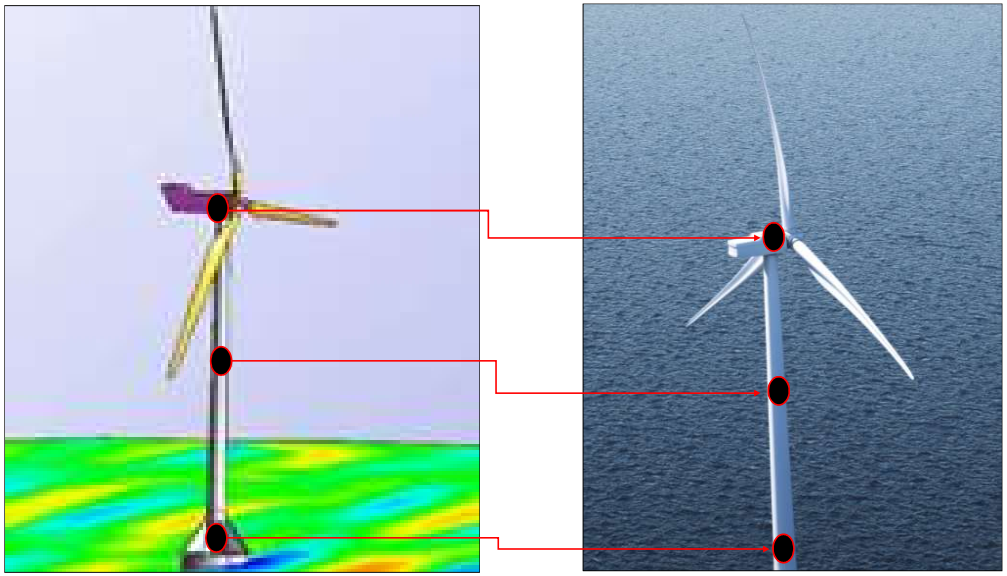
- The wind turbine analysis tool **OpenFAST** will be extended to handle the structural dynamics of **multiple wind turbines** operating on the same platform

FIBREGY

Development of a digital twin (DT) for structural health monitoring (SHM)

- An analysis solution **SHM**, based on a **Digital Twin (DT)** of the structure (MOR) will be implemented. The DT model will be integrated with SeaFEM-OpenFAST to run in a closed loop with sensor data, offering real-time stress patterns of the whole structure

Structural Health Monitoring (SHM)



Digital Twin numerical model

Real time measurements

FIBREGY

Development of a digital twin (DT) for structural health monitoring (SHM)

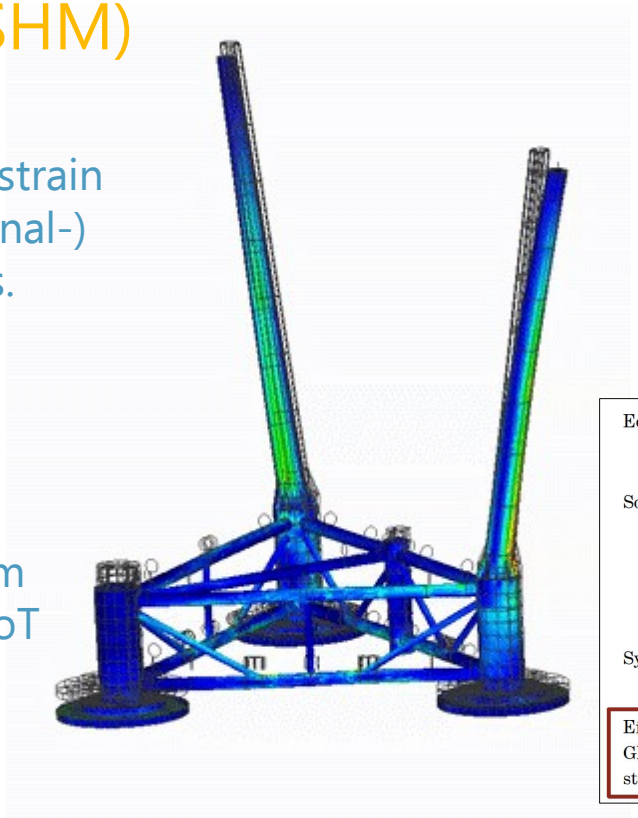
MONITORING SYSTEM

1. Sensors (accelerometers + strain gauges + fibre glass -optional-) installed in key ROM points.
2. Sea state monitoring.

STRUCTURAL HEALTH MONITORING

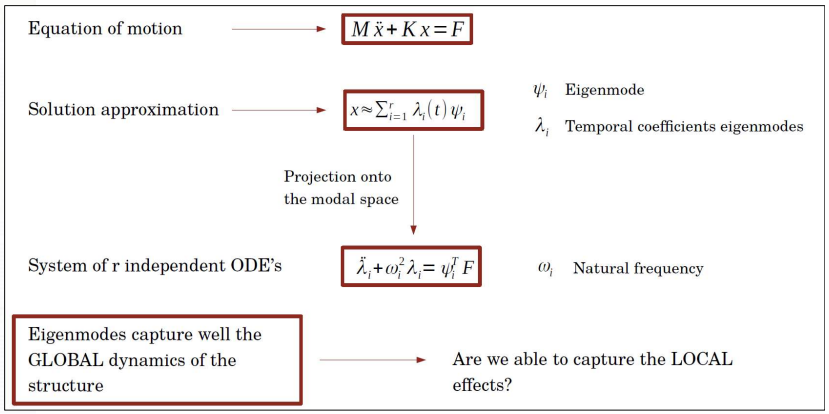
1. Integrate monitoring system and ROM by means of an IoT platform (OSI4IOT).

SI4IOT



STEPS to build the REDUCED ORDER MODEL

1. Compute the first n global eigen-modes of the structure (modal analysis)
2. Create a dynamic MOR, projecting sea and wind loads on the reduced modal space.
3. Resulting low cost operation model running in parallel. Current TRL 5-6.



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Development of a digital twin (DT) for structural health monitoring (SHM)

Increase accuracy to compute local effects (e.g. hot spots)

Partitioned Singular Value Decomposition — Data-driven strategy

full scale FEM analysis → Snapshots matrix

$$\mathbf{X}_d = \begin{bmatrix} x_{11} & x_{12} & \cdots \\ \vdots & \ddots & \\ x_{N1} & & x_{NP} \end{bmatrix}$$

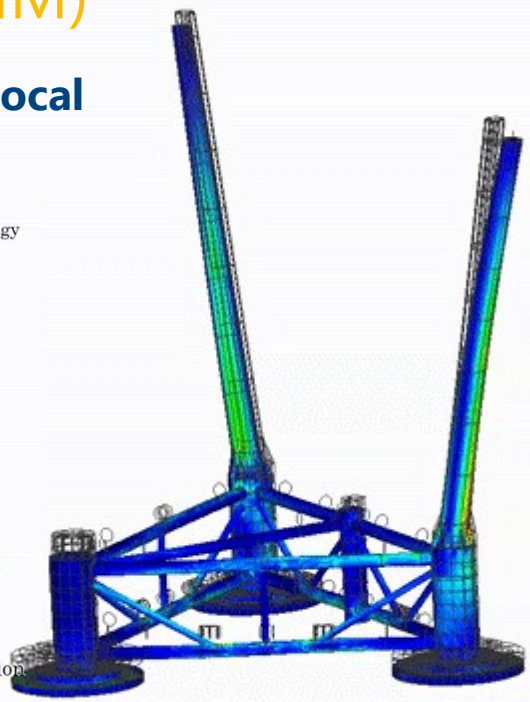
N Degrees of Freedom
P time steps

$\mathbf{X}_d = [\mathbf{X}_1 \quad \mathbf{X}_2 \cdots \mathbf{X}_Q]$ Partition into Q block matrices

$\mathbf{X}_d = \mathbf{U}\mathbf{S}\mathbf{V}^{*T}$ Truncated Singular Value Decomposition

Projection of the motion equation onto the reduced space → Computation of the temporal coefficients $q_i(t)$

$x(t) \approx \mathbf{u_1} q_1(t) + \mathbf{u_2} q_2(t) \cdots \mathbf{u_k} q_k(t)$ Solution approximation



STEPS to build the REDUCED ORDER MODEL

1. Compute the first n global eigen-modes of the structure (modal analysis)
2. Compute a set of representative load cases (i.e. those defined in the applicable norms)
3. Use the Model Order Reduction technique to calculate local (non-linear) modes (partitioned approach).
4. Build a Reduced Order Model combining the local and global models.
5. Couple the Reduced Order Model with a (reduced) seakeeping solver.
6. Run the model in operational

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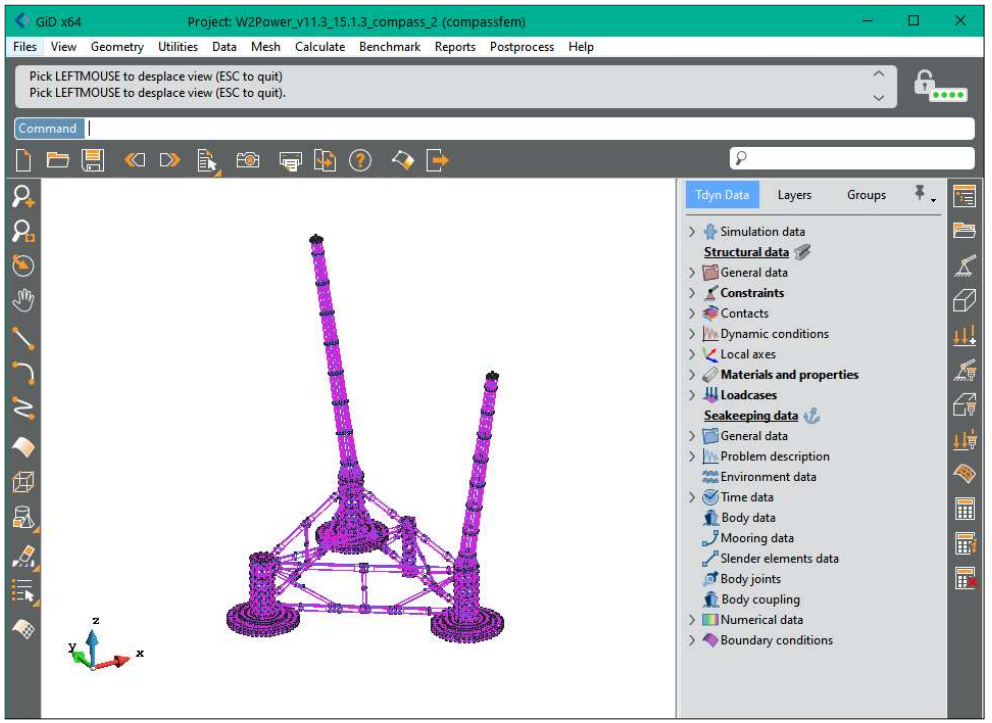
Graphical user interface integration of the developments and implementations

Integration of all the numerical developments into a unified GUI to supply end-users with a ready-to-use analysis and assessment tool

- CAD design tools
- FEM structural analysis
- FEM seakeeping solver
- OpenFAST integration
- FRP materials definition
- Fatigue Damage Assessment tools
- MOR-based Digital Twin model



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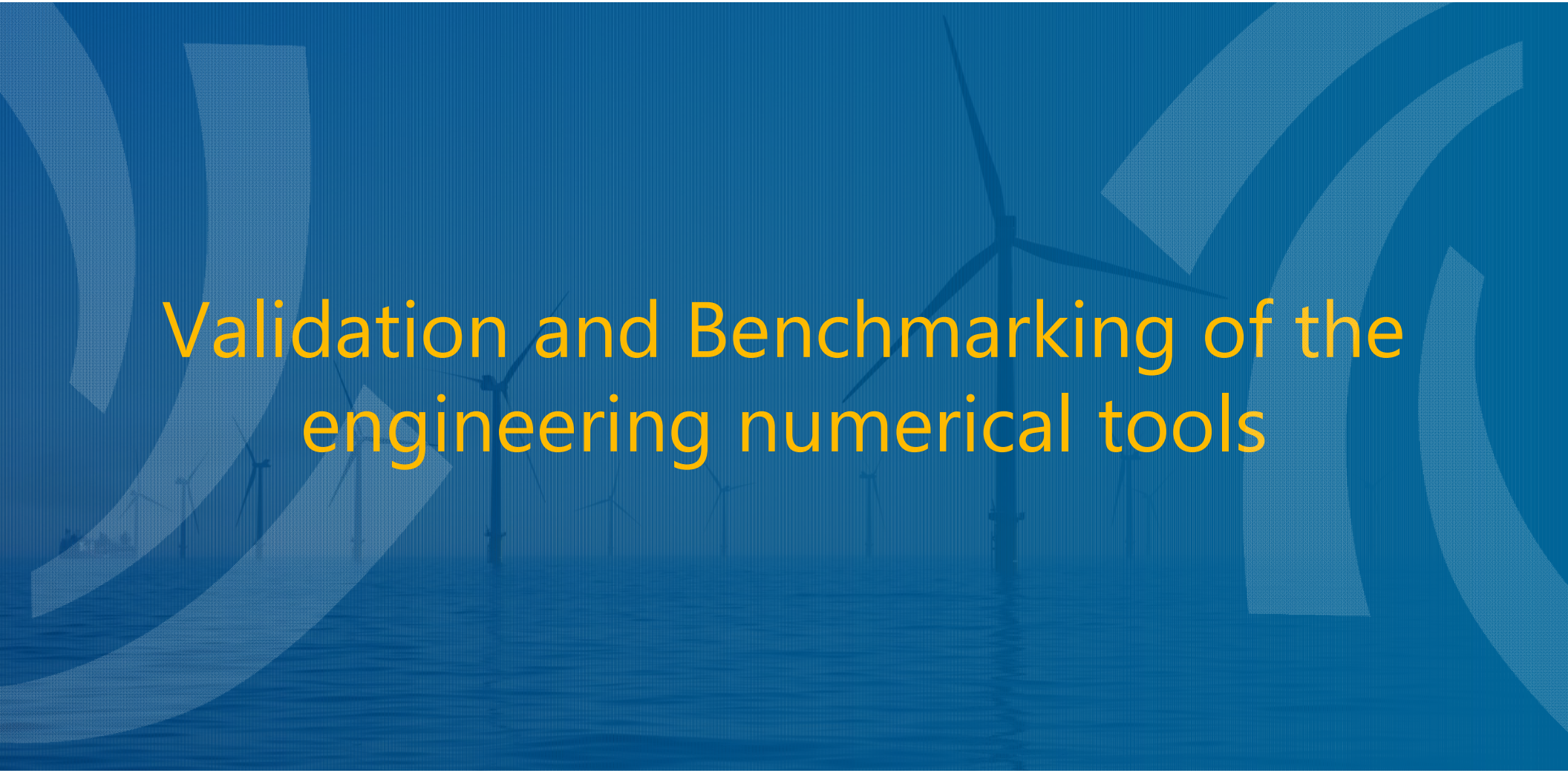

Validation and Benchmarking of the engineering numerical tools

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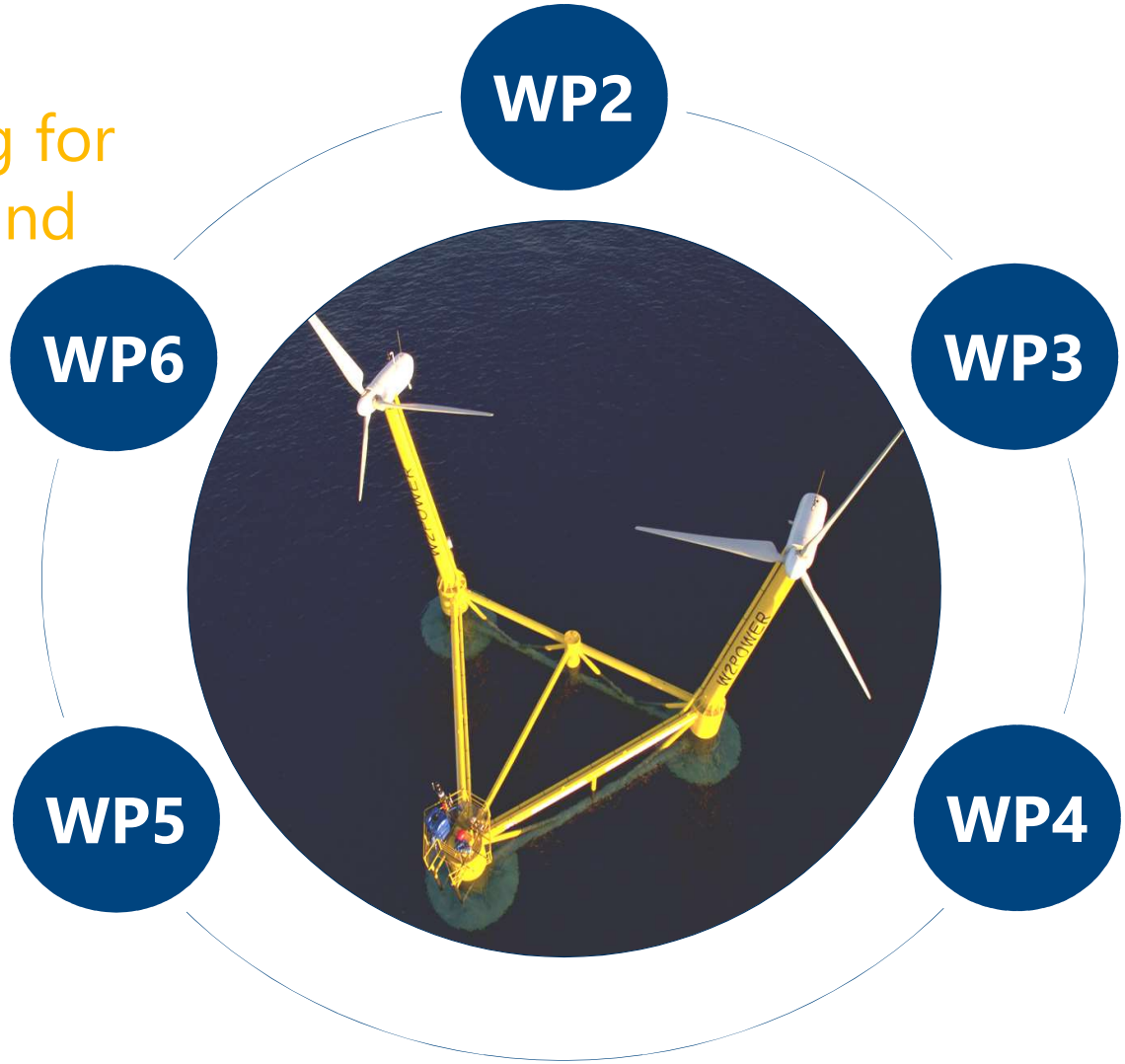
Validation and benchmarking for the software developments and applications

- Adjust the numerical tools for the prediction of the mechanical behavior and fatigue performance of FRP materials
- Generation of benchmark models for testing each development
- Test and verification of the GUI tools and their usability
- Application of the numerical tools in all stages of the design and assessment of the two OWTP concepts



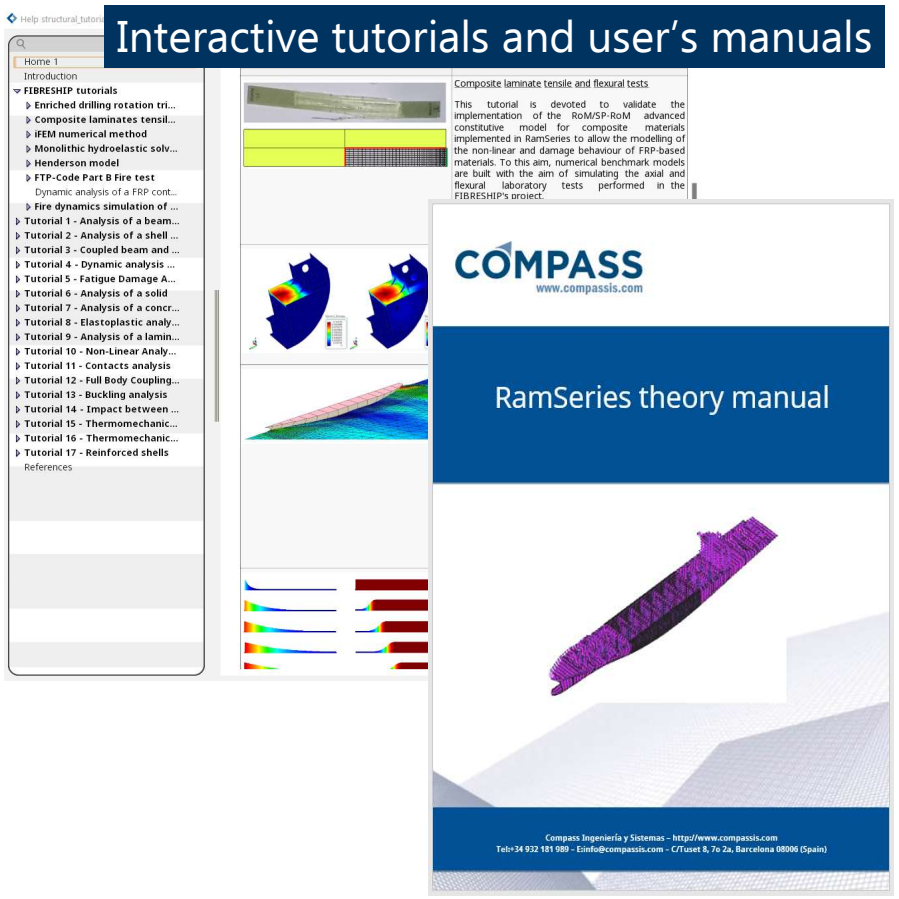
Release of the analysis tools, documentation and training

Outputs to be provided to the technical partners of the project

- Preparation of training material, courses and webinars to be offered to the technical partners involved in the design assessment activities

Outputs to be provided to all stakeholders

- Release of a validated version of the computational tools developed within the project
- Generation of the necessary documentation for each validation case
- Provide a reference user manual for the new developed tools (including recommended guidelines and tutorials)



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THANKS