Part 2

Performance in Tidal Energy – Technical Session 1710-1750

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 727689

Increased Reliability of Tidal Rotors: FMEA & RAM Assessments

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FMEA (1/2)

- <u>Objectives</u>

➢ Understand and increase the reliability of tidal energy devices

➢ Develop a reliability methodology based on Failure Modes and Effect Analysis (FMEA) methodology with inputs from partners' experience and existing literature.

➢ Recommend actions which will mitigate or eliminate the critical failures

  ➢ Address redesign recommendations development of novel and advanced components

  ➢ Address Monitoring recommendations for for development of advanced monitoring strategies

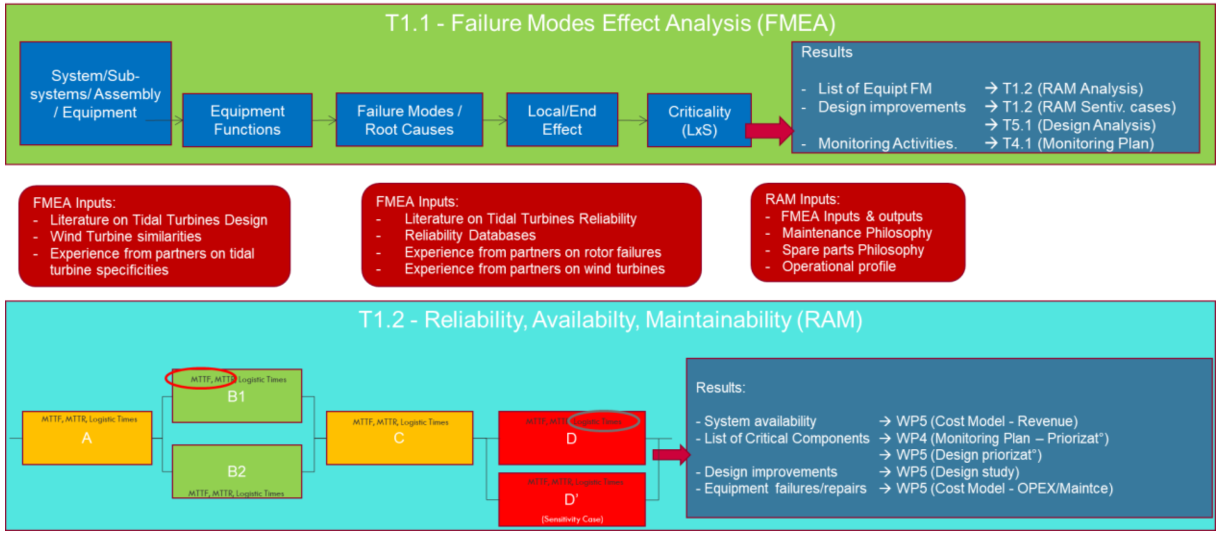
- <u>Achievements</u>

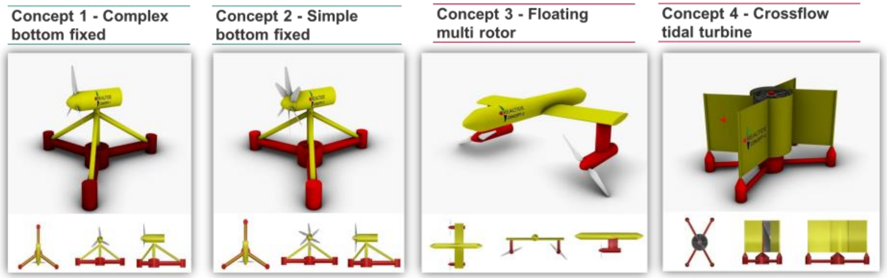
➢ Definition of 4 generic tidal turbine concepts in order to reflect as much as possible future likely commercial design

➢ Redefinition of FMEA methodology in order to obtain a Reliability analysis in line with the objectives and specificities of RealTide project and which is adapted for an application on a "generic" Tidal Turbine

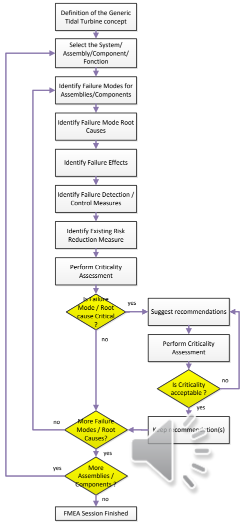
➢ FMEA performed on the 4 generic tidal concepts

T1.1 & T1.2 process and interaction with other WPs





4 generic tidal turbine concepts



FMEA Methodology process

FMEA (2/2)

- Results

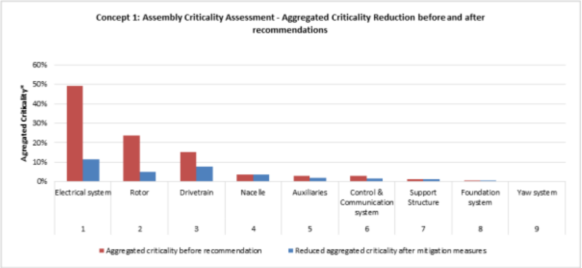
➢ FMEA resulted in a total of 243 recommendations for all of the 4 concepts

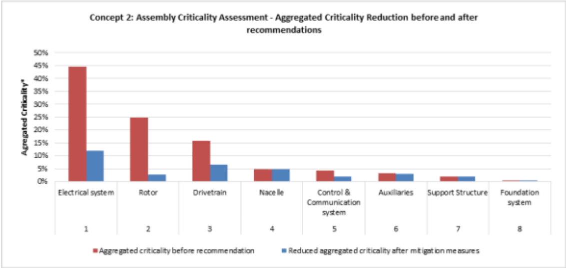
  - ➢ 137 are monitoring recommendations
  - ➢ 106 are redesign recommendation

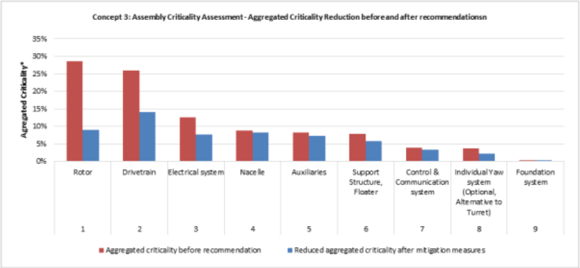
➢ Most critical assemblies highlighted by FMEA

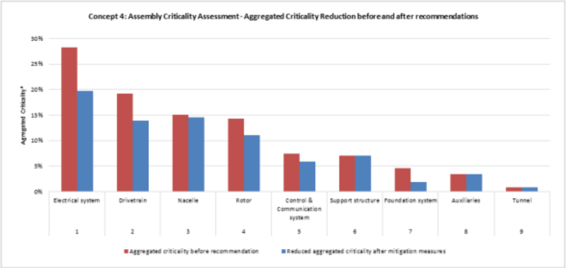
Rotor	Drivetrain	Electric system
• Blades • Pitch System • Yaw System	• Gearbox / Low speed shaft • Low speed shaft dynamic seals	• Power Electronic Converter • Generator • Control System • Transformer(s)

FMEA Results: Ranking of most critical Assemblies for the 4 Generic Tidal Turbines
& potential risk reduction after implementation of recommendations:









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RAM Assessment (1/2)

- <u>Objectives</u>

➢ Conducting a Reliability, Availability and Maintainability (RAM) assessment to understand and increase the reliability of tidal energy devices using the inputs from the FMEA developed in task 1.1.

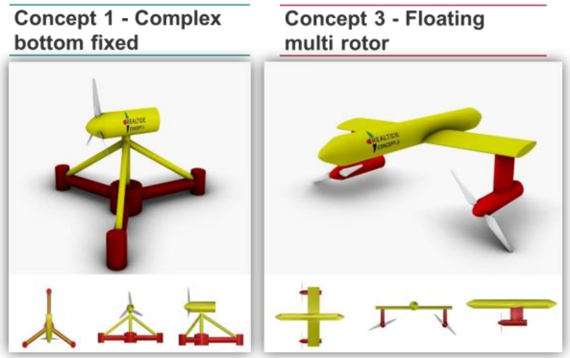
- <u>Scope</u>

➢ The generic tidal turbine concepts “complex bottom fixed tidal turbine” and “floating multirotor tidal turbine” (herewith called concept 1 and concept 3 respectively) were selected from previous D1.1 FMEA study for having their designs and monitoring performances assessed

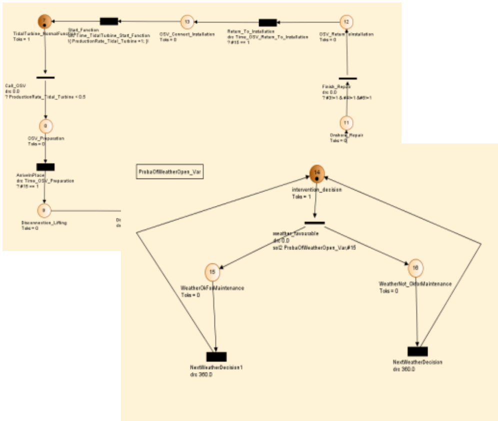
- <u>Data collection</u>

➢ Due to lack of public data bases related to Tidal Turbine, the reliability data describing unplanned failures and subsequent repair of equipment’s has been collected from different sources related to Wind Turbines which provides similarities with tidal turbines in term of functionalities, components types and operability. Thus, data utilized in this study has been taken from Generic Wind Turbine Reliability data sources but mainly from Ingeteam Historical Data (on extended wind turbine farms).

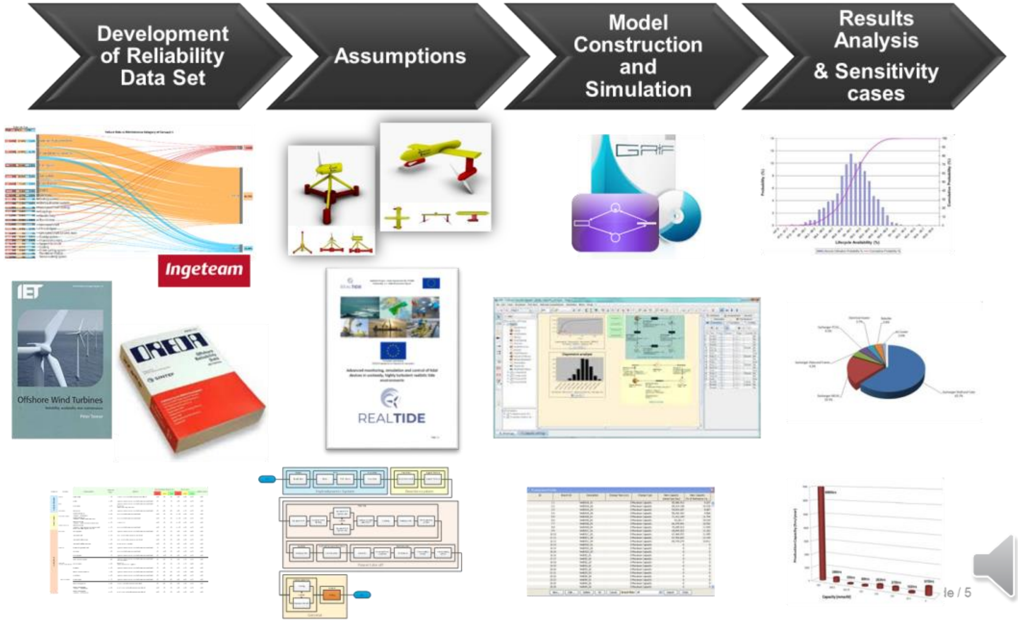
2 selected tidal turbine concepts



Petri-Net RAM Models



RAM Methodology process



RAM Assessment (2/2)

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- <u>Achievements</u>

➢ RAM performed on 2 generic tidal turbine concepts to define critical components (highest contributors to unavailability).

➢ Design and monitoring recommendations from FMEA have been proposed on those components

➢ Alternative cases performed in order to assess effectiveness of the recommendations to increase system availability.

➢ Sensitivity cases were performed to assess the model robustness due to the reliability data uncertainties.

- <u>Conclusions</u>

Recommendations to increase tidal turbine performance in terms of reliability and availability:

➢ Simplify design (reduce quantity of systems components)

➢ Implement Condition Monitoring on critical elements (failure anticipations)

➢ Install turbine in location with good weather conditions / reduce time of connection/disconnection

➢ Perform maintenance in situ as much as possible

➢ Optimise logistic times (OSV/CTV mobilization)

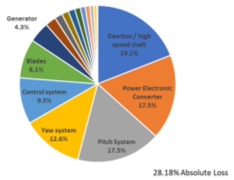
Critical components

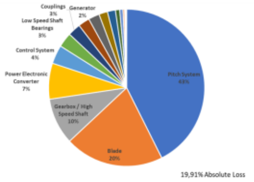
CONCEPT 1

Performance measured	Value
Average Production Availability (%)	71.82%
Annual Average Downtime (days/year)	102.84
Annual Average OSV Mobilisation	2.45

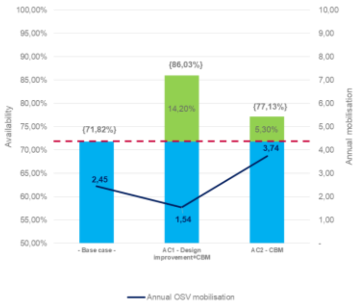
CONCEPT 3

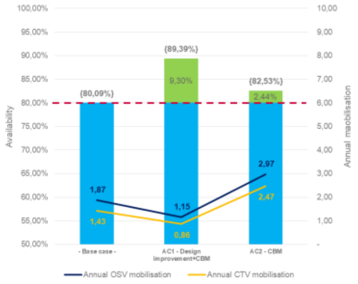
Performance measured	Value
Average Production Availability (%)	80.09%
Annual Average Downtime (days/year)	72.68
Annual Average OSV Mobilisation	1.87
Annual Average CTV Mobilisation	1.43



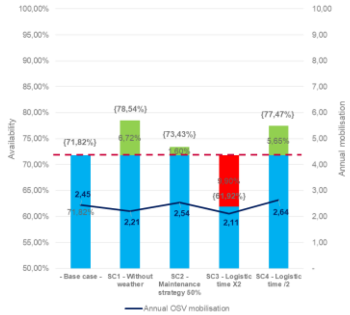


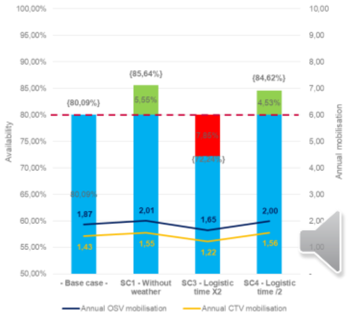
Alternative cases





Sensitivity cases





Further information

- Public project reports
  - D1.1 FMEA Report
  - D1.2 RAM Assessment Report
  - D1.6 Guidelines for the development of tidal turbines reliability databases

- Scientific publications
  - Improving reliability of tidal turbines: a new step by step methodology for initial quantification of criticality, EWTEC2019
  - Increased reliability of tidal turbines thanks to a better knowledge of realistic tidal conditions, use of RAM analysis, advanced monitoring, maintenance strategies and intelligent design components, EWTEC 2021

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Variation Mode Effect Analysis (VMEA) for Supporting Reliability Assessment in the Design, Development and Operation of a Tidal Energy Converter (TEC)

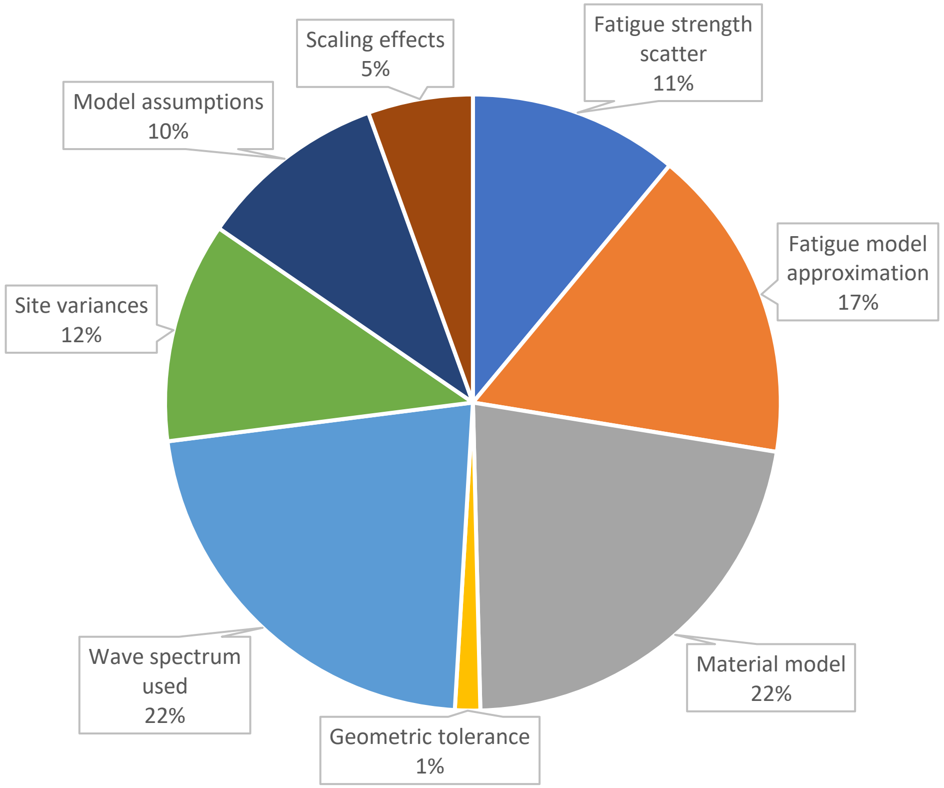
Alasdair MacLeod, John Walker & George Pexton
Offshore Renewable Energy Catapult

Impact of VMEA as a Reliability Tool

- Utilising Variation Mode Effect Analysis (VMEA) to identify noise sources which increase risk of failure
- VMEA can be utilised from design through to operation, refining inputs to develop a better understanding or reliability
- Closely linked with the BEMT and Techno-Economic Modelling

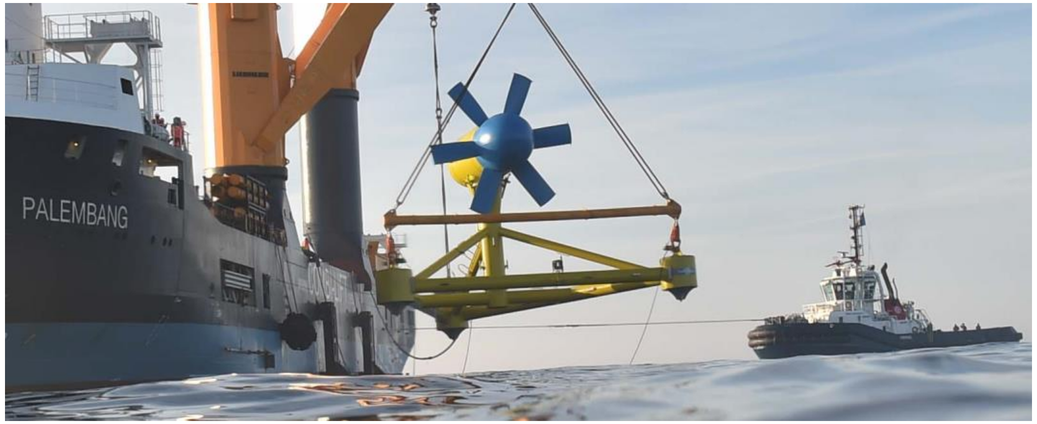
Outputs & lessons learned

- Enhanced VMEA Top 3 Uncertainty Factors:
  - Material model
  - Wave spectrum used in modelling
  - Fatigue model approximation
- Lessons learned
  - Ensure material data is available early enough in the design process to inform the outcome
  - Understand wave conditions at a proposed site
  - Undertake coupon testing to better understand materials



Research highlight

- At early stages of development material modelling & fatigue life characteristics account for approx. 50% of uncertainty in component failure
- What are the important factors to focus on obtaining data for when considering reliability
  - This can help drive the development of refined fit for purpose components reducing costs of over/under-engineering
- Important to establish from an early stage reliable materials data
  - Particularly true for blade design



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Further information

- Links to papers/reports/presentations:
  - [Introduction to VMEA]
  - [Developer Forum 2 MONITOR VMEA]
- Contact Details:
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CATAPULT
Offshore Renewable Energy

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Resource Characterisation for Tidal Energy Applications

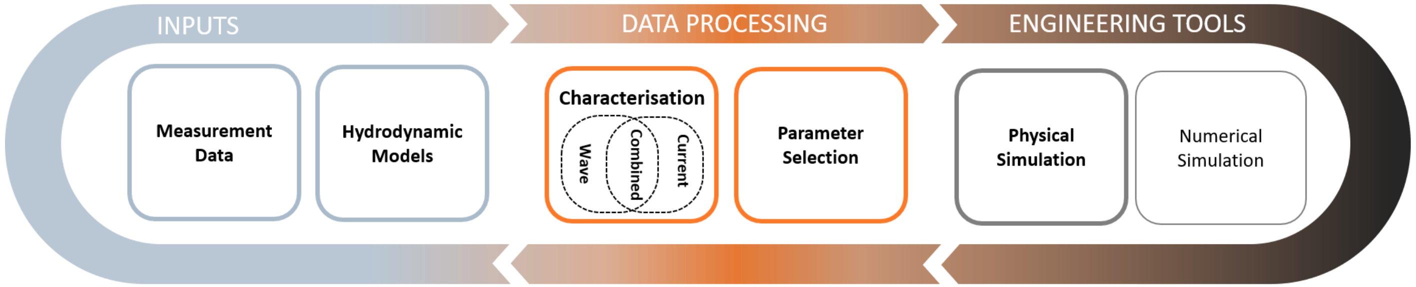
Dr Brian G. Sellar – Work Package Lead (Resource), RealTide
School of Engineering, The University of Edinburgh

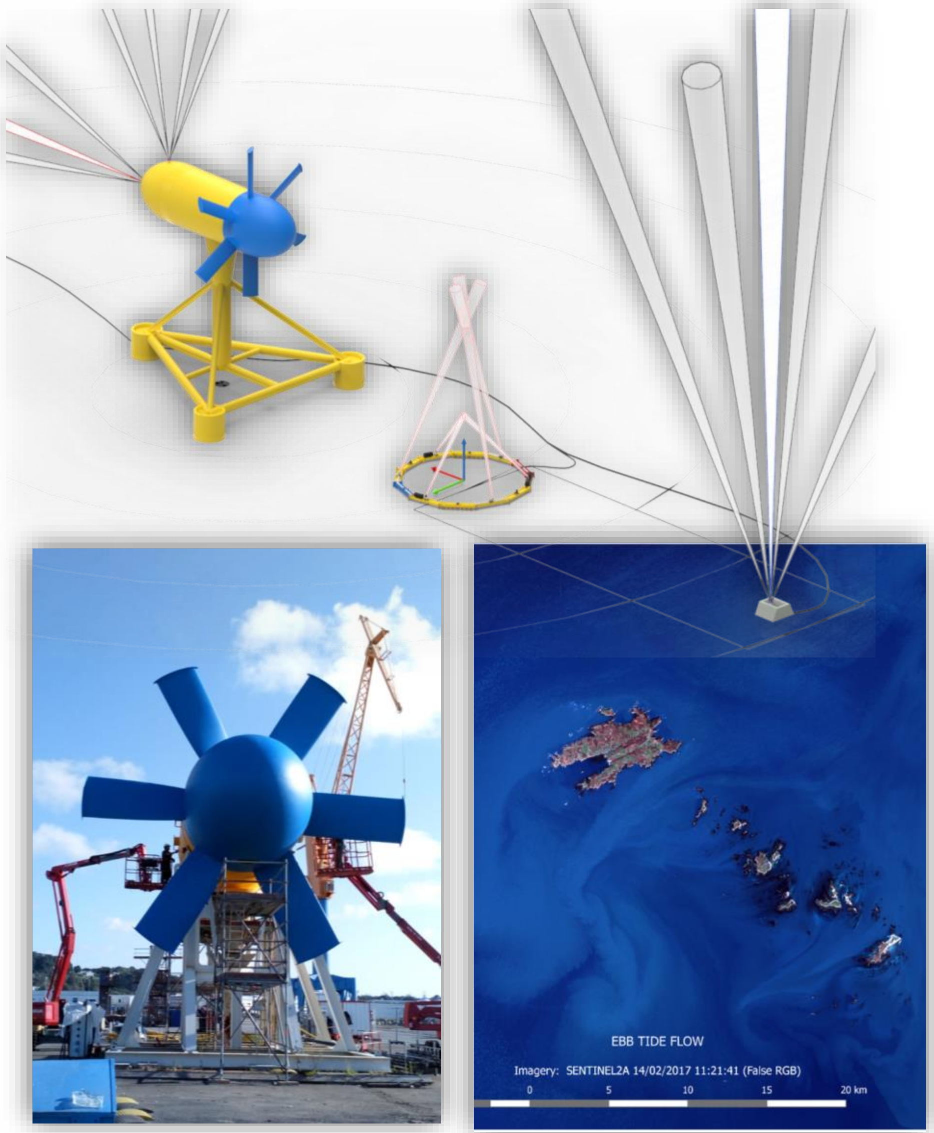
Impact of Advanced Resource Characterisation for Tidal Energy

Offshore renewable energy harnesses complex, dynamic and interacting fluid velocities driven by wind, waves, currents and turbulence.

These velocities produce forces and drive energy yield. Their characteristics affect device design, operation and reliability.

Improved understanding of the dynamics of tidal currents and oceanic waves and their complex interaction enables informed designs and better decision making -> lower cost of energy





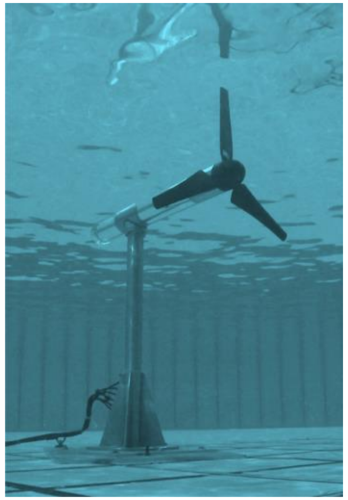
Overview of Outputs

Planning and specification
D2.1 Tech. Report

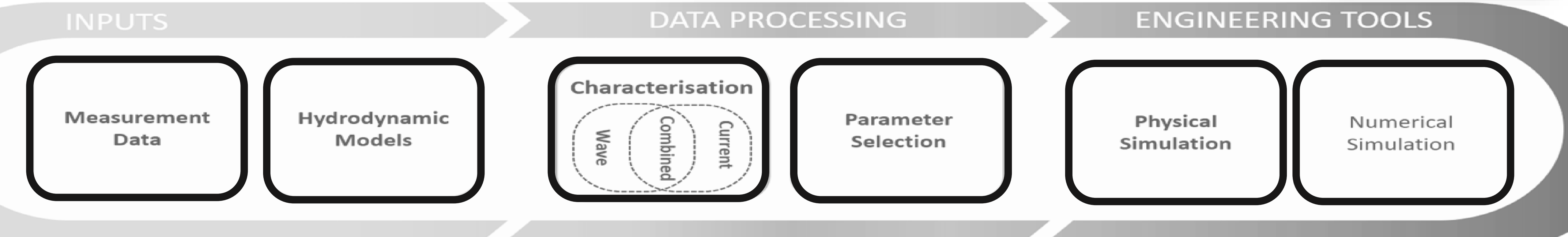
Implementation & Guidance
D2.2 Tech. Report

Data for Tidal Sector
D2.3 Dedicated database

Different machines under
combined wave-current conditions



Tide-to-Wire
Numerical Simulation



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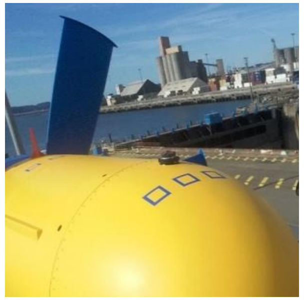
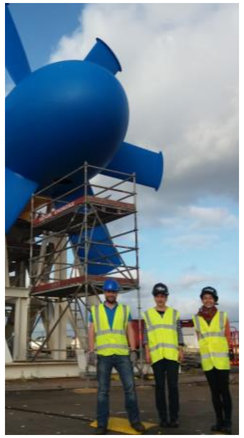
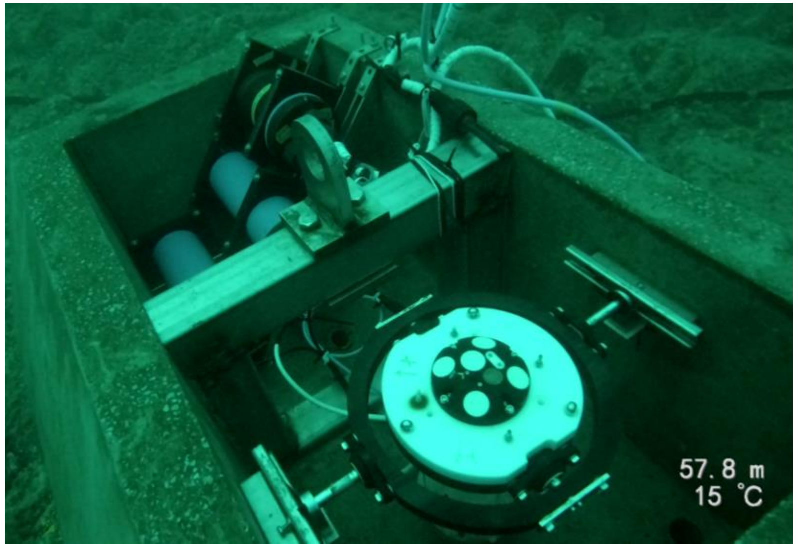
Getting Better Data: Implementation







Getting Better Data: Implementation

- RealTide - Advanced Sensing
  - Deployment at EMEC tidal energy test site (instead of Fromveur Passage due to Covid19)
  - Prototype actuated Convergent-beam ADP
  - Features
    - OTS 5-beam ADCP
    - 2 x 3-Beam C-ADP (1 Fixed, 1 Moveable)
    - 3D position information
- Autonomously operated via onboard low-power computers
- Deployed successfully 4 weeks ago
- Due for recovery as we speak

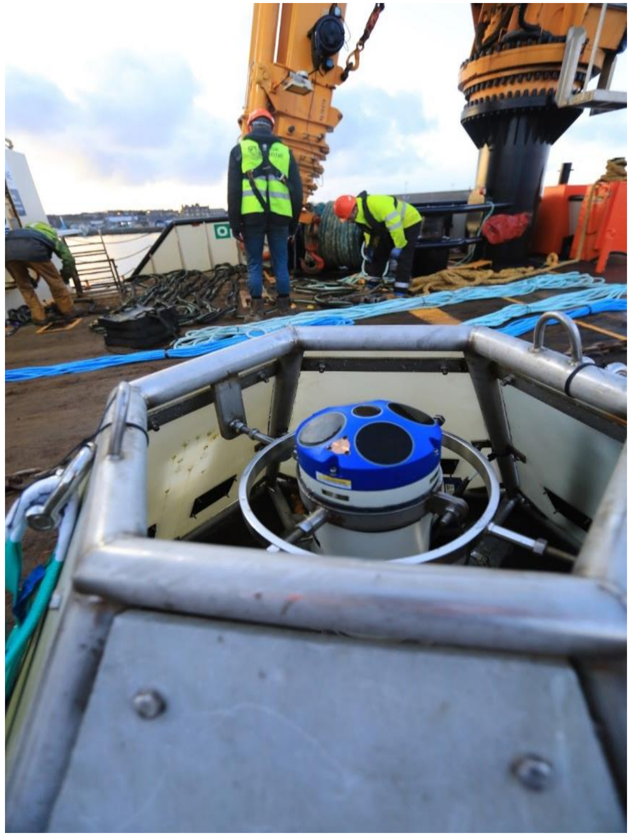
RealTide - Lessons learned on Data Acquisition

- Cabled systems are difficult: high-risk / high-reward
- Cable-free comes with disadvantages –> requirement for “smart/er” operation
- Retrofitting to machines is high-risk and expensive
- Redundancy is essential
- Online switching and smart power systems is a good idea
- Aligning schedules of multiple programme “moving-parts” is difficult
- Plan B’s and Plan C’s are necessary
- Diver-removable kit works well if properly designed in consultation with the divers
- Lessons Learned on Data Processing still ongoing…
- Partnerships work – leveraging synergies, equipment sharing, people-sharing, cost-sharing, student-travel awards etc.

Getting Better Data: MONITOR

Monitor focusses on understanding how environmental events and conditions correspond to observed device performance and loading….

- Measuring those loads simultaneously with measured environmental conditions
    - High-resolution oceanographic data
    - Combined wave-current conditions
- Capture load intensities in different resource and operational settings E.g. stress levels that device' blades and structures undergo in operation



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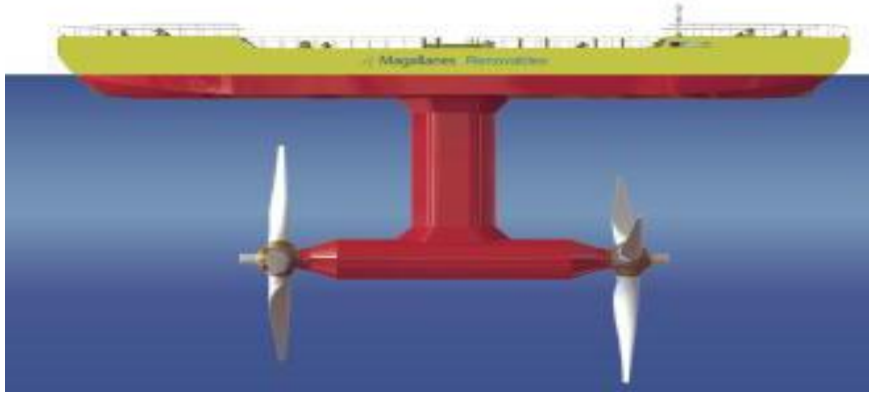
Outputs & lessons learned

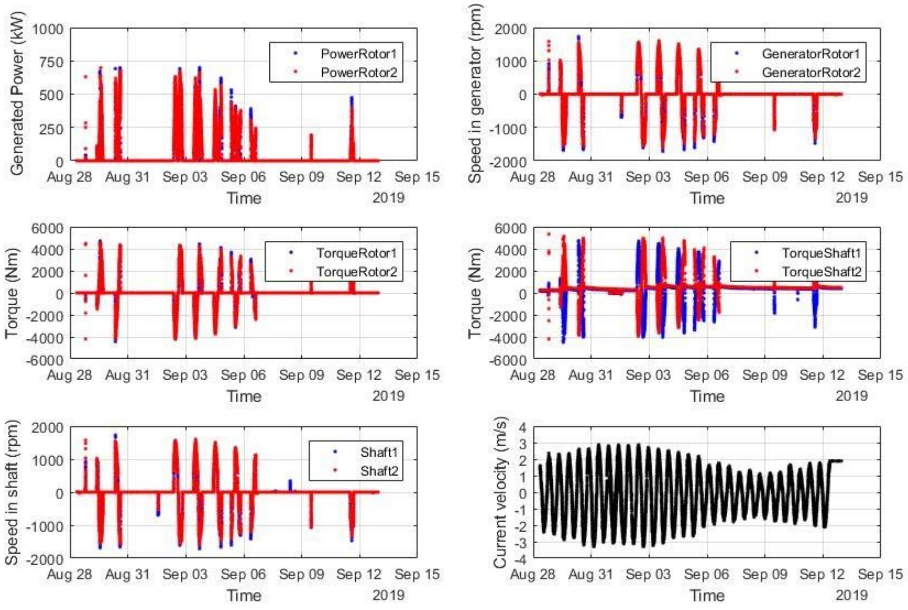
- Device Testing
  - ATIR Platform, Magallanes Renovables S.L.
  - Dual coaxial horizontal axis rotor, floating TEC
  - Being tested at Berth 1 of EMEC, FoW

- Data Collection
  - Fromveur Passage, France: Dual ADCP Winter Set
  - Fall of Warness, Orkney, UK: 5-Beam RDI Sentinel
    - The Fall of Warness currents reach almost 4 m/s at spring tides;
    - Mean flows and turbulence vary significantly between flood/ebb tides;

Research highlight

- The ATIR tidal device moored ~70m to the west from the ADCP
- On the first deployment there was no strain gauges placed on the blades
- The best knowledge of loads comes from actually measuring loads on real devices
- The device was now re-deployed and simultaneous measurements of environmental conditions and load intensities are being acquired
- The data is fundamental to ground-truth the load variation, and the sensitivity of that variation to the measured environmental factors





Further information

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Technical Report | D2.1 Deployment and Instrument Specification for Advanced Flow Characterisation
Technical Report | D2.2 Advanced Flow Characterisation for Tidal Energy Applications [due Q4 2021]
Technical Report | D2.3 Multi-data Database: Tidal Site, Test-Tank and Numerical Simulation Database [due Q4 2021]
EWTEC'21 | Experimental measurement of the loads on tidal turbines using conditions derived from field measurements

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Summary Technical Report | At-Sea Work. Data available, measurement and analysis strategies.

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