EPSRC Marine Wave Energy Programme

New Generation Modelling Suite for the Survivability of Wave Energy Convertors in Marine Environments (WavE-Suite)

Outline

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Research Team

Research teams			
Investogators			
Title	Name	Role in the project	Organisation
Prof.	Qingwei Ma (QM)	PI, overall management of project	City, University of London
Dr.	Shiqiang Yan	Co-I, leading WP1 and 5	City, University of London
Prof.	Vengatesan Venugopal	Co-I, leading WP4	University of Edinburgh
Prof.	Christopher Pain	Co-I, co-leading WP2 and WP1	Imperial College London
Dr.	Rossella Arcucci	Co-I, leading WP2	Imperial College London
Dr	Jun Zang	Co-I, leading WP3	University of Bath
Dr.	Zhihua Xie	Co-I, co-leading WP3 and WP5	University of Cardiff
Dr.	David Pizer	Project Advisor	Consultant Scientist
Researchers			
Dr.	César Quilodrán Casas	Named researcher	Imperial College London
Dr.	Haoyu Ding	Researcher	University of Bath
Dr.	John Samuel	Researcher	University of Edinburgh
Dr.	Qian Li	Researcher	City, University of London
Dr.	Aristos Christou	Researcher	University of Cardiff

Advisory Board

Advisory Board for WavE-Suite				
Title	**Name**	**Role in the board**	**Expertise**	**Organisation**
Dr. and FREng	RV Ahilan	Chair and partner member	hydrodynamics and, offs	AqualisBraemar LOC
Dr.	Chris Retzler	Partner member	Wave energy;	Mocean Energy Ltd
Dr.	Jørgen Hals Todalshaug	Partner member	Wave energy;	CorPower Ocean
Dr.	Yago Torre-Enciso	Partner member	Wave energy;	BiMEP
Dr.	Jon Lekube Garagarza	Partner member	Wave energy;	BiMEP
Prof.	Decheng Wan	Partner member	Numerical modelling	Shanghai Jiaotong Univ
Dr.	Songwei Sheng	Partner member	Wave energy;	Guangzhou Institute of Energy Conversion
Dr.	V Sriram	Partner member	Hydrodynamics and num	IIT Madras
Dr.	Hakim Mouslim	Partner member	Offshore renewable ener	INNOSEA with ABL LOC
Prof. and FREng	Alistair BORTHWICK	invited member	Hydrodynamics and num	University of Edinburgh
Prof.	Andrew Moore	invited member	Data Assimilation and c	University of California Santa Cruz
Prof.	Paul Taylor	invited member	Wave dynamics and appl	University of West Australia
Prof.	Nigel Barltrop	invited member	Offshore engineering	university of Strathclyde

State-of-Art Numerical tool for modelling WECs

The momentum for developing wave energy is quite strong.

The programme funded by EPSRC (about £8m); and

One of key challenges for the sector: lack of accurate and efficient numerical tool for assessing survivability of WECs

State-of-Art Numerical tool for modelling WECs

- Nonlinearity, wave breaking and turbulence play important roles for WECs survivability.
- Long duration and large spatial domain modelling required to provide reliable extreme loading and motion events.
- Turbulence in breaking waves is a huge challenge as the existing turbulent models are not suitable for many breaking-waves cases and modelling it is very costing.
- Existing models are either too simple and inaccurate or too computationally expensive.

Model	Theory	Examples	Main features	Capability for WECs in survival waves	Comp. costs
Potential	Linear and/or weak nonlinear	*WEC-slim*	Linear or second order for waves, hydrodynamics and body motions; artificial viscosity	No strong nonlinearity	+
	Fully nonlinear potential	*QALE-FEM**	Waves/current, multibody hydrodynamics and motions; artificial viscosity	fully nonlinear but not breaking waves/viscosity	++
NS (CFD or high fidelity)	Navier-Stokes equation	*OpenFOAM*, *Star-CCM+*, *Fluidity**, *SPH**, *PIC**, *Xdolphin3D**	1 or 2-phases, breaking waves, viscosity, restricting to a small region near the structures with prescribed linear/2^{nd} order wave inlets; not widely used for random waves	Resolve physical details, run in small domain; numerical dissemination if run in large domain or long duration;	+++++
MMS (hybrid)	Combined theories	*qaleFOAM**, *OceanWave3D/ OpenFOAM or SPH*	Potential model in large domain, 2-phases/breaking waves/viscosity in small domain near the structures	Deal with wave breaking, turbulence and viscosity, two-phase flow and less numerical damping	+++

Fig. 1. Numerical models (+: order of computing costs; * developed by team members)

Objectives - What do we plan to achieve

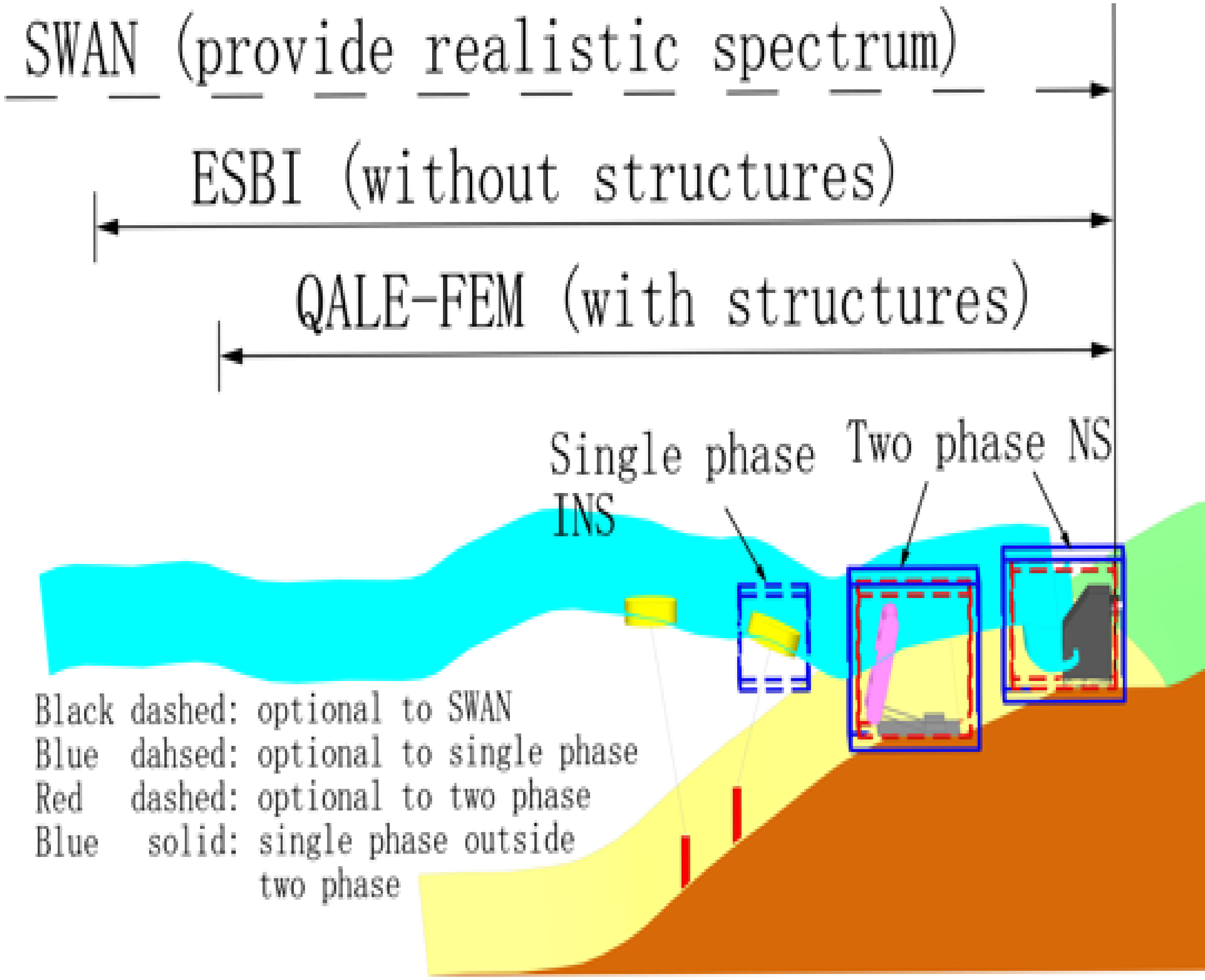
Main Objectives:

- Develop a new numerical modelling suite (WavE-Suite) equipped with advanced machine leaning algorithms by coupling five individual numerical models that are suitable for physics of different scales and nature, supported by dedicated databases, which is efficient and accurate enough.
- Realise that WavE-Suite has the ability to deal with irregular waves together with current and to simultaneously capture both large and small-scale physics.
- Validate the WavE-Suite by bespoke experiments and sea trial data.
- Demonstrate WavE-Suite to be able to identify the survival conditions and quantify extreme loads and motions of WECs

Features of WavE-Suite - 01

Multimodel multiscale simulation(MMS) principle:

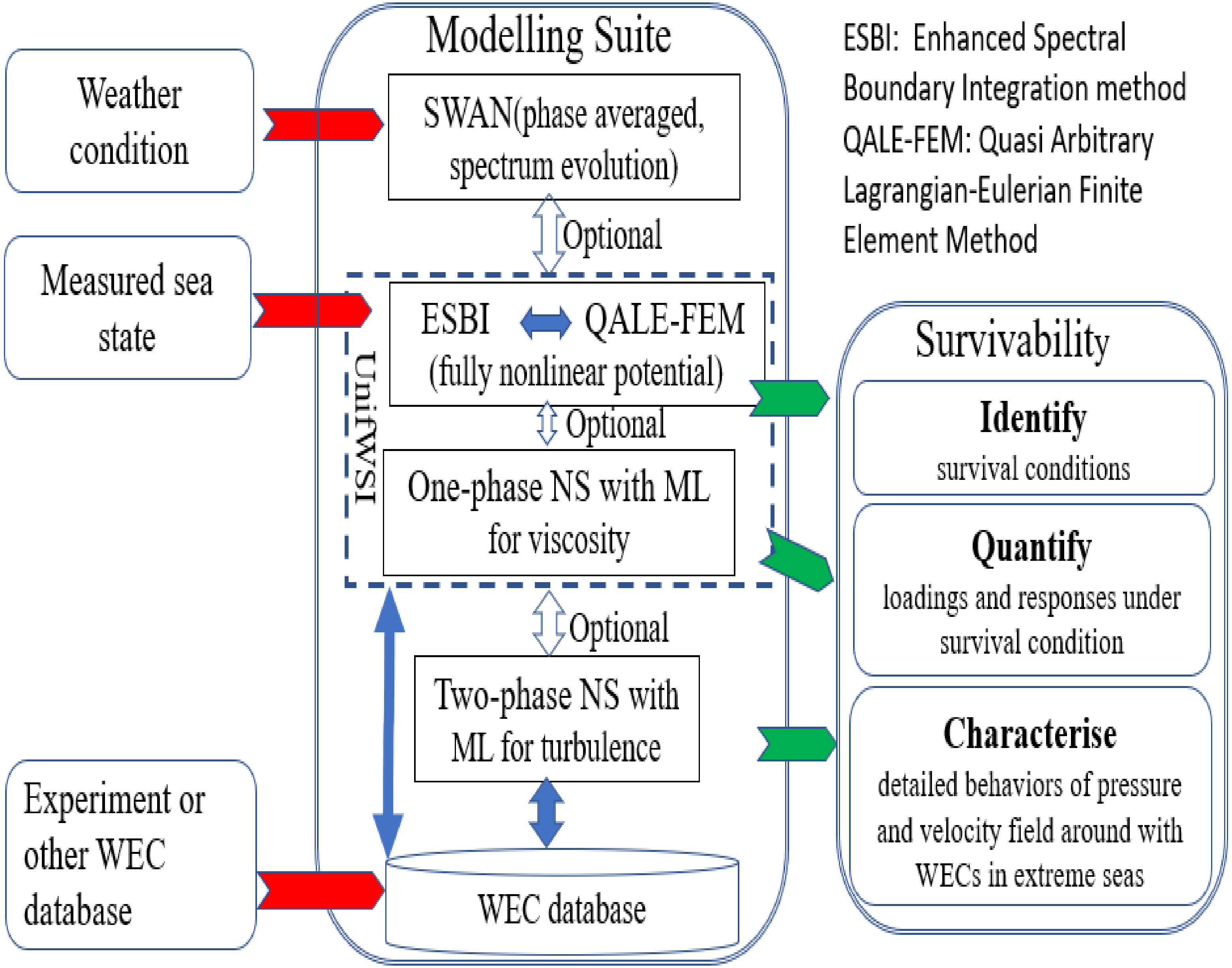
- Two-phase NS models only run at very violent cases for quantifying flow details in smaller domain around WECs;
- Single phase NS model used as alternatives;
- Nonlinear wave fields with current simulated by potential models (QALE-FEM and/or ESBI);
- Regional wave spectrum evolution modelled by phased averaged models.
- Different coupling approaches adopted



Features of WavE-Suite - 02

Nature and flexibility:

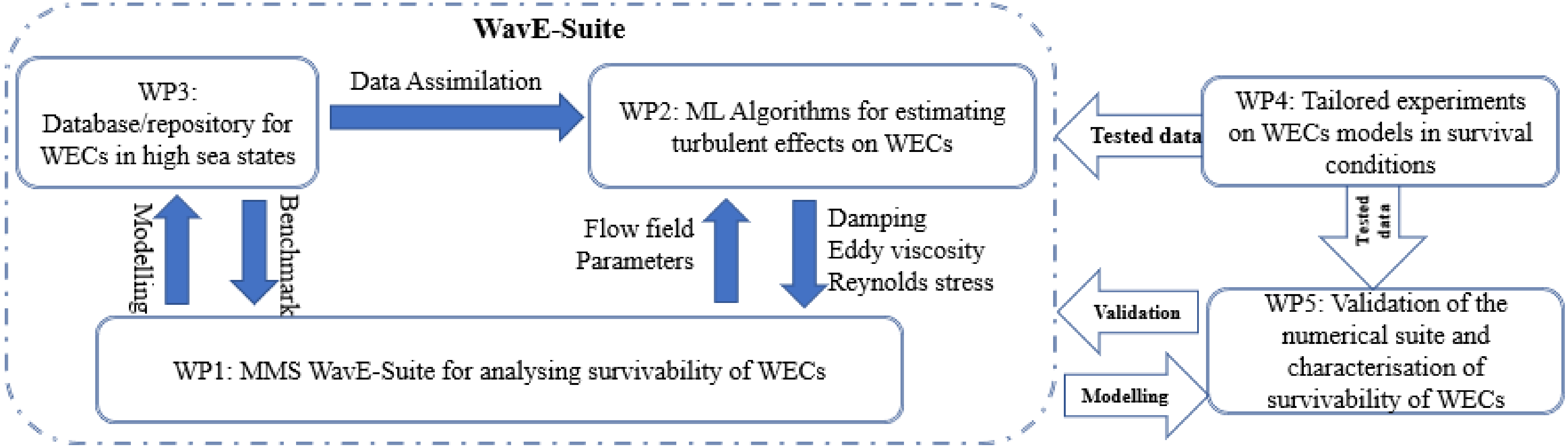
- All models built in;
- Automatically selected using the information for input and tasks;
- Accept global weather forecast;
- Accept measured sea state;
- Also accept spectra specified or lab conditions;
- Full range of survival analysis tasks: identifying the survival conditions; quantifying extreme loading and responses and characterise the pressure and velocity field.



ESBI: Enhanced Spectral Boundary Integration method
QALE-FEM: Quasi Arbitrary Lagrangian-Eulerian Finite Element Method

Workpackages - How do we do this

- WP1: MMS modelling software for analysing survivability of WECs
- WP2: ML Algorithms for estimating turbulent effects on WECs
- WP3: Databases and repository for WECs in high sea states
- WP4: Tailored model tests on WECs in survival conditions
- *WP5: Validation of WavE-Suite and* characterisation of survivability



Timeline - when we will achieve them

	Year 1				Year 2				Year 3				Milestones and PDRA allocations (PDRA time is given in months (m))
	1	2	3	4	1	2	3	4	1	2	3	4	
WP1: MMS WavE-Suite for analysing survivability of WECs													**M1**: Couple ESBI with QALE-FEM; **M2**: Couple QALE-FEM with INS and create the UnifWSI; **M3**: Couple UnifWSI with NS2P; **M4**: Couple ESBI with SWAN; **M5**: Develop algorithm for auto-switch models (*PDRA1* 7-33 m; *CUL PhD student*)
1.1	M1			M2									
1.2								M3					
1.3		M4											
1.4												M5	
WP2: ML algorithms for estimating turbulent effects on WECs													**M6**: ML-damping, merged into QALE-FEM in M1; **M7**: ML-eddyV, merged into INS in M2; **M8**: ML-Rstress, merged into NS2P in M3; **M9:** Refined ML algorithms and guideline for extending ML-damping (*PDRA2* 1-36 m 40%)
2.1		M6											
2.2					M7								
2.3								M8					
2.4												M9	
WP3: Database & repository for WECs in high sea states													**M10**: Database (DB) of eddy viscosity for M7; **M11**: DB of Reynolds stress for M8; **M12**: DB on viscos damping for M6; **M13**: Repository for survivability of WECs (*PDRA3* 1-12 m; *PDRA4* 7-18 m)
3.1				M10									
3.2						M11							
3.3						M12							
3.4												M13	
WP4: Tailored model tests on WECs in survival conditions (Dashed: to be done by IIT Madras)													**M14**: Model test for OWC; **M15**: Model test for point absorbers; **M16**: Model test for attenuator WEC; **M17**: Scaling effects on point absorber (*PDRA5* 13-24 m, *In-kind contribution by IIT Madras*)
4.1			M14										
4.2					M15	M17							
4.3							M16						
WP5: Validation of the numerical suite and characterisation of survivability of typical WECs													**M17**: Validated WavE-Suite; **M18**: Survival condition of single WEC; **M19**: Survival condition for a WEC array; **M20**: Quantified extreme loading/responses of WECs; **M21**: Characterised flow field for WECs(*PDRA1* 7-33 m, *CUL PhD student*)
5.1								M17					
5.2			M18							M19			
5.3												M20	
5.4												M21	
	+		+*		+		+		+		+	*	Project meeting +; Workshops *

- Last for 36 months
- Clear defined milestones for each WP, corresponding to deliverables
- Project meeting and/or workshops every 6 months;
- Project partners play important role;
- Advice and suggestions from all advisory board members are welcome

Progresses made so far

- WP1 - (a) large area field modelling; (b) Coupling QALE-FEM with single phase NS to form UnifWSI; (c) Coupling UnifWSI with two-phase NS (qaleFOAM)
- WP2 – (a) Machine learning algorithm for predicting the turbulent dynamic viscosity (b) Case study on turbulent dynamic viscosity around a point absorber
- WP3 – Data base for point absorber