EPSRC NHP-WEC Research Project
2nd Advisory Board Meeting

Professor George Aggidis

FIMechE, FIMarEST, FEI, FIET

Head of Energy Engineering

g.aggidis@lancaster.ac.uk

Wednesday 4 May 2022

UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

UKRI Engineering and Physical Sciences Research Council

Engineering | Lancaster University

Project Team

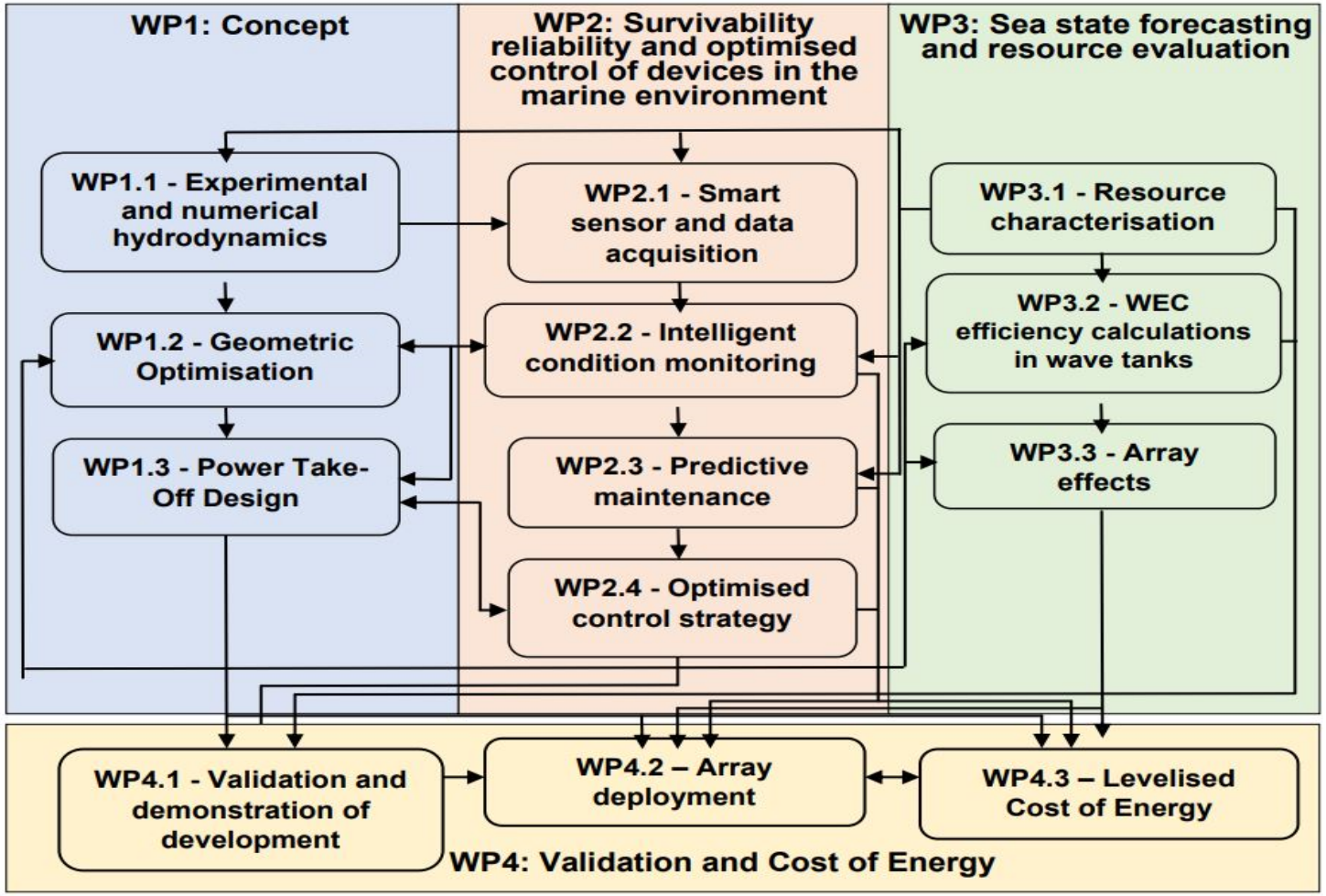
Lancaster University

- P-I - Professor George AGGIDIS
- Co-I - Dr Xiandong MA
- Co-I - Professor C. James TAYLOR
- PDRA1 - SRA - Dr Wanan SHENG
- PDRA2 – RA – Dr Yueqi WU

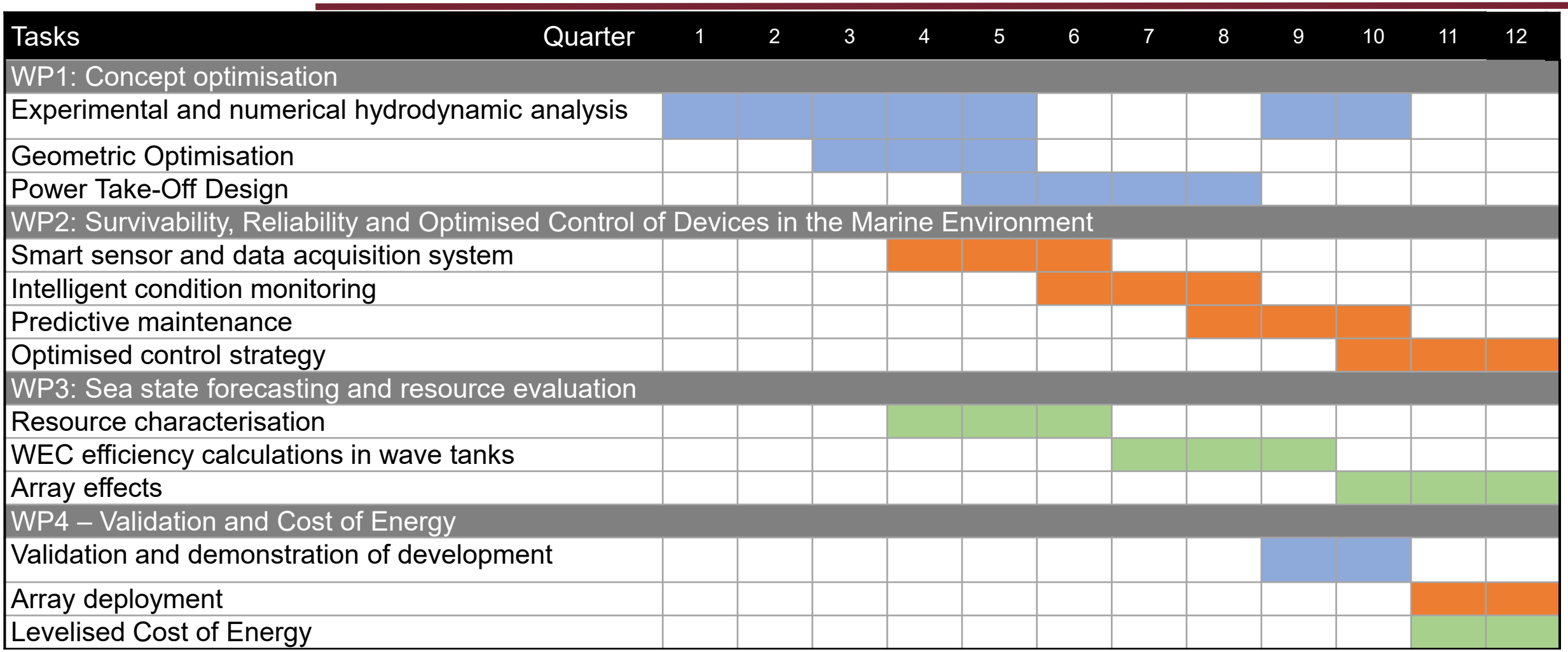
UNIVERSITY OF HULL

- Co-I - Dr Robert DORRELL
- Co-I - Professor Daniel PARSONS
- PDRA3–SRA – Dr Igor RIZAEV

Work Package Structure



Work Package Tasks Timeline



Tasks, Management

Tasks	1	2	3	4	5	6	7	8	9	10	11	12
Determined hydrodynamic characteristics												
Validation of numerical model/s												
Advanced optimisation of geometry												
Manufacturing of final model												
PTO design incorporation and model												
Established data acquisition framework												
Established condition monitoring method												
Predictive maintenance methods												
Optimised control method												
Machine learning model for wave evaluation from satellite images												
Model for the calculation of the efficiency of the device in tank tests												
Determination of array effects from tank tests												
Numerical data to validate development												
Experimental data to validate development												
Levelised cost of energy and potential												
Array deployment potential												

Project Management	1	2	3	4	5	6	7	8	9	10	11	12
Progress Meetings	Twice monthly											
Group face-to-face meetings	Quarterly											
Advisory Board meetings												
Workshops												

EPSRC NHP-WEC Research Project Website

TALOS wave energy converter (LU):

The research proposed is simultaneously generic while significantly contributing to the development of a concept device that has shown potential, namely the multi-axis TALOS that has been developed and tank tested at Lancaster University.

TALOS is a novel multi-axis moving parts, and the internal PTO system is made up of an inertial mass (a ball) with hydraulic cylinders that attach it to the hull. The motion of the ball moves the hydraulic cylinders causing them to pump hydraulic fluid through a circuit, thus to generate electricity i.e. an inertial mass PTO approach.

Key strengths of TALOS device include:

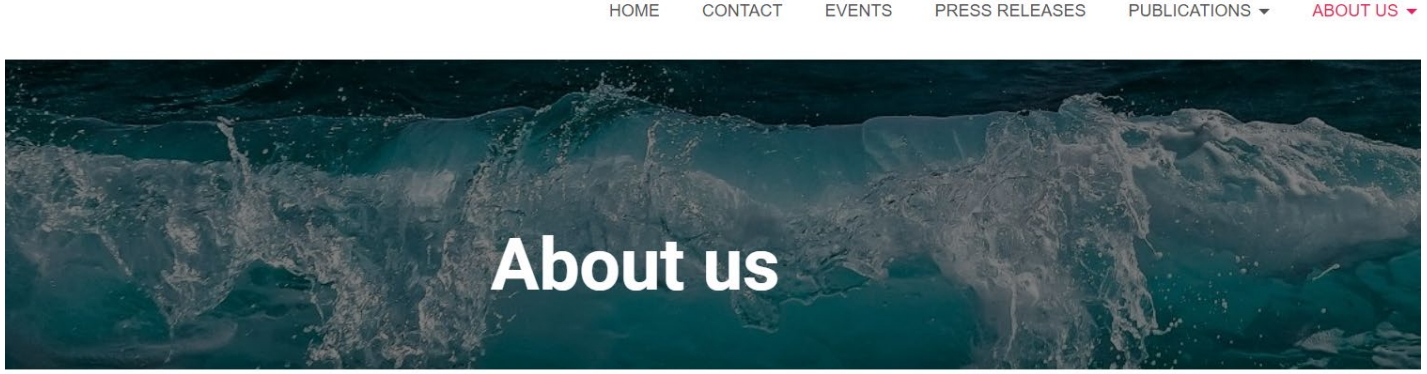
- Fully enclosed wave energy converter, so to avoid the harsh sea environments on the energy conversion system;
- The arrangement of the rams allows for the ball to move in multiple directions, allowing energy to be captured from multiple degrees of freedom;
- The flow of hydraulic fluid will change as the ball's motion changes, so an internal hydraulic smoothing circuit is utilised to regulate the output.

SmartWave (UoH):

SmartWave is a tool capable of deriving high resolution sea state conditions from satellite images using machine learning. It integrates recent advances in all-weather satellite monitoring to map and study the temporal and spatial distribution of sea surface wave characteristics.

Key strengths:

- based on a novel forecasting methodology;
- capable of resolving sea state within offshore windfarms for sector O&M logistics.



The NHP-WEC project aims to advance data-driven monitoring and control in connection to both device technology and sea state predictions for WEC arrays, combining the TALOS technologies of Lancaster University (LU) and the SmarWave technologies of University of Hull (UoH). The NHP-WEC project aims to optimise the design of the wave energy converter and the PTO system (TALOS) in response to time-varying inputs from waves (SmartWave). as such, the operational conditions, including wave characteristics, must be quantified to estimate dynamic loads, constraining manufacturing techniques and materials, so to improve wave energy production as well as the survivability of the wave energy system.

[EPSRC NHP-WEC project: A TALOS and SmartWave Project (lancs.ac.uk)]

UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

UKRI Engineering and Physical Sciences Research Council

Engineering | Lancaster University

1st Workshop

Supergen Offshore Renewable Energy

Join our newsletter | Research Lands

Home | About | Impact | Funding | Research Landscape | ORE Facilities | ECR Community | News & Events

EPSRC Project Workshop: NHP-WEC Marine Energy Project

Online, 25 October 2021 at 2:00pm - 3:30pm

University of Hull | UKRI Engineering and Physical Sciences Research Council | Lancaster University

EPSRC Marine Wave Programme 2020 - Novel High Performance Wave Energy Converter Research Project (NHP-WEC)

The NHP-WEC team would like to invite you to the 1st workshop of their EPSRC funded project: 'Novel High Performance Wave Energy Converters with advanced control, reliability and survivability systems through machine-learning forecasting (NHP-WEC)' project. Find out more about the project in this PDF.

Workshop details

- Date: 25 October 2021
- Time: 14:00 - 15:30 BST
- Location: Virtually (via Microsoft Teams) Please find the link to join the meeting in the PDF here

Agenda

14:00 Welcome & Introduction to NHP-WEC - George Aggidis (Lancaster University - LU)

14:05 TALOS & WP4 - George Aggidis (LU)

14:10 SmartWave - Robert Dorrell (University of Hull - UoH)

14:15 WP2: Survivability, reliability and optimized control of devices in the marine environment - Xiandong Ma (LU)

14:20 WP1: Concept Wanan Sheng (LU)

14:35 WP3: Sea state forecasting and resource evaluation - Evdokia Tapoglou (UoH)

14:50 Q&A Panel Discussion - All

15:30 Close

LancasterEngineering
@LancsUniEng

Prof George Aggidis is holding the EPSRC Wave Energy NHP-WEC Project Workshop on TALOS Wave Energy Converter and SmartWave online (Mon 25 Oct 2021 at 14:00 UK Time). To book click👉

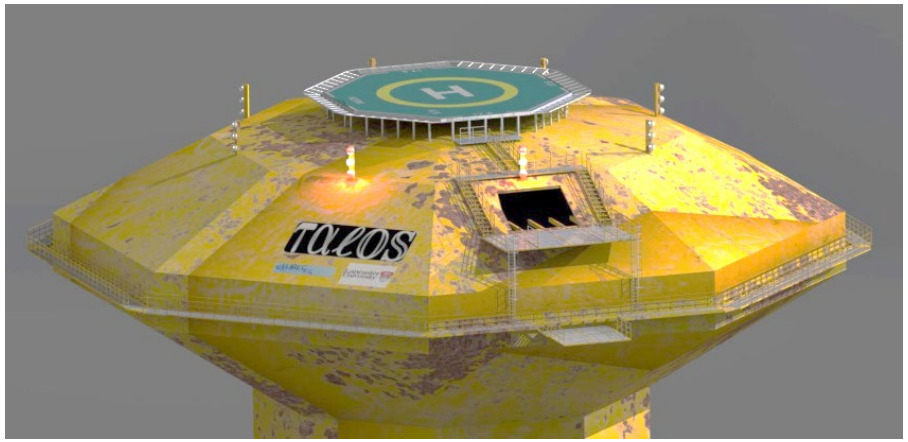
supergen-ore.net
Supergen ORE - Supergen ORE
We provide research leadership to connect academia, industry, policy and public stakeholders, inspire innovation and maximise societal value in offshore wind, ...

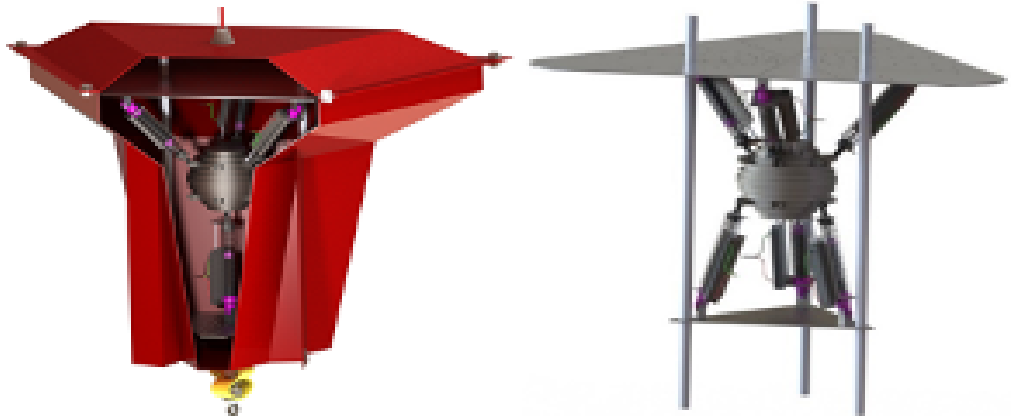
10:27 AM · Oct 20, 2021 · Twitter Web App

1st Advisory Board Meeting, 25/10/2021

Chair of the Advisory Board:

Neil Kermode EMEC Managing Director





EMEC ORKNEY
THE EUROPEAN MARINE ENERGY CENTRE LTD

CATAPULT
Offshore Renewable Energy

DNV

aura

THE DEEP
For conservation, not profit

AMRC
ADVANCED MANUFACTURING RESEARCH CENTRE

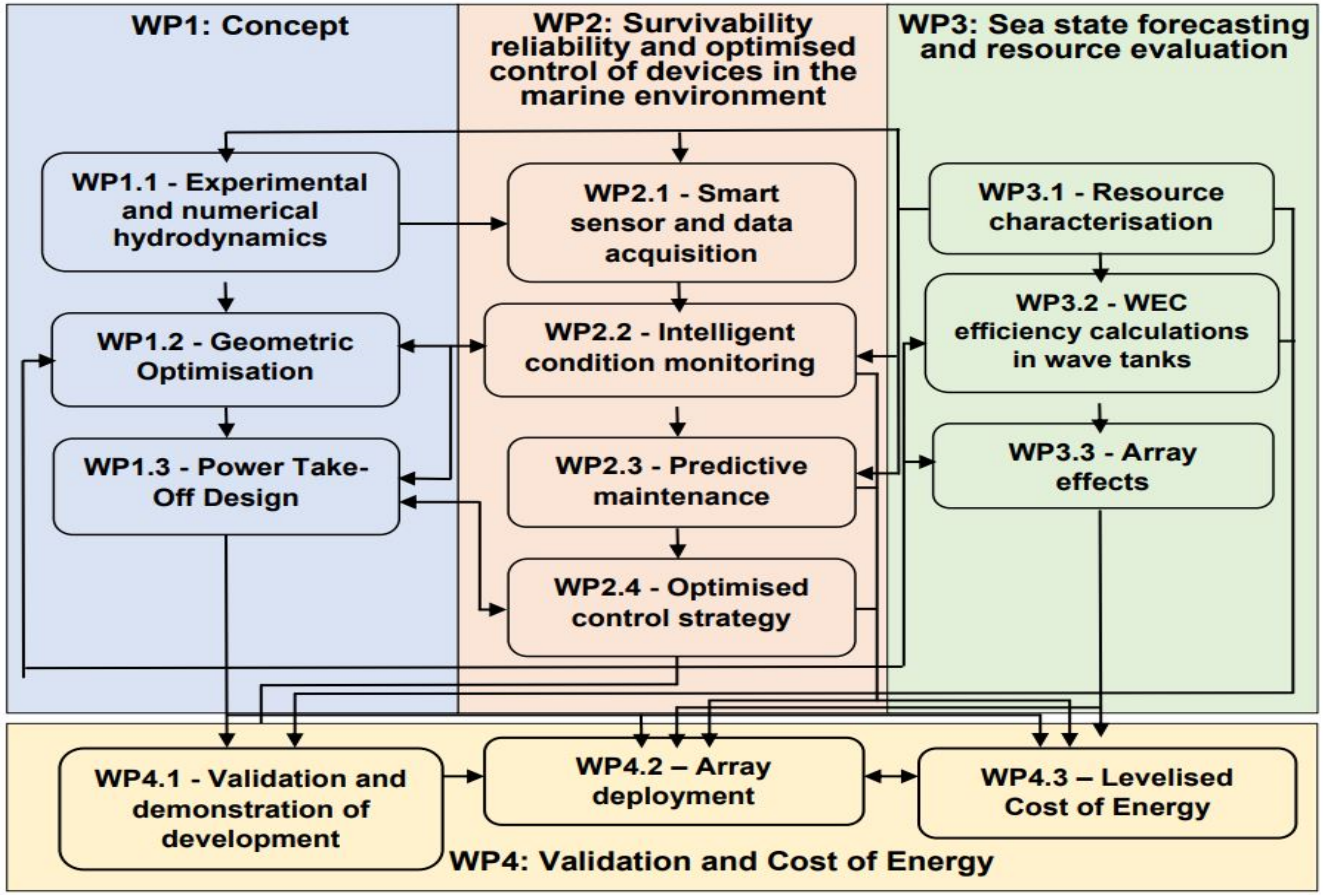
Supergen ORE, Annual Assembly, January 2022

Work Package Structure – WP1

Dr Wanan SHENG

Alasdair Ayre
(Wave Tank Testing)

Aaron Chin
(Wave Tank Testing
Sensors &
Data Acquisition)



Professor Spyros Mavrakos
Professor John Anagnostopoulos

INTERNATIONAL HELLENIC UNIVERSITY

Ass Professor Constantine Michaelides

ARISTOTLE UNIVERSITY OF THESSALONIKI

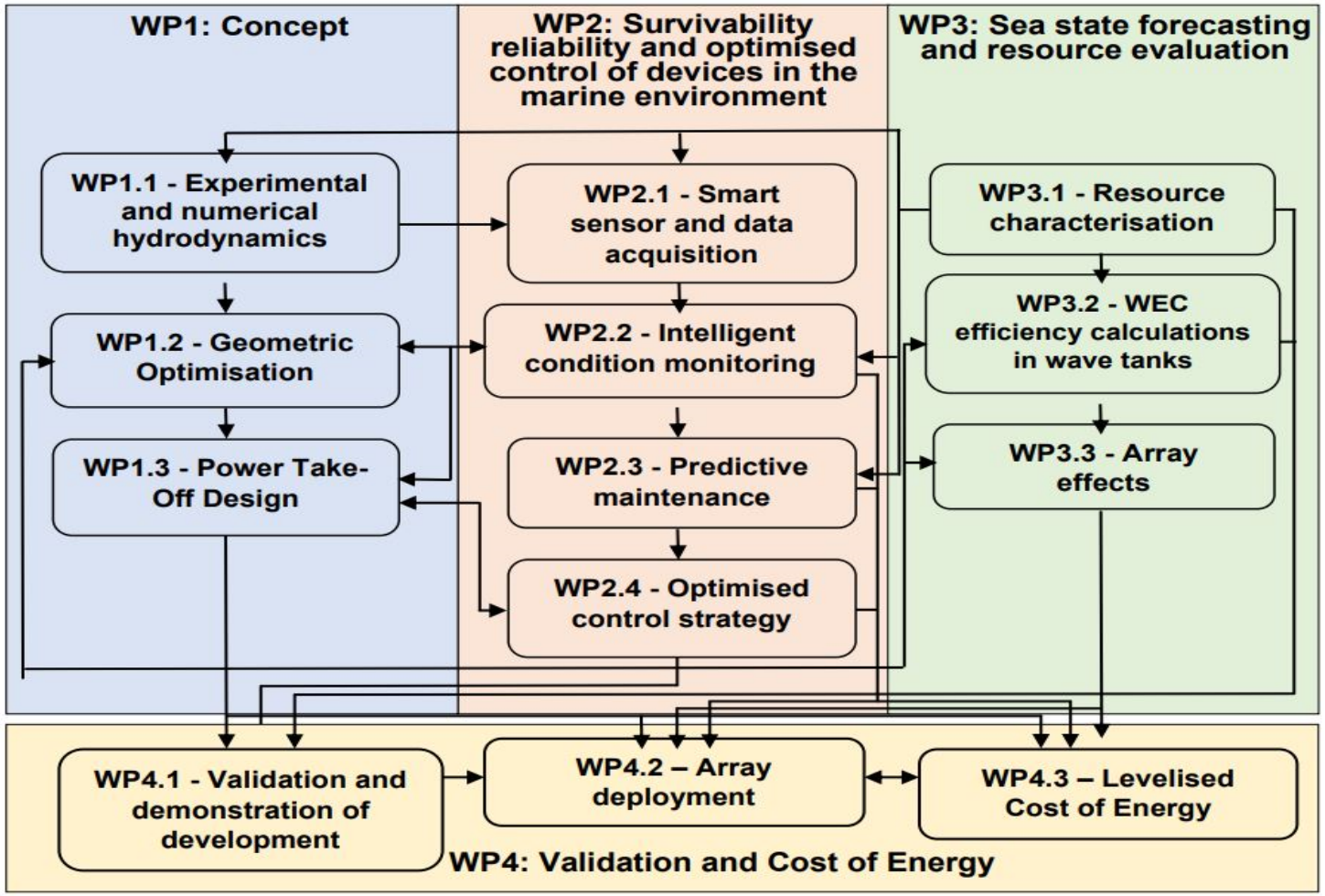
Ass Professor Eva Loukogeorgaki

ILLINOIS TECH

Ass Professor Carrie Hall

Sheng, W., Tapoglou, E., Ma, X., Taylor, C.J., Dorrell, R.M., Parsons, D.R. and Aggidis, G., 2022. Hydrodynamic studies of floating structures: Comparison of wave-structure interaction modelling. *Ocean Engineering*, *249*, p.110878.

Work Package Structure – WP4



Professor Dakshina G. De Silva
Lancaster University

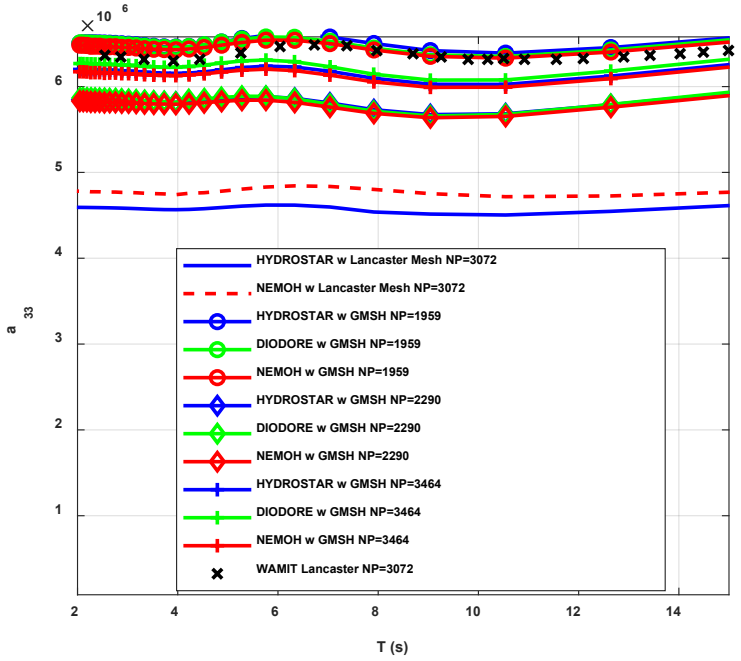
南京林業大學 NANJING FORESTRY UNIVERSITY

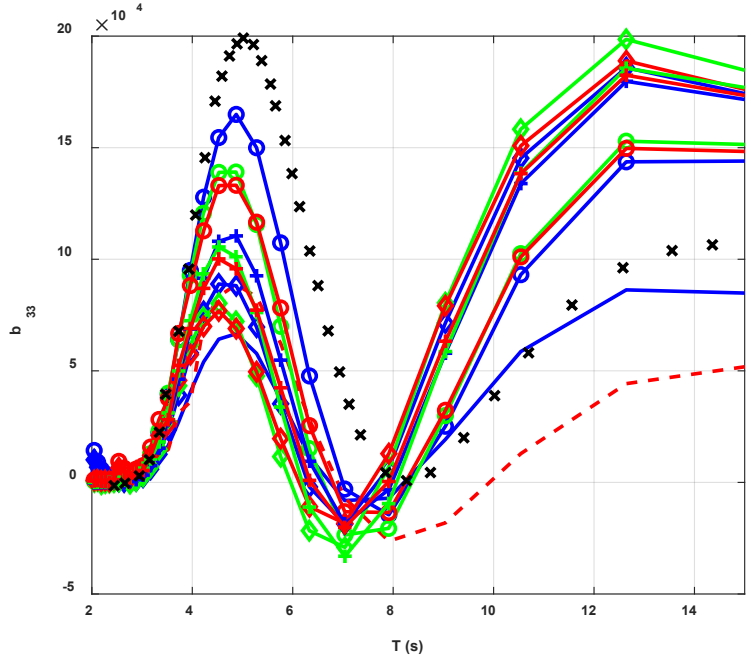
Ass Professor Chenglong Guo

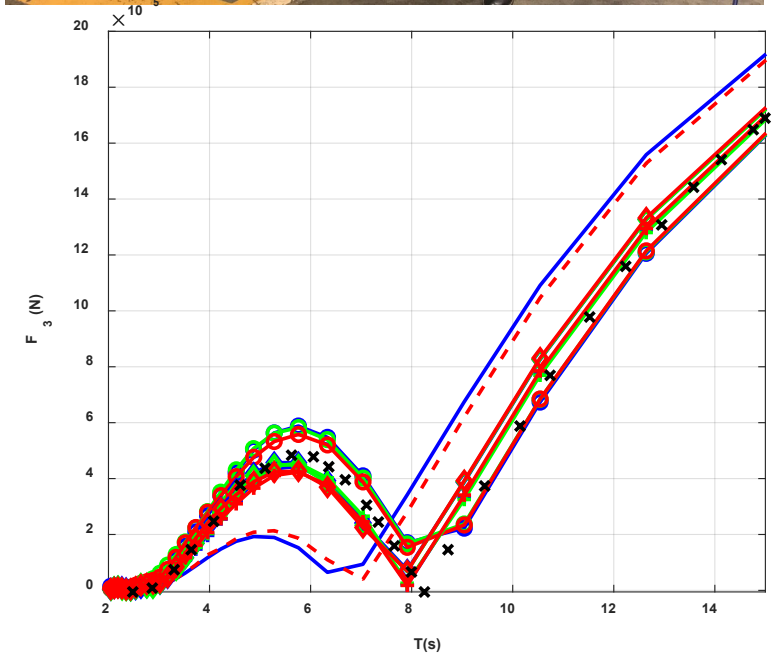
TALOS - International Collaboration

CENTRALE NANTES

Professor Pierre Ferrant
Professor Alain Clément
Dr Aurélien Babarit
Ass Professor Guillaume Ducrozet
Dr Jean-Christophe Gilloteaux
Dr Ruddy Kurnia







UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

UKRI Engineering and Physical Sciences Research Council

Engineering | Lancaster University

NREL – TALOS Research Collaboration – ongoing work

TALOS /NREL Collaboration on WP1

- OpenFAST
- Capytaine Python package
- A good case for further investigation and development

TALOS /NREL Collaboration on WP2

- Control
- Integrating a machine learning (primarily Reinforced learning) loop into the WECSim eco-system

Dr Jochem Weber
Dr Robert Thresher
Dr Aidan Bharath
Dr David Ogden
Dr Matthieu Ancellin

NREL – TALOS Research Collaboration - next steps

TALOS /NREL Collaboration through the TEAMER program 2022

- Computational Modelling and Control (WP1, WP2, WP3)
- Experimental Modelling using the new wave tank NREL is building this year (2022) in Denver Colorado.
- Experimental Modelling using the NREL motion platform (LAMP) specifically constructed to be able to mimic ocean wave action while being out of the water
- Experimental Modelling using the NREL motion platform (LAMP) for extended operational testing

NREL Transforming ENERGY

Dr Jochem Weber
Dr Robert Thresher
Dr Aidan Bharath
Dr David Ogden
Dr Matthieu Ancellin

TALOS/NREL Collaboration through the US Department of Energy (DoE) beyond the EPSRC Project timescales:

- Open-water testing

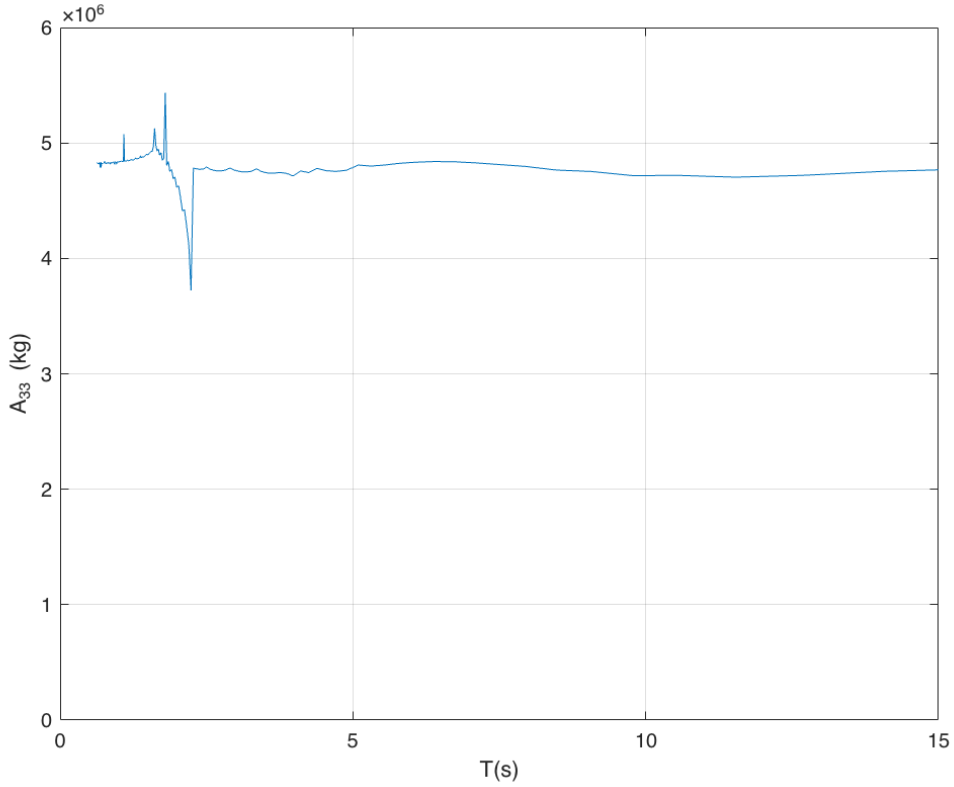
TALOS - International Collaboration

國立陽明交通大學
NATIONAL YANG MING CHIAO TUNG UNIVERSITY

Ass Professor Yi-Hsiang Yu

SENER

Iñaki Zabala Calvo



NYMCTU & SENER

- Capytaine: Python-based linear potential flow solver

Biomimetics & TALOS Paper: Published – energies Journal

energies

MDPI

Article

A Preliminary Study on Identifying Biomimetic Entities for Generating Novel Wave Energy Converters

Hui Zhang [1], Wanan Sheng [2], Zhimin Zha [1] and George Aggidis [2,*]

[1] Marine Engineering Equipment College, Zhejiang Ocean University, Zhoushan 316022, China; zhanghui@zjou.edu.cn (H.Z.); zhazhimin96@126.com (Z.Z.)
[2] Renewable Energy and Fluid Machinery Group, Engineering Department, Lancaster University, Lancaster LA1 4YW, UK; w.sheng@lancaster.ac.uk
* Correspondence: g.aggidis@lancaster.ac.uk; Tel.: +44-15-2459-3052

Abstract: Biomimetics and creatures could contribute to novel design inspiration for wave energy converters, as we have seen numerous examples in applications of other branches of engineering. However, the issue of how to obtain valuable biological entities, or bionic design cases, that could produce inspiration for novel designs, may be challenging for the designers of wave energy converters (WECs). This study carries out preliminary research on the acquisition of biological entities for designers, to obtain innovative bio-inspired ideas for designing novel WECs. In the proposed method, the first step is to draw out engineering terminologies based on the function, structure, and energy extraction principles of existing WECs. Then, by applying WordNet, candidate biological terminologies can be obtained. Next, using AskNature, along with manual selection and filtering, biological terminologies can be acquired. The last step is to use the biological terminologies to establish the reference biological entities, and to use the information and knowledge of these entities in the design of an innovative WEC. Using the proposed methodology, a novel WEC was conceived and verified.

Keywords: design inspiration; biological entities; innovative designs; wave energy converters

Citation: Zhang, H.; Sheng, W.; Zha, Z.; Aggidis, G. A Preliminary Study on Identifying Biomimetic Entities for Generating Novel Wave Energy Converters. *Energies* 2022, *15*, 2485. https://doi.org/10.3390/en15072485

Academic Editor: Eugen Rusu

Received: 24 February 2022
Accepted: 22 March 2022
Published: 28 March 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Wave energy is a clean and sustainable energy source with huge potential to provide a continuous energy supply to the energy mix. To make use of abundant ocean energy, WECs are essential devices, as they can extract the energy contained in waves and convert it into useful energy and electricity. In order to convert ocean energy effectively, efficient wave energy converters must be developed. In principle, wave energy converters can use different motions of the WEC—for instance, surge, heave, and pitch motions—as well as different energy conversion principles, such as point absorbers, attenuators, oscillating wave surge converters, overtopping, oscillating water columns, bulge waves, etc. In deployment, different types of WECs may be deployed on the shoreline, nearshore, or offshore, and can be on the surface, in the water, or on the seabed, so to better extract the wave energy at different depths and different locations. Currently, WECs have many disadvantages, such as high cost of energy production, low energy conversion efficiency, low survivability and reliability, and so on. Therefore, it is very desirable to design innovative wave energy converters, or improve existing WECs, to overcome all or some of the aforementioned disadvantages.

At same time, due to the nature of ocean waves, wave energy generation generally takes place under large forces and at low frequencies/speeds, which creates challenges for efficient and reliable wave energy production; wave energy extraction becomes even more challenging during extreme weather conditions, in which waves can generate significantly larger forces and cause significant damage to the wave energy converters.

Table 1. Features of existing bio-WECs (All pictures are loyalty free).

Bio-WEC Examples	Types of WEC	Mimicked Types	Mimicked Objects	Methods of Power Extraction	Advantages	Disadvantages	Images of Bio-WEC
Pelamis [10]	Attenuator	Shape, Motion	Sea Snake	Pitch, Yaw	High conversion efficiency when the wavelength matches the pitch.	Low adaptability, the pitch is fixed, and cannot adjust to sea conditions.	
Wave Dragon [11]	Overtopping/Terminator	Shape	Dragon	Overtopping	High flexibility, freely up-scale, and adjust to varying wave heights.	Low conversion efficiency; optimization of the power production is required.	
BioWAVE [13]	Oscillating Wave Surge Converter	Function, Motion	Kelp	Surge	High survivability, protected on the seabed during storm conditions.	Low adaptability; appropriate water depths required to be selected.	
Centipod [14]	Attenuator	Structure	Centipod	Heave	Low environment impact.	Low cost-effectiveness; the loads and stresses on the structure require reduction.	
Oyster [9]	Oscillating Wave Surge Converter	Behavior	Oyster	Surge	High survivability.	Low conversion efficiency; need to form cluster arrays and unit field.	
Sea Heart [8]	Point Absorber	Principle	Human Heart	Heave, Surge	High flexibility; hybridization of marine waves and sea current energy sources.	Low stability; the stability of electrical energy requires solving.	
Anaconda [12]	Bulge Wave	Shape, Principle	Anaconda& Human Heart	Bulge Wave	High cost-effectiveness owing to simple structure and durable material.	Low conversion efficiency; the parameters and the performance require improvement.	

Zhang, H., Sheng, W., Zha, Z. and Aggidis, G., 2022. A Preliminary Study on Identifying Biomimetic Entities for Generating Novel Wave Energy Converters. *Energies*, *15*(7), p.2485.

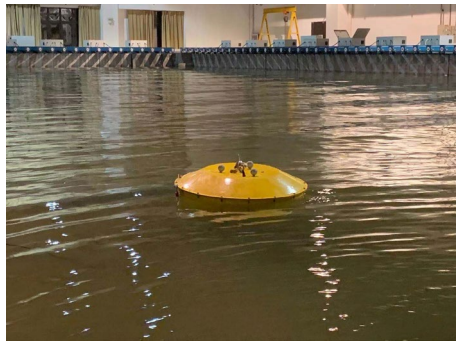
Ass Professor Hui Zhang

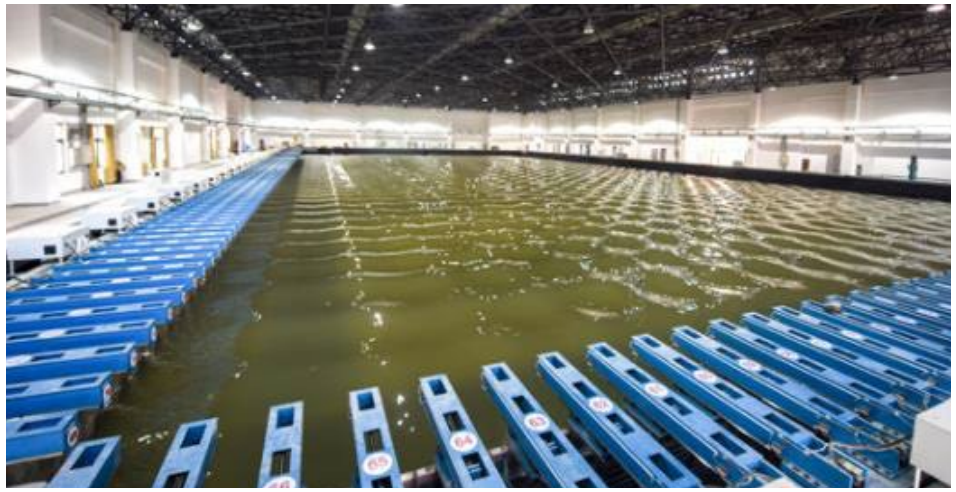
UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

UKRI Engineering and Physical Sciences Research Council

Engineering | Lancaster University

TALOS - International Collaboration





Experimental Modelling and Validation of the Computational Modelling for TALOS WEC

Professor Dahai Zhang
Tan Ming

UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

Engineering and Physical Sciences Research Council

Engineering | Lancaster University

TALOS - International Collaboration

Professor Spyros Mavrakos
Professor John Anagnostopoulos

Dr Jochem Weber
Dr Robert Thresher
Dr Aidan Bharath
Dr David Ogden
Dr Matthieu Ancellin

Ass Professor Constantine Michaelides

Ass Professor Yi-Hsiang Yu

Ass Professor Eva Loukogeorgaki

Professor Pierre Ferrant
Professor Alain Clément
Dr Aurélien Babarit
Ass Professor Guillaume Ducrozet
Dr Jean-Christophe Gilloteaux
Dr Ruddy Kurnia

Dr Evdokia Tapoglou

Professor John Ringwood

Ass Professor Carrie Hall

Professor Brad Buckham
Professor Curran Crawford

Ass Professor Hui Zhang

Ass Professor Chenglong Guo

Professor Dahai Zhang
Tan Ming

Iñaki Zabala Calvo

UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

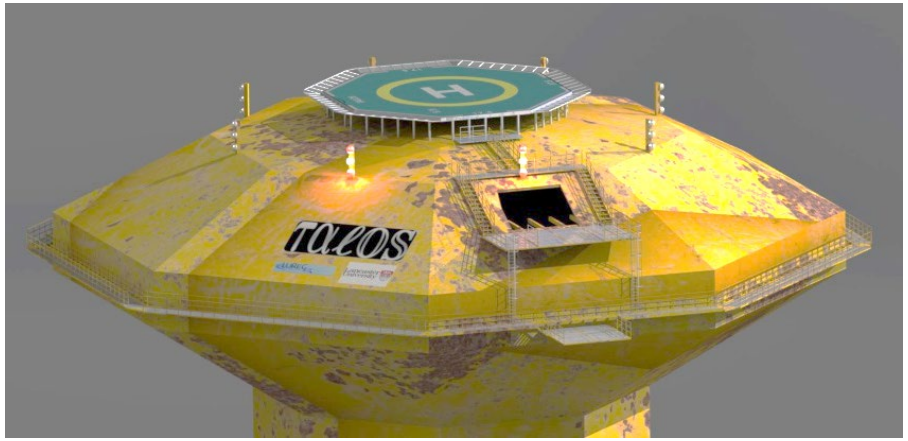
Engineering and Physical Sciences Research Council

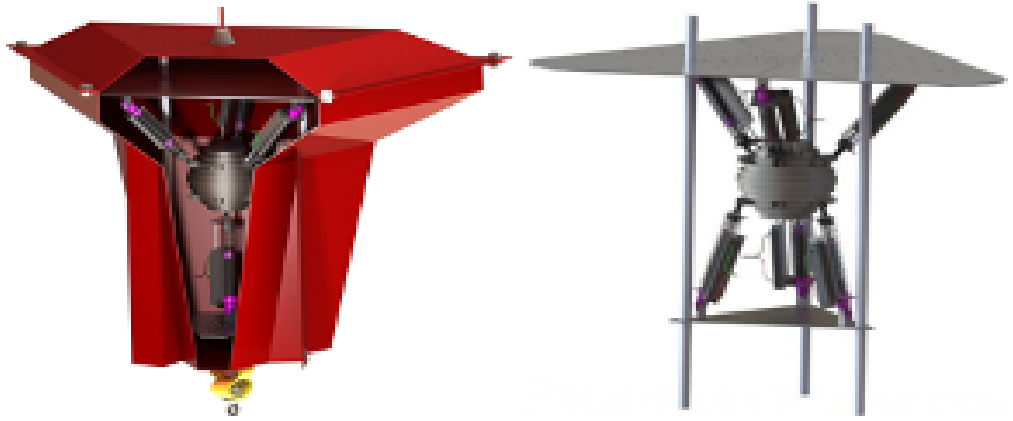
Engineering | Lancaster University

2nd Advisory Board Meeting, 04/05/2022

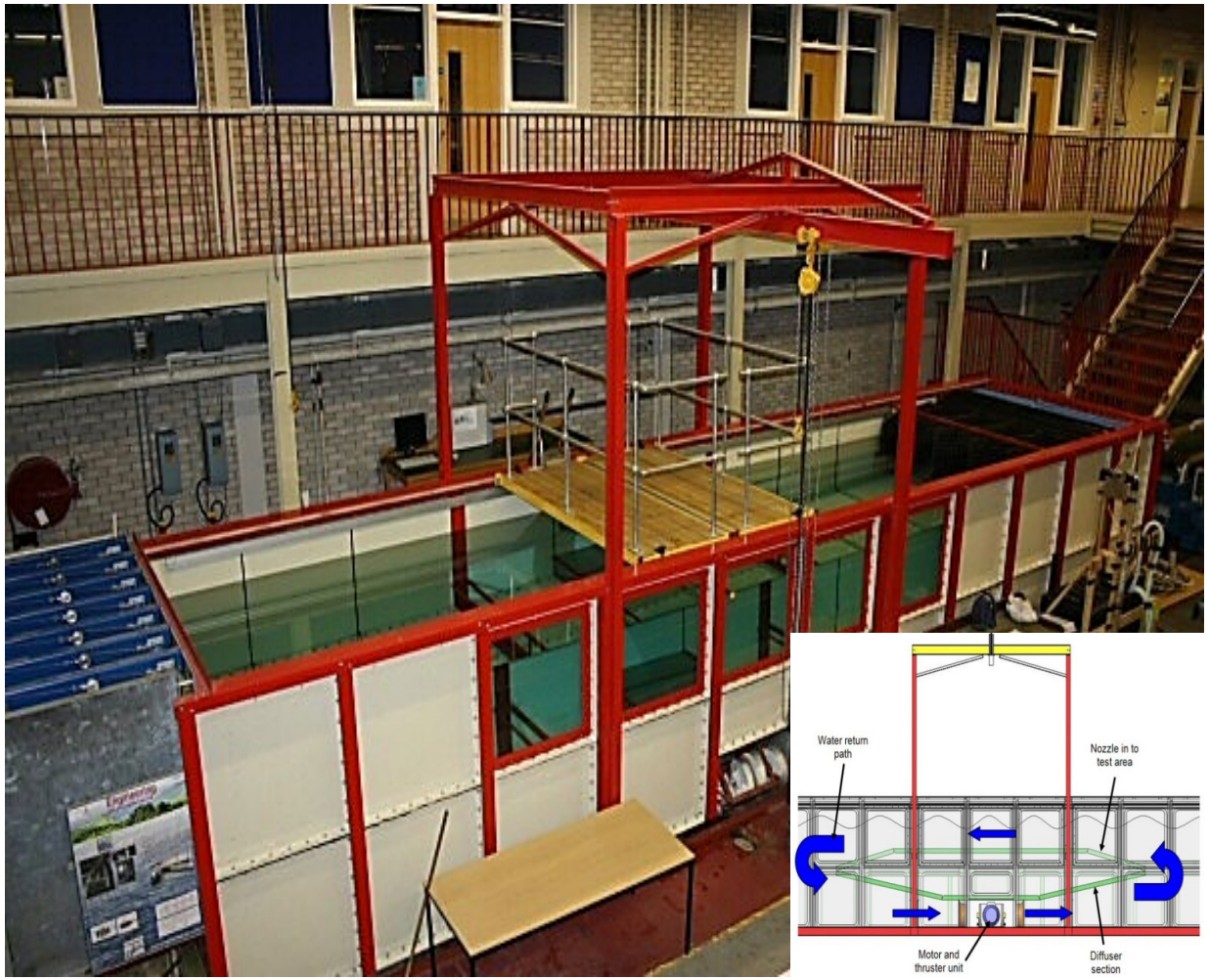
Chair of the Advisory Board:

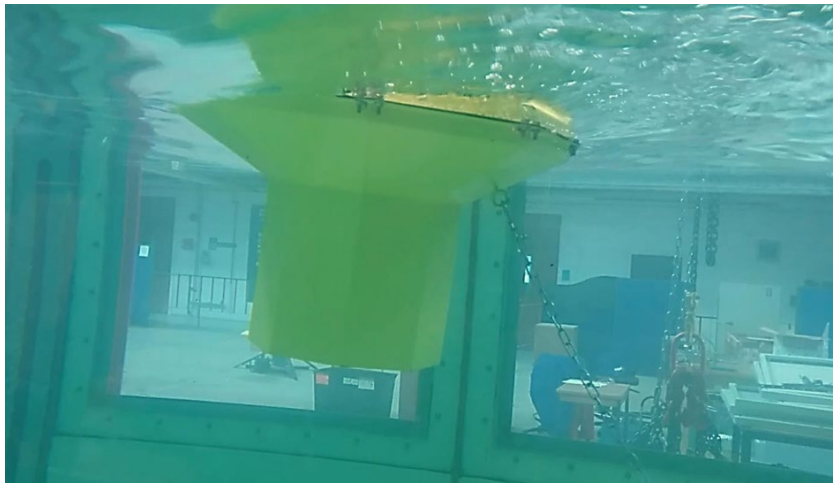
Neil Kermode EMEC Managing Director





Thank you





Professor George Aggidis

FIMechE, FIMarEST, FEI, FIET

Head of Energy Engineering

g.aggidis@lancaster.ac.uk

UNIVERSITY OF HULL | ENERGY AND ENVIRONMENT INSTITUTE

UKRI Engineering and Physical Sciences Research Council

Engineering | Lancaster University