EWTEC 2019

WES updates and project progress

2 September 2019

Overview

WES Background

Elva Bannon

WES in brief

Established in November 2014 as a subsidiary of Highlands and Islands Enterprise

Four competitive programmes:
Power Take-Offs
Wave Devices
Controls Systems
Materials

200 Organisations
88 Projects

Developing Cost Competitive Wave Technology

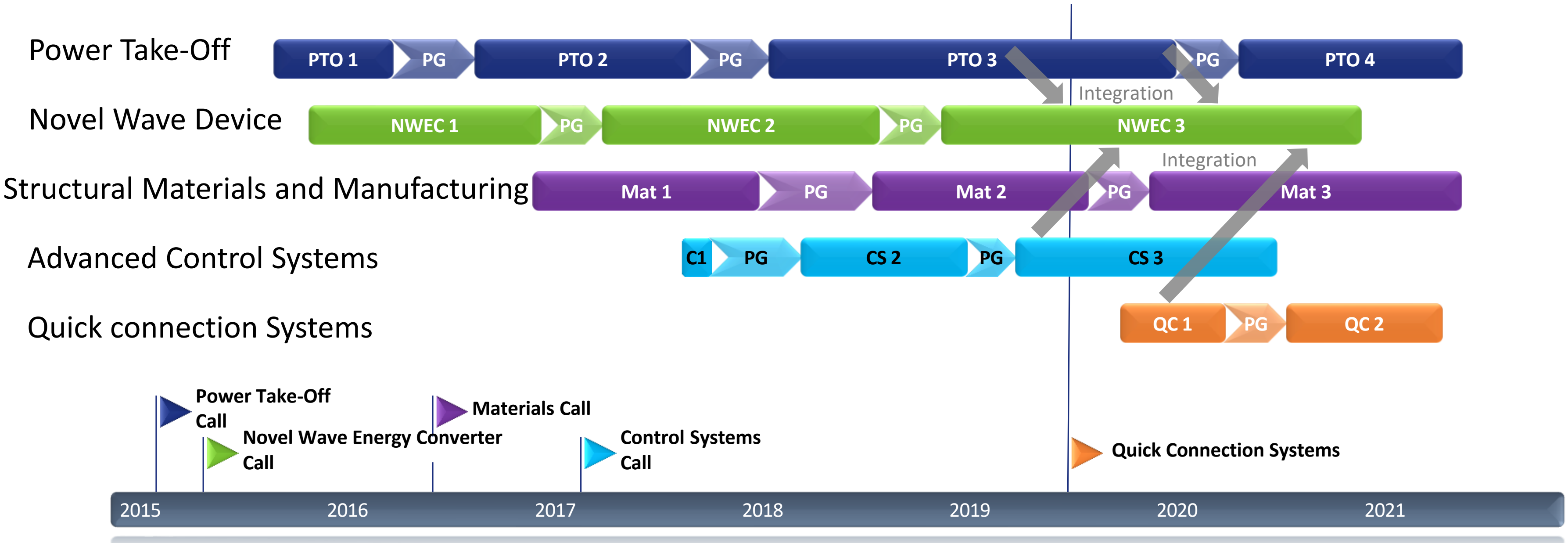
£39.6M committed expenditure

Delivering objectives through a Research, Development and Innovation Programme

13 Countries

Funded by the Scottish Government

WES Technology Programme



Quick Connection Systems

- Design and development of a rapid connection/disconnection system for wave energy converters…

- with the aim of reducing the duration, cost and risk of offshore operations. Such a system would be an integral element of the mooring system, the electrical system, or both. In this case, the electrical system would reasonably be expected to include the provision for wired communications within the electrical cable

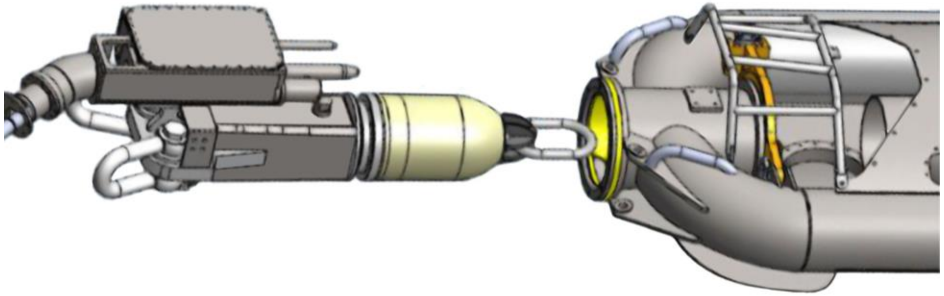
Closing Date September 16th

http://tiny.cc/QuickConnect

QCS Scope

This competition is for Quick Connection Systems for a wave energy converter which target the connection and disconnection of either the:

- Mooring system,
- Electrical system,
- Mooring and electrical systems combined.



QCS Scope

This competition is for Quick Connection Systems for a wave energy converter which target the connection and disconnection of either the:

- Mooring system,
- Electrical system,
- Mooring and electrical systems combined.

- External Experts needed to review applications
  - Design and modelling of mooring systems
  - Design of cables and electrical infrastructure
  - Marine operations planning and implementation
  - Offshore structure engineering design and development

EXTERNAL EXPERTS – Deadline to apply September 17th

http://tiny.cc/ExternalExperts

Other Activities

- IEC – 62600 Standards Development
- Sponsorship of EIMR 2018 (Environmental Interactions of Marine Renewables)
- INORE
- PhD - Multidisciplinary Optimisation
  - University of the Highlands and Islands
- PhD - Alternative Generation Technologies
  - University of Edinburgh
  - Energy Technology Partnership
- Bryden Centre
- Supergen ORE Hub
- (FlexFund project with SupergenMarine)
- Ocean Energy Europe
- IEA-OES
- EU Commission SET Plan

library.waveenergyscotland.co.uk/

EWTEC 2019 –Programme Update

Matthew Holland

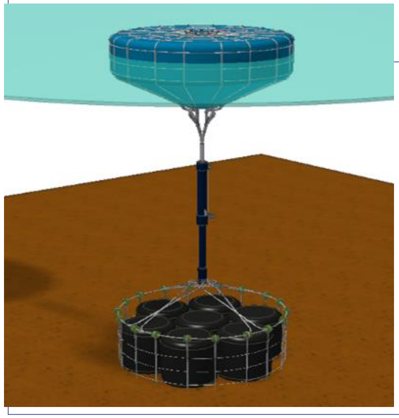
wave energy SCOTLAND

HIE Highlands and Islands Enterprise Iomairt na Gàidhealtachd 's nan Eilean

Structural Materials Programme

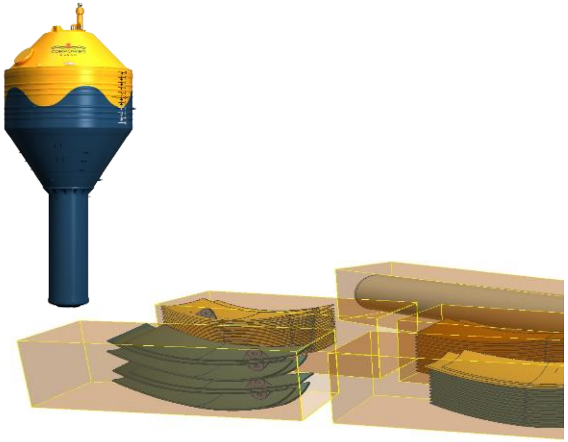
Net Buoy
Tension Technology International Ltd

Scalable and cost-effective prime mover used to replace conventional point absorber buoys applicable to other WEC categories



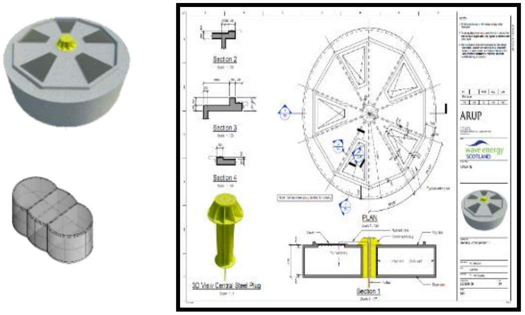
HydroComp
CorPower Ocean AB

Identify best material choice for hybrid polymer structures



CREATE
Arup

Reinforced concrete has the potential to offer a low cost solution taking advantage of a mature supply chain.



Control Systems

Cost of Energy Optimations Reinforcement Learning (CEORL)

MaxSim Ltd

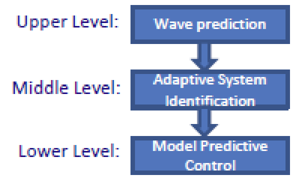
- Wave-by-wave vs sea-state control:
  - Best use of load/stroke range
  - Subwave wave period control timescale
- Control policy trained in simulation
- Policy applied on physical device
- Uses only standard on-board sensor data
- Goal: minimise LCOE vs maximise power

Adaptive hierarchical MPC of WECs

Queen Mary University

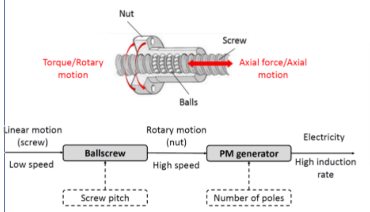
A hierarchical adaptive model predictive control framework (AHMPC) for wave energy converter (WEC)control based on the fusion of the strengths of several key enabling technologies in control and wave.

The control scheme will be validated in Stage 3 using M100 WEC developed by Mocean Energy Ltd by wave tank testing.



Power Take-Off Programme

Project
EMERGE - Reciprocating linear drive recirculating ball screw technology



Project
Neptune Linear Generator

Project
HiDrive Cascade Drive

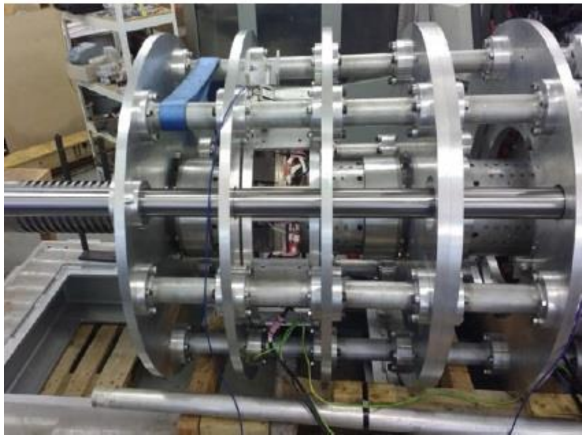
Power Take-Off Programme

Project
Quantor

http://www.artemisip.com/

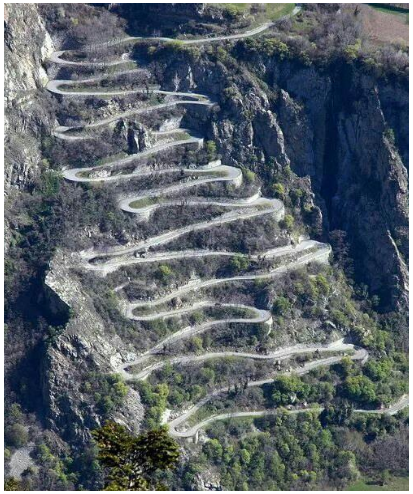
Project
Power Electronic Controlled Magnet Gear (PECMAG)

http://www.ecosse-subsea.com

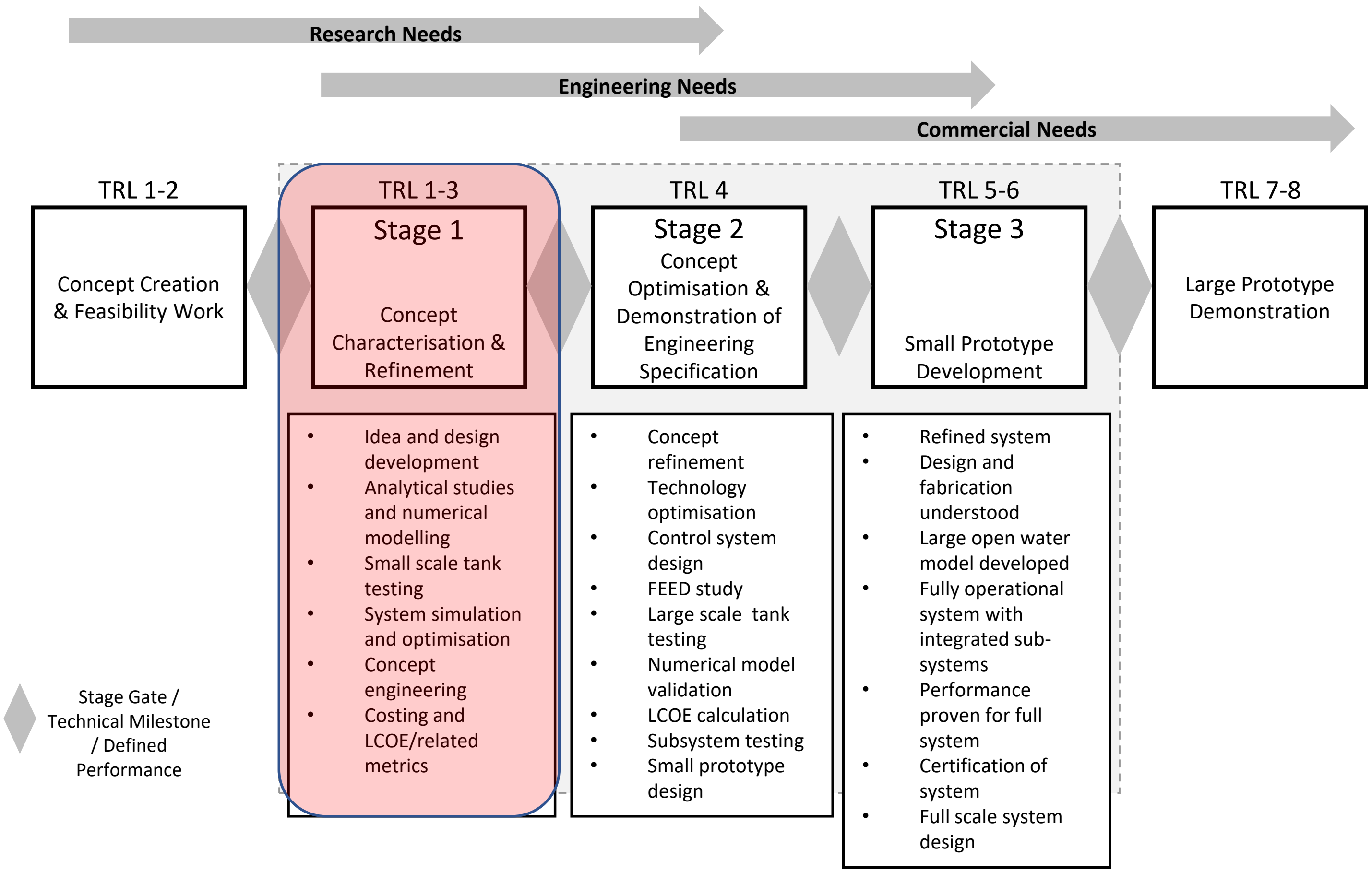


What is NWEC doing?

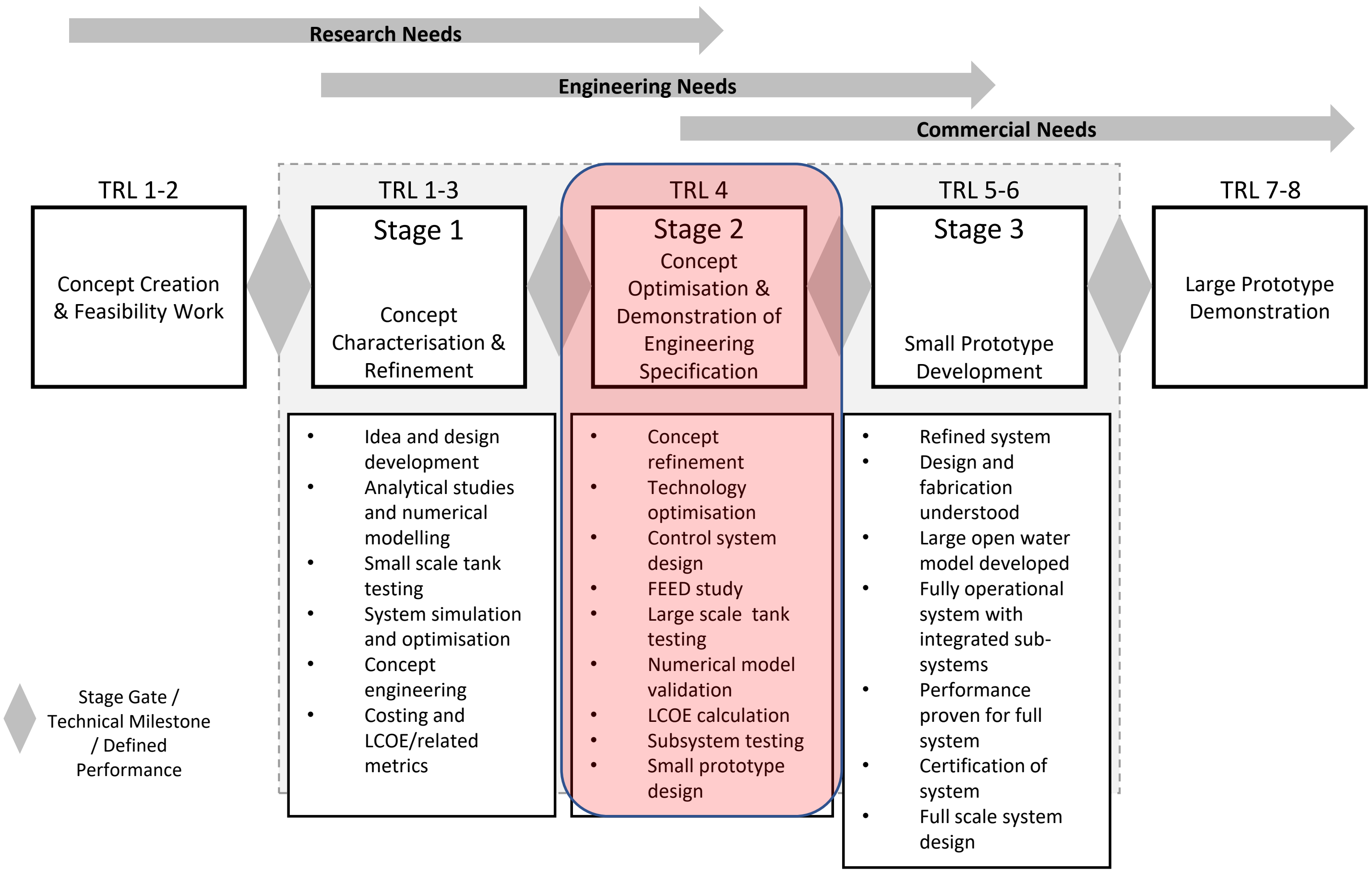
- Sustainable and pragmatic technology development
- Robust design review process
- Appraised testing in a controlled environment



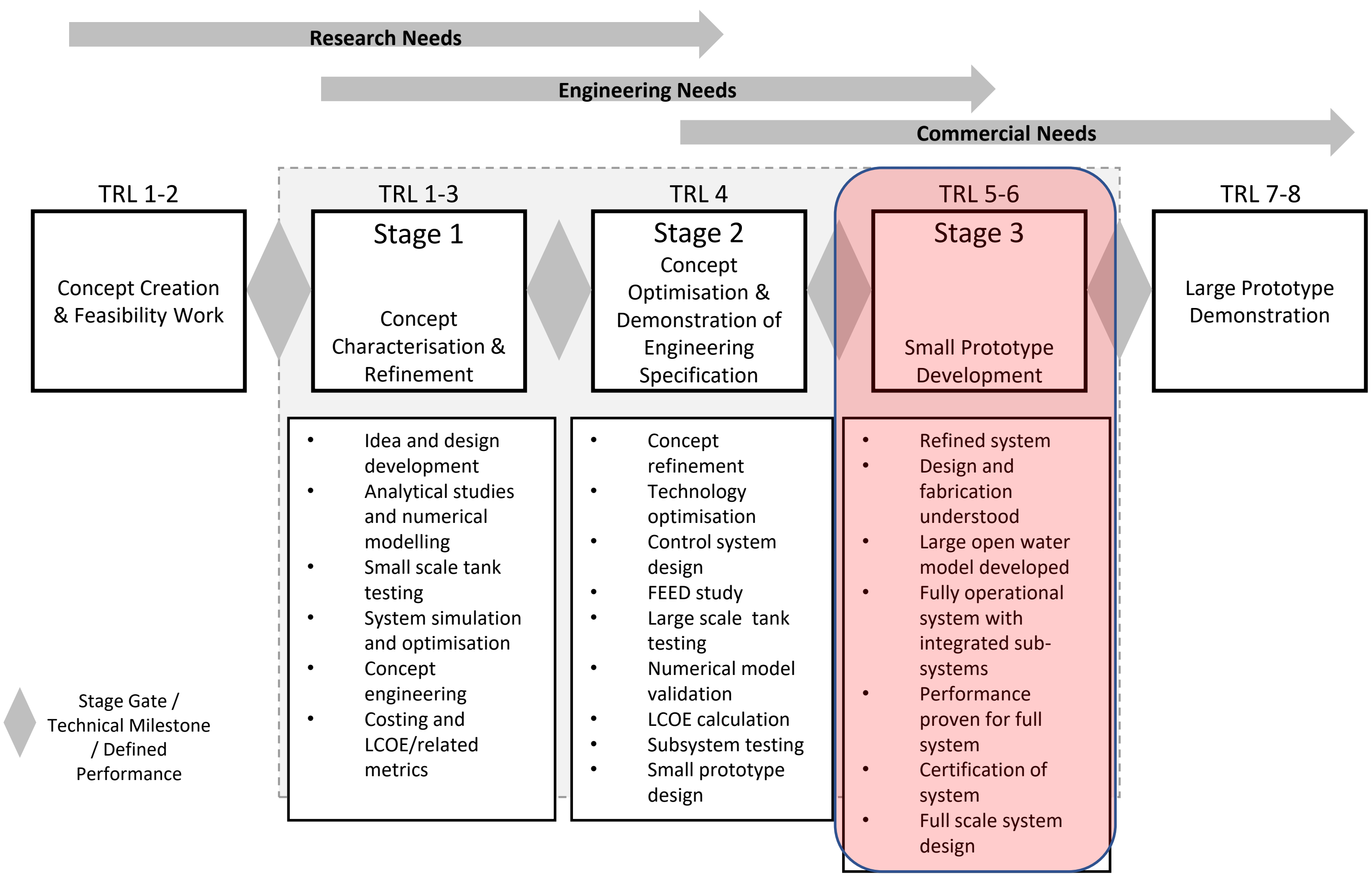
Novel WEC Programme Pathway



Novel WEC Programme Pathway

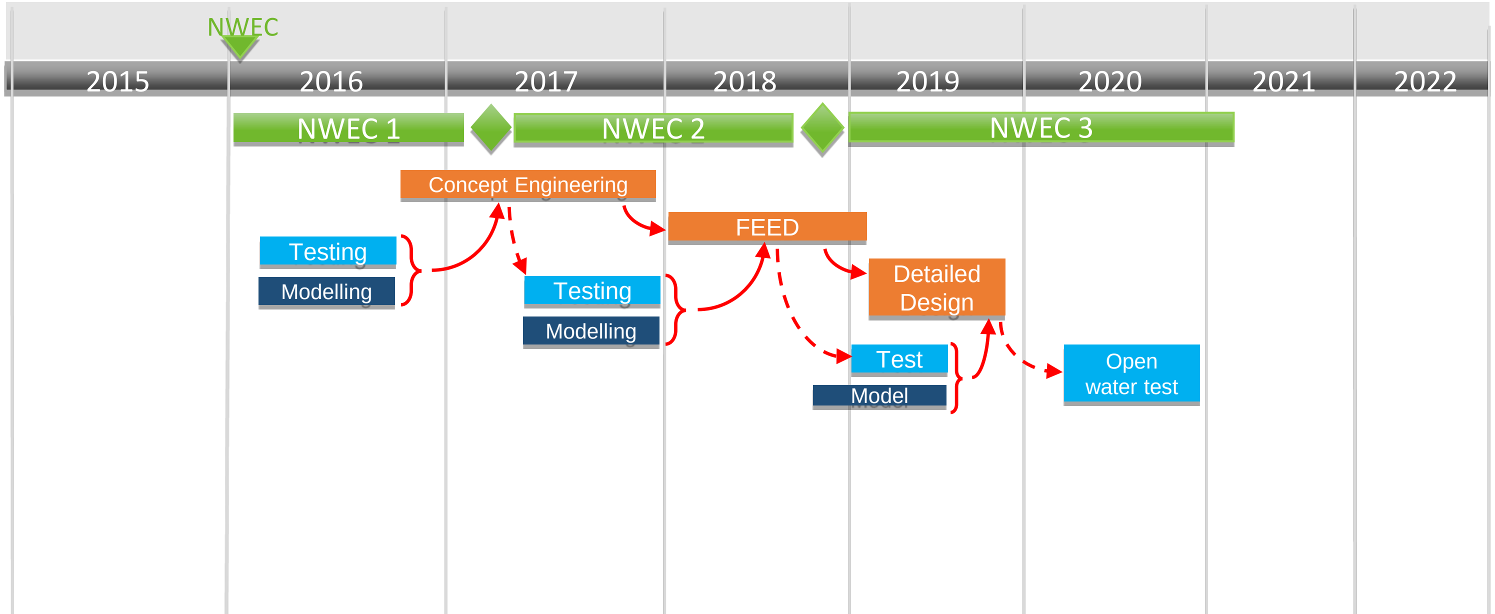


Novel WEC Programme Pathway



Engineering Approach

- Iterative design development
- Learning from past experiences incorporated
- Appraisal of engineering
- Robust design review procedure for independent system(s) review



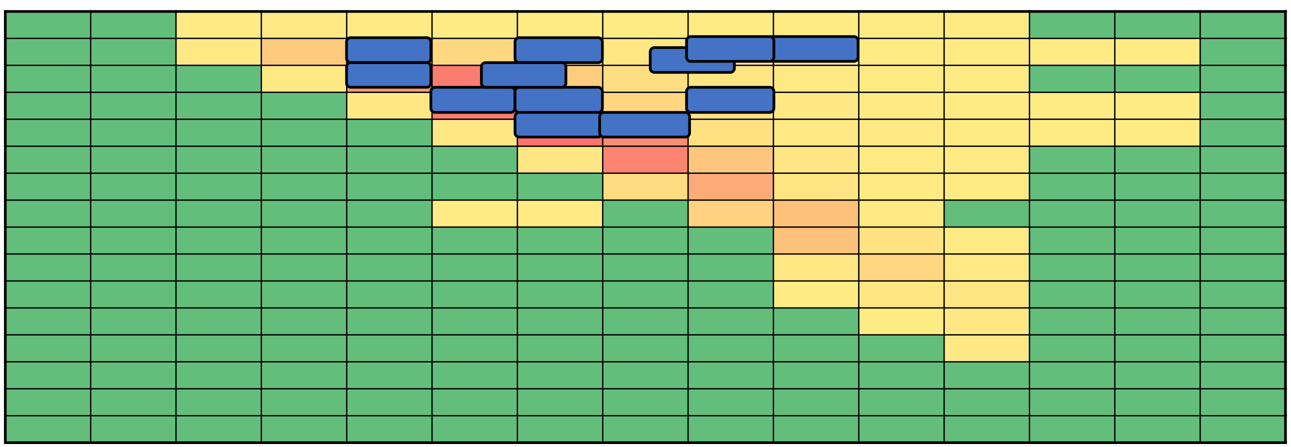
Novel WEC Testing

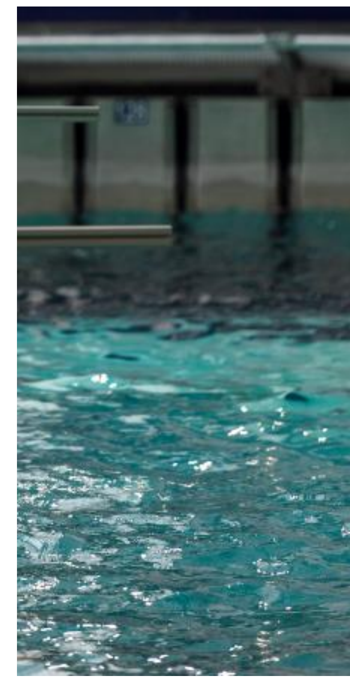
- Evolution of testing objectives:
- Stage 1
  - Aim: Performance baseline
  - Third Party Verification (organised by the developer)
- Stage 2
  - Aim: Optimisation/comparison
  - Third Party Appraisal (organised by WES)
- Stage 3
  - Aim: Validation and response in a real environment
  - WES Performance Appraisal (WES)

Sea State ID	T_p [sec]	H_{m0} [m]	γ [2]	θ_m [3]	s [4]
IR01	7.7	1.5	1.0	0°	∞
IR02	10.5	1.5	1.0	0°	∞
IR03	13.3	1.5	1.0	0°	∞
IR04	14.7	1.5	1.0	0°	∞
IR05	12.6	2.0	1.0	0°	∞
IR06	7.7	2.5	1.0	0°	∞
IR07	9.9	2.5	1.0	0°	∞
IR08	9.1	3.5	1.0	0°	∞
IR09	10.5	4.5	1.0	0°	∞
IR10	11.9	4.5	1.0	0°	∞
IR11	13.3	3.5	1.0	0°	∞
IR12	10.5	3.5	1.0	0°	∞
IR13	7.7	2.5	3.3	0°	6.0
IR14	10.5	3.5	3.3	0°	6.0
IR15	11.9	4.5	3.3	0°	6.0
IR16	10.5	3.5	3.3	0°	10.0
IR17	11.9	4.5	3.3	0°	10.0

NWEC Stage 1 & 2 – Testing

- Mandatory seas
  - 11 regular
  - 12 irregular long-crested
- Compliant with TC114 62600-103
- *Guidance on WES Sea States available online*





NWEC Stage 3 – Testing

- Further tank testing
- Open water testing – Summer 2020

- Objectives of open water testing:
  - Test in conditions representative of the full-scale environment,
  - Evidence sustained electrical output,
  - Gain confidence through reliable operation of the WEC systems,
  - Demonstrate planned O&M activities,
  - Demonstrate proposed full-scale survival systems,
  - Gather learning applicable to full-scale system,
  - Contribute to a refined estimate of full-scale WEC performance.

What else is NWEC 3 doing?

- Overall technical de-risking – building confidence
- Programme integration
  - System integration and technical convergence
  - Awareness of system/subsystem requirements
- Contributing to the long term goal – commercial-scale markets

https://www.offshorewind.biz/wp-content/uploads/2016/11/photo-of-the-day-port-of-esbjerg-displays-offshore-wind-bounty-768x326.jpg

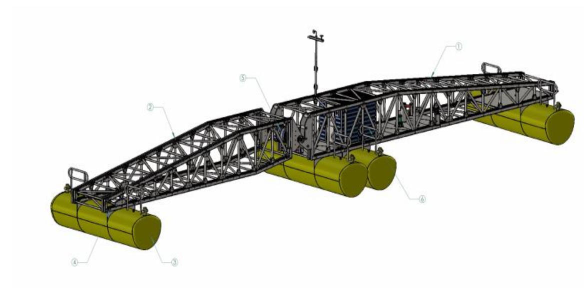
NWEC – Stage 2 Projects

wave energy SCOTLAND

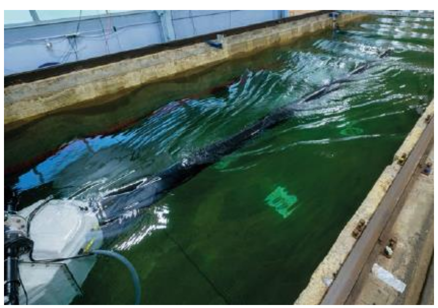
HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

mocean energy

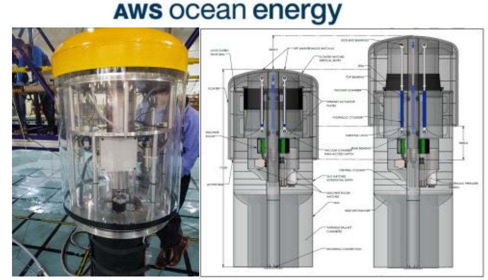
4c Engineering Technology



CHECKMATE



AWS
AWS ocean energy



NWEC – Stage 3

AWS: *At-Sea Demonstration of the Archimedes Waveswing*

Project Summary

The project will advance the award-winning Scottish Archimedes Waveswing™ wave energy converter from TRL4 to TRL7 through design, build and testing of a half-scale device in a real-sea environment.

In 3 years through NWEC1 and NWEC2 AWS Ocean Energy has achieved a three-fold increase in performance for the Waveswing through improved understanding of the device fundamentals. New configurations offer a very significant improvement to the cost of energy whilst reducing technical risk.

This project will build confidence and reduce risk in the Waveswing™ technology through a real-world demonstration of:

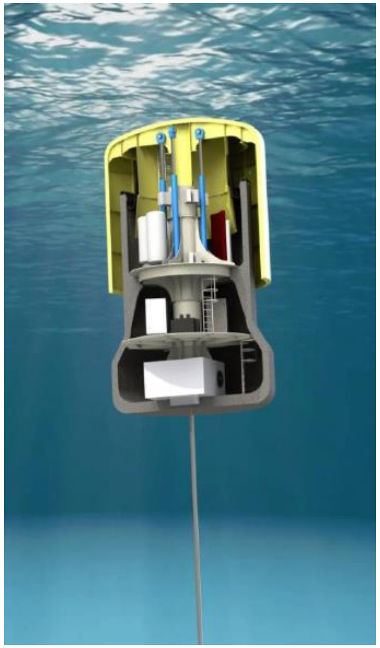
- Survivability
- Operation
- Performance

Lead Contractor

AWS Ocean Energy

Partners

EMEC, Pelagic Innovation, Green Marine, Quoceant, 4C Engineering, REOptimize Systems, JGC Engineering



Mocean – NWEC Stage 3

Cameron McNatt

mocean energy

Power your next horizon

Cameron McNatt
Co-founder and Managing Director
cameron.mcnatt@mocean.energy

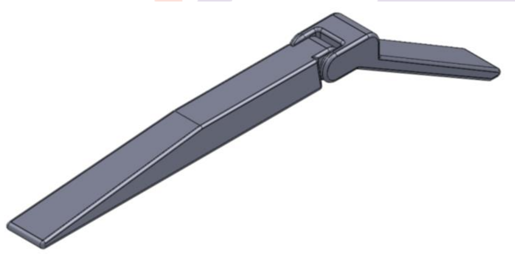
www.mocean.energy

Hinged Raft WEC

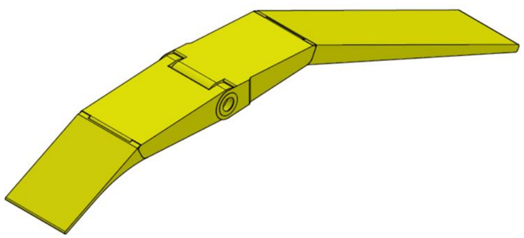
- https://www.youtube.com/watch?v=vSItXQ8rbdE

WEC Evolution

NWEC Application



NWEC Stage 1



NWEC Stage 2

Advanced geometrics in numerical optimisation

Identified issue with model validation

50% increase in mean power/mass

Added nonlinear spectral modelling.
Added torque cost to optimisation

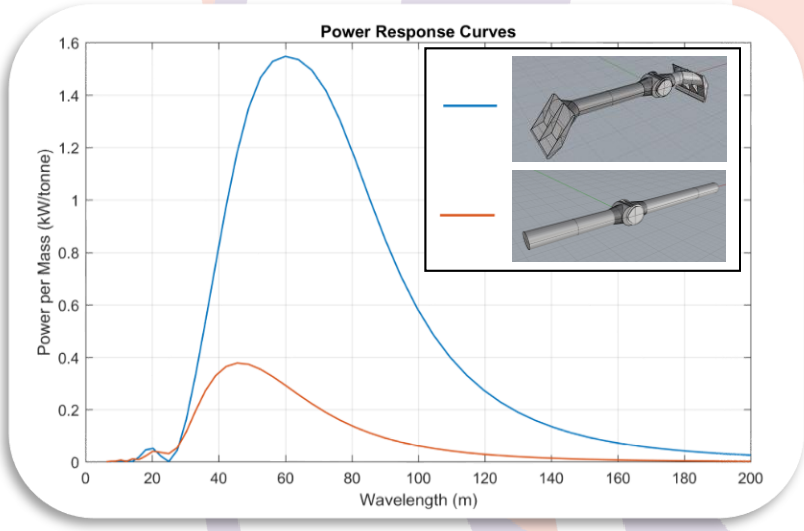
Initial working model of wave channels

Reduced draft, improved manufacturability

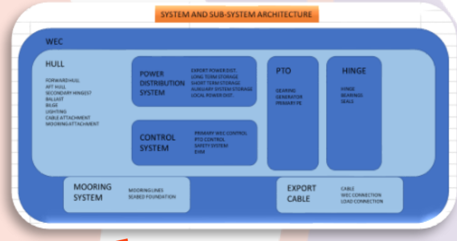
Further 80% increase in mean power/mass
3x improvement in power/torque

Technology and IP

Innovative geometry developed through numerical optimization produced 3x more energy than traditional designs

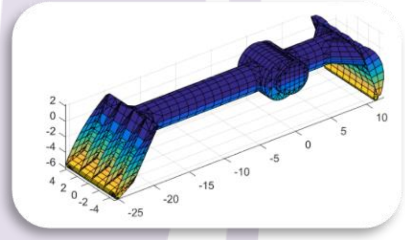


Engineering Requirements



Wave Tank Validation

Numerical Optimisation

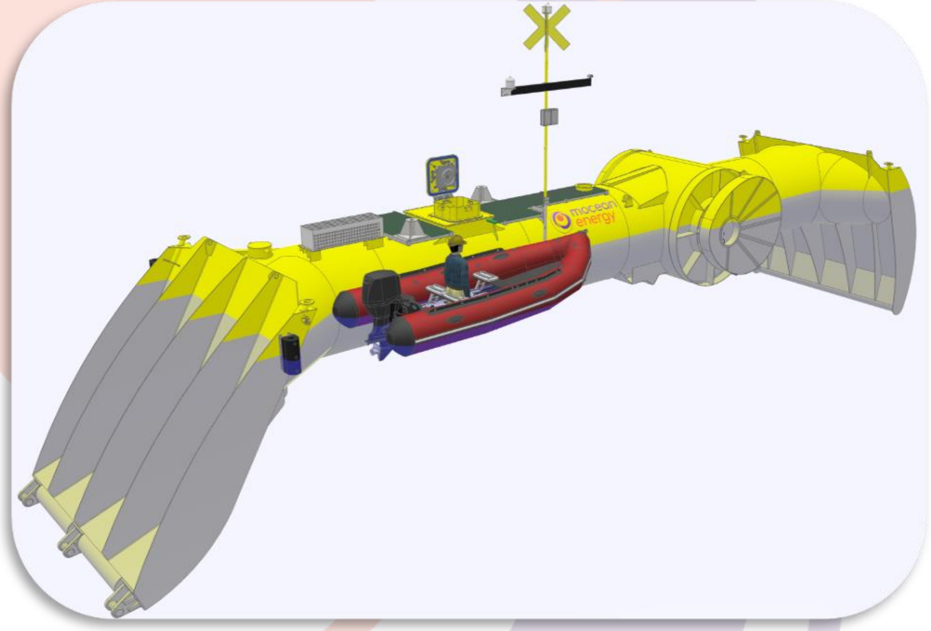


Numerical optimisation complimented by wave tank testing, and engineering requirements and in-house expertise.

NWEC Stage 3 Project

wave energy SCOTLAND

- 10 kW
- 20 m long
- 30 tons
- Fabricated in Fife, Scotland
- Tested in Orkney on East Coast and at EMEC



BLACKFISH ENGINEERING DESIGN AND PRODUCT DEVELOPMENT

THE UNIVERSITY OF EDINBURGH

SUPPLYDESIGN

sequentec

industrial systems and control

mocean energy

Cameron McNatt
Co-founder and Managing Director
cameron.mcnatt@mocean.energy

Paper ID: 1647

Session: Wave device development and testing

Time: **Tuesday 3 September, 16:00**

www.mocean.energy

Site selection for scaled open water testing of a wave energy converter

EWTEC 2019 Napoli

Niall McLean PhD (Presenter)
Matthew Holland MEng
Elva Bannon BEng MEng
Ruairi MacIver PhD

3 September 2019

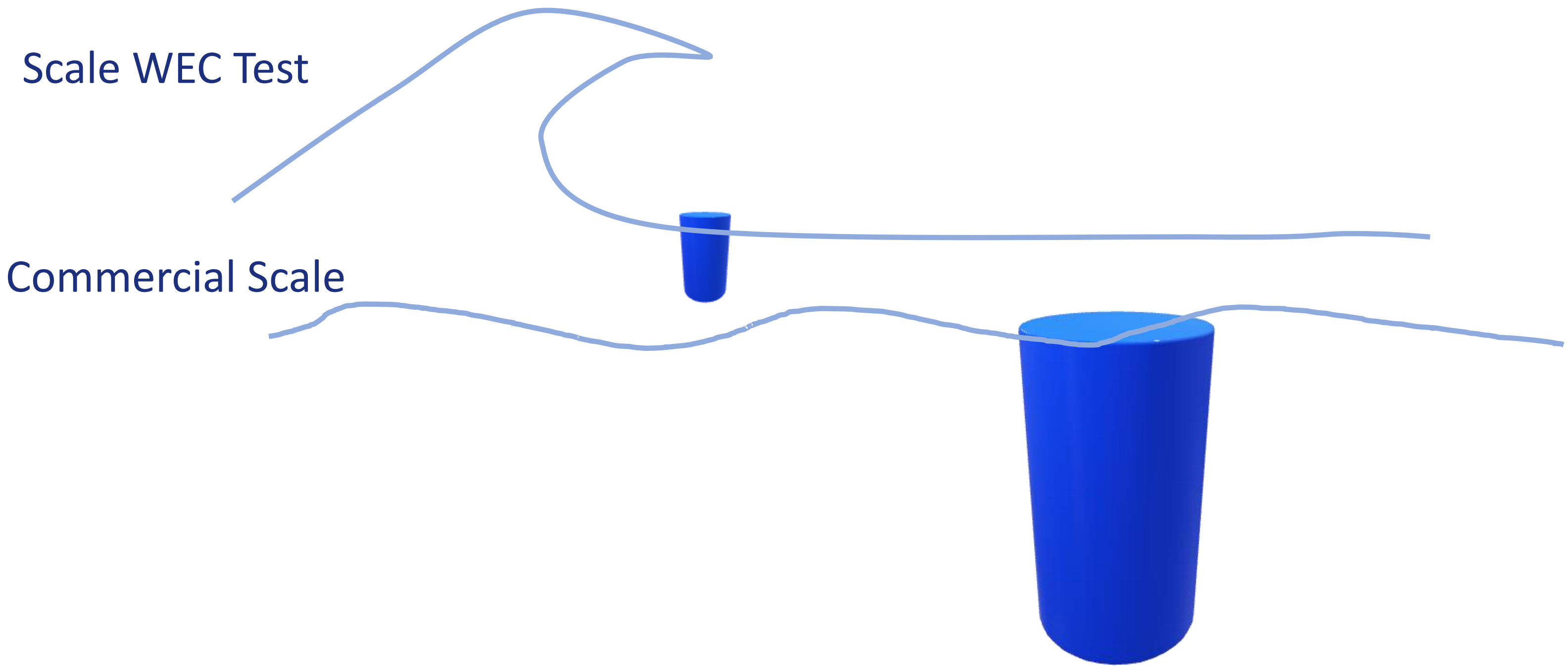
wave energy SCOTLAND

HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

Aim of work described in paper

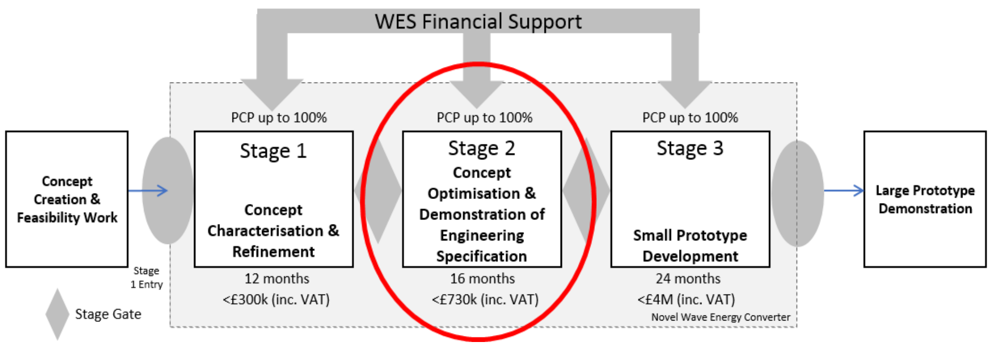
Want to choose scale WEC testing sites where scale WEC response is representative of commercial scale response.

Potential consequence of getting this wrong:



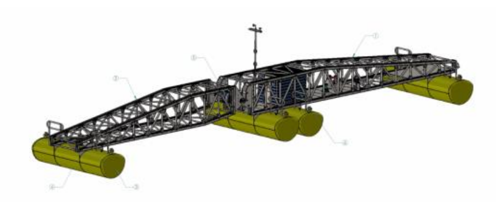
wave energy SCOTLAND
HIE Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

Novel WEC programme



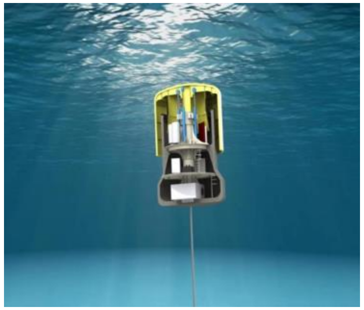
NWEC2 Participants

4c Engineering Technology

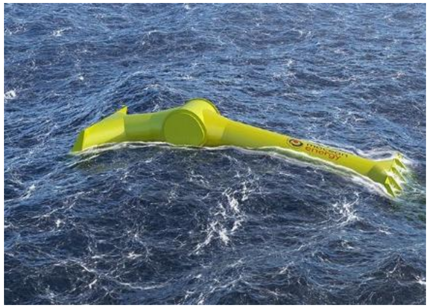


CHECKMATE®

AWS ocean energy



mocean energy



NWEC3 scale prototype open water testing requirements

1) WEC is equipped with a power take-off (PTO) capable of generating electricity from extracted wave power (with behaviour/feedback representative of the intended commercial scale device's PTO).
2) WEC performance measurements made in range of sea-states that commercial-scale device will generate power from.
3) Testing must be undertaken in Scotland.

1) and 2) consistent with IEC TS 6200-103(2018) Stage 3.

IEC TS 62600-103 (2018):
Marine energy - Wave, tidal and other water current converters - Part 103:
Guidelines for the early stage development of wave energy converters –
Best practices and recommended procedures for the testing of pre-prototype devices.

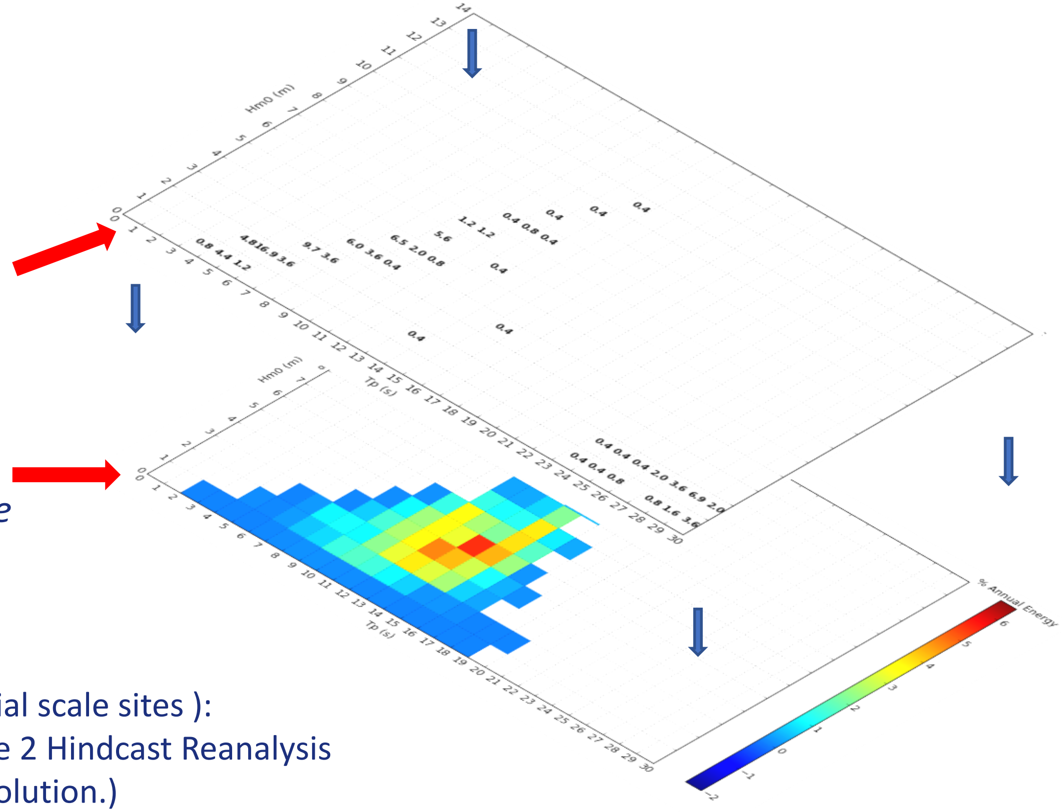
Case Study

Suitability of various prospective quarter scale (1:4) sites in Scottish Waters explored in a case study by superimposing:

full scale equivalent (Hm0, Tp) % occurrence scatter table for each prospective site

on top of

% annual incident energy (Hm0, Tp) scatter table for a commercial scale site (EMEC Billia Croo)



Scatter data used (for both quarter scale and commercial scale sites):
2008 scatter data extracted from the NOAA NCEP Phase 2 Hindcast Reanalysis
(4 minute spatial resolution and 3 hourly temporal resolution.)

WES Site selection paper

TUESDAY 3rd

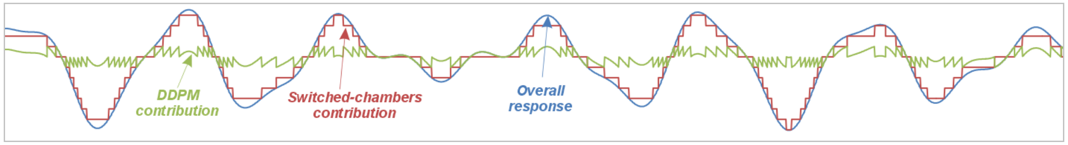
WDD	Wave device development and testing		ROOM PERSEIDE
			CHAIR E. Di Lauro and J. Cândido
15.40 16.00	1628	The WETFEET Project – A disruptive approach to wave energy	Jose Cândido, Antonio Sarmento, Fred E. Gardner, Luis M. C. Gato, Marco Fontana, Keri Collins
16.00 16.20	1647	The performance of the Mocean M100 wave energy converter described through numerical and physical modelling	J. Cameron McNatt, and Christopher H. Retzler
16.20 16.40	1357	Development and assessment of a new geometry for CECO wave energy converter	Paulo Rosa-Santos, Francisco Taveira-Pinto, Claudio A. Rodríguez, Gonçalo Coelho, Daniel Clemente, Hélio Mendonça, A. Paulo Moreira
16.40 17.00	1234	New MoonWEC concept and its device optimization	Adria Moreno Miquel, Renata Archetti
17.00 17.20	1762	Site selection for scaled open water testing of a wave energy converter	Niall D. McLean, Matthew A. Holland, Ruairi D. Maciver and Elva B. Bannon

Artemis Quantor (PTO Stage 3)

Sarah Acheson

Hybrid Digital Displacement®
Hydraulic Power Take-Off (Quantor)

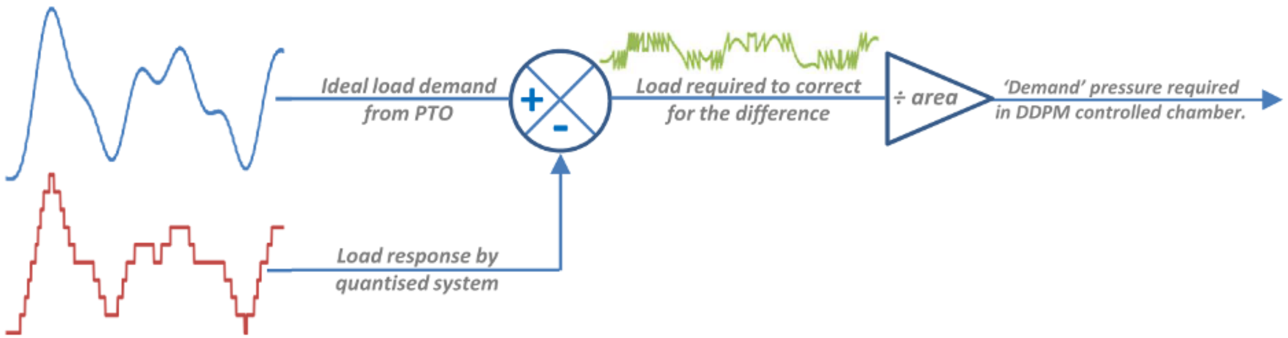
Stage 3 PTO Project

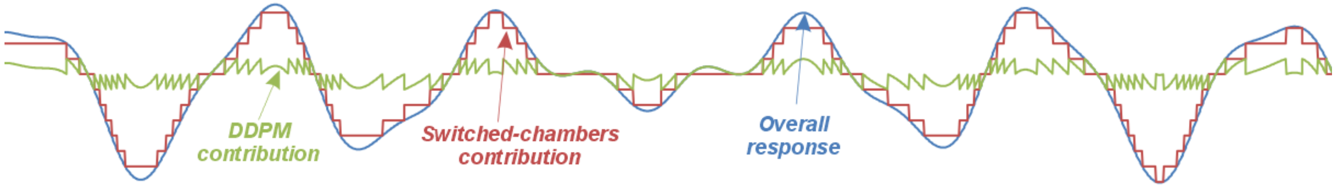


Artemis Intelligent Power

Quoceant Ltd

Quantor Concept





Project Aims

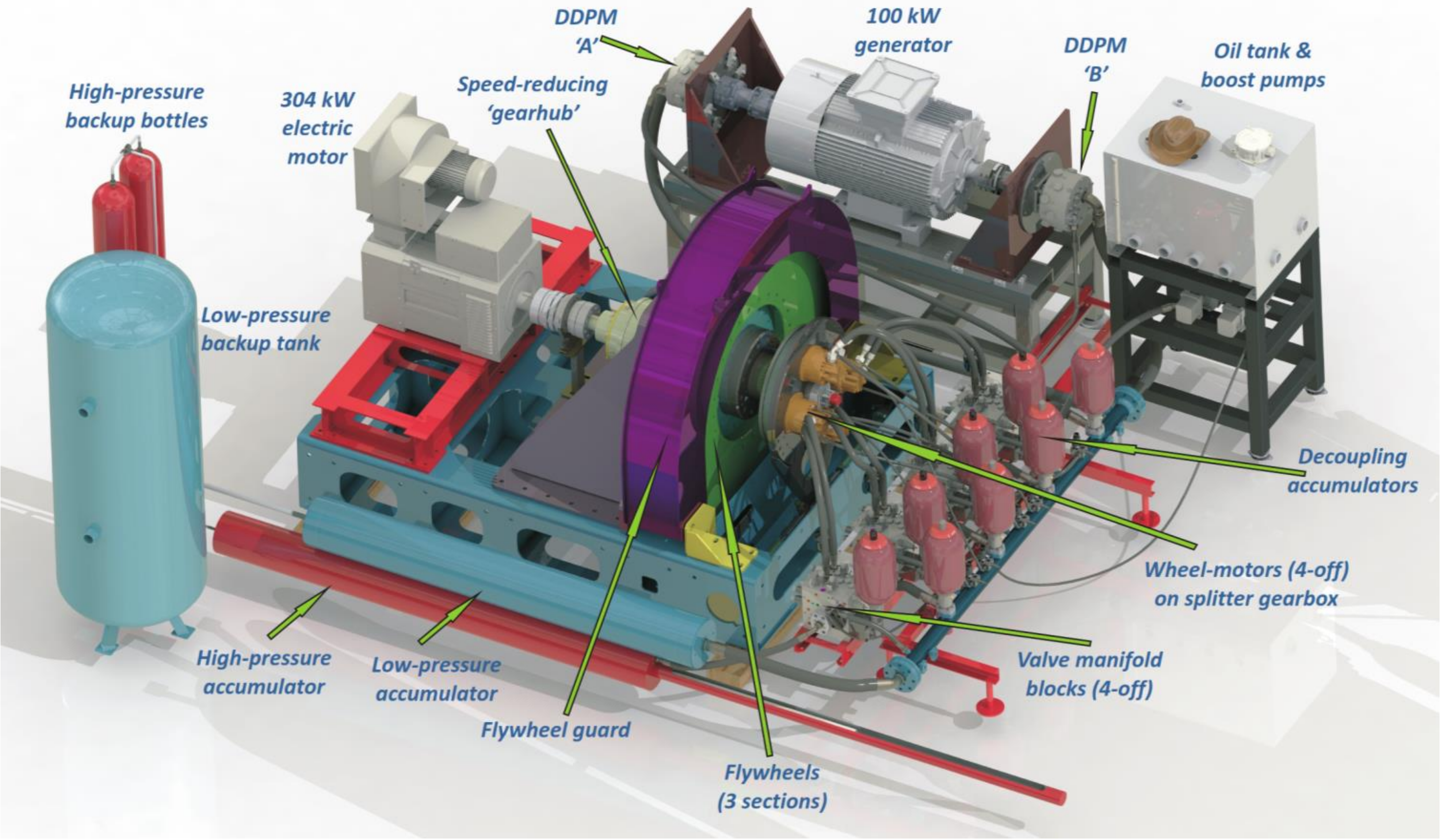
- Experimentally demonstrate continuous control of PTO torque
- Experimentally demonstrate high efficiency over a broad power range
- Experimentally demonstrate fully reactive four-quadrant capability
- Produce validated scalable model of Quantor PTO

ARTEMIS INTELLIGENT POWER

wave energy SCOTLAND

Idcore Industrial Doctoral Centre for Offshore Renewable Energy

Quantor Test Rig

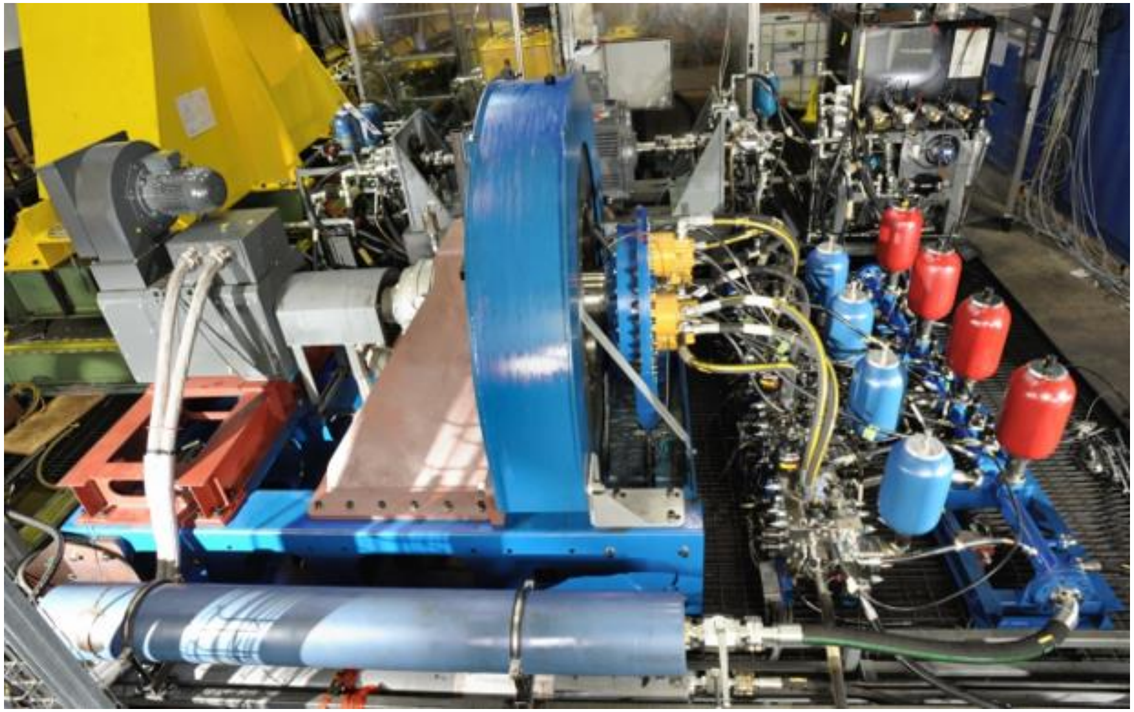


ARTEMIS INTELLIGENT POWER

wave energy SCOTLAND

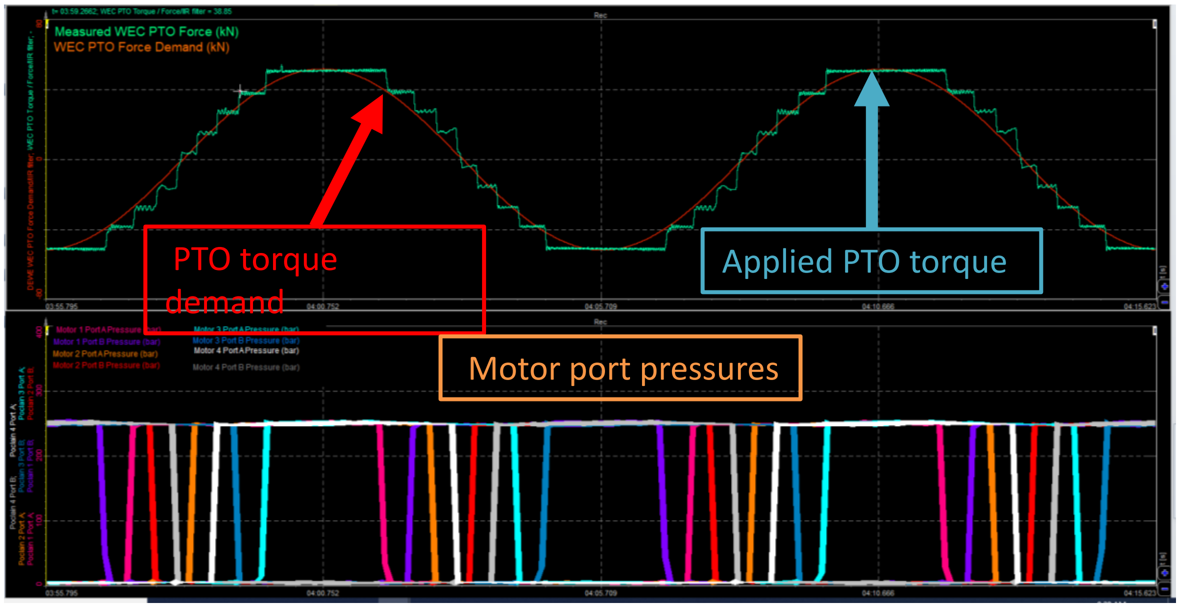
Idcore Industrial Doctoral Centre for Offshore Renewable Energy

Quantor Test Rig



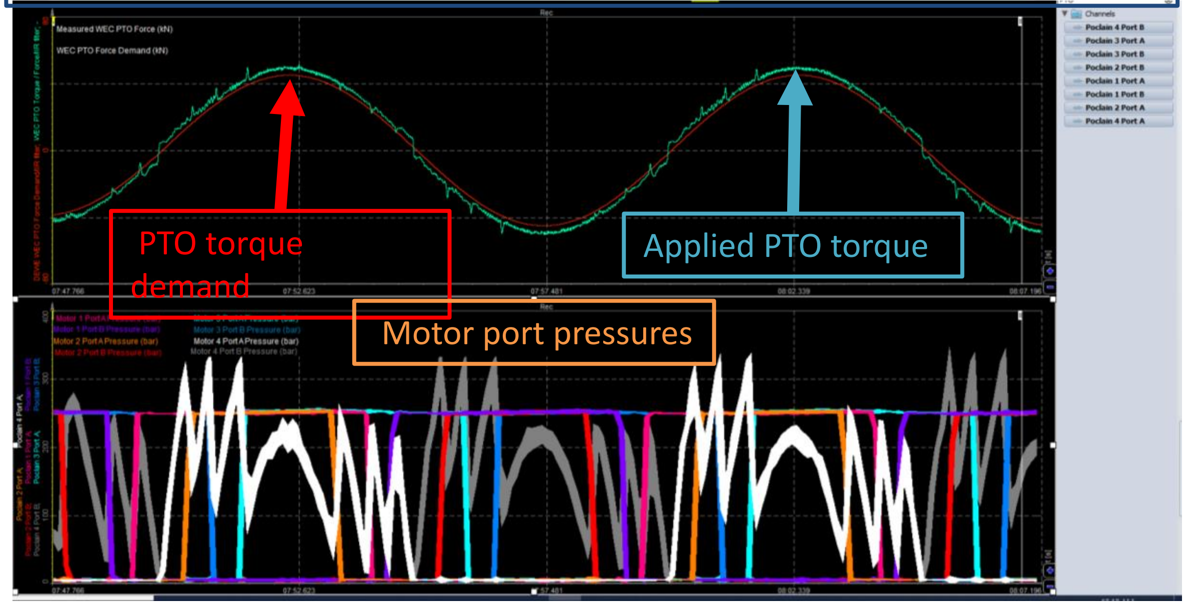
Test Results

Quantised control: all fixed displacement motors connected or disconnected to HP accumulator by algorithm following PTO torque demand

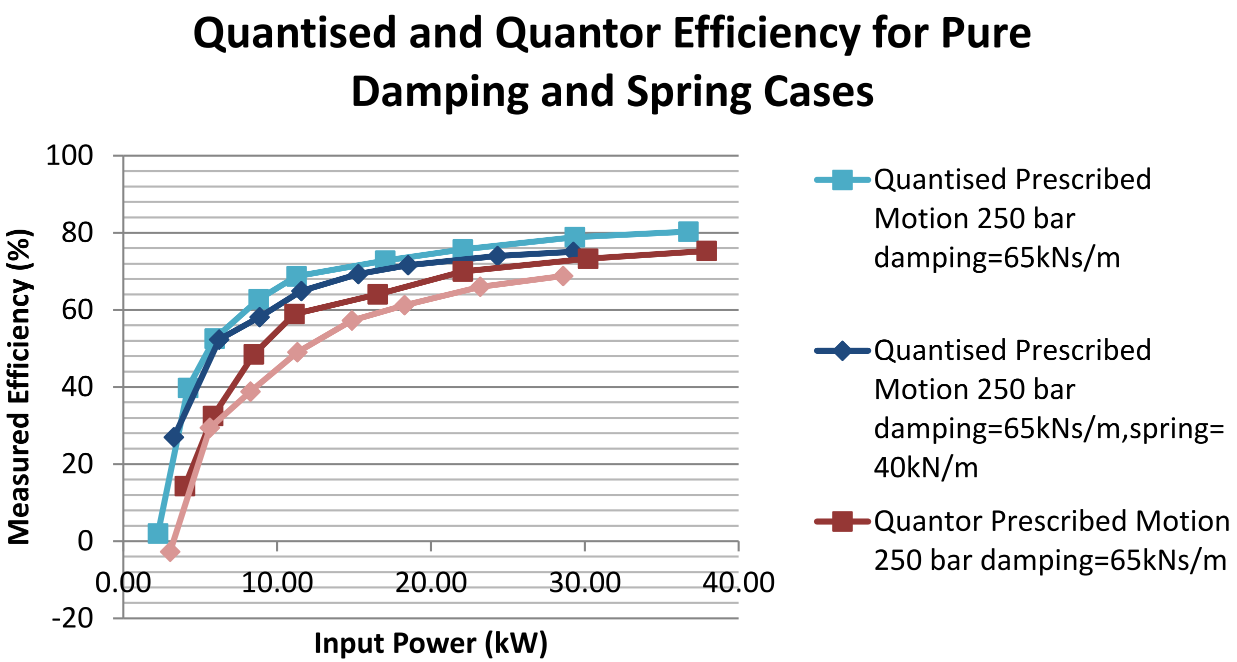


Test Results

Quantor control: three fixed displacement motors under quantised control and one under continuous control of DDPM giving smooth torque



Test Results



Preliminary Conclusions

Results so far show system is smoothly controllable in all four quadrants, efficient over a broad range of absorbed input power and scalable to much larger power regimes

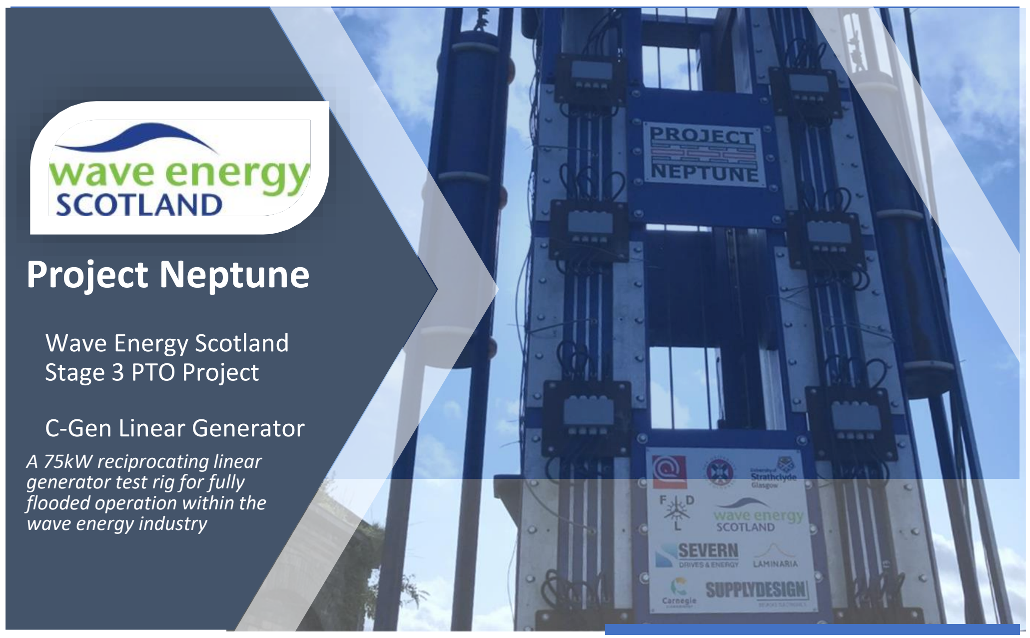
- Continuous control works and incurs efficiency penalty of ~5% relative to pure quantised
- Reactive control works and incurs an efficiency penalty of ~2% relative to pure damping

Further Work

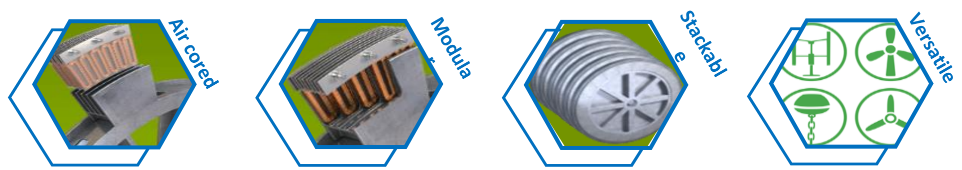
- Testing with WEC hardware-in-the-loop model in regular and irregular seas
- Completion of model validation
- Model extension to larger PTOs
- Future applications

C-Gen Linear Generator (PTO Stage 3)

Jonathan Shek


wave energy SCOTLAND
Project Neptune
Wave Energy Scotland Stage 3 PTO Project
C-Gen Linear Generator
A 75kW reciprocating linear generator test rig for fully flooded operation within the wave energy industry
PROJECT NEPTUNE

C-GEN is an advanced multi-stage air-cored direct drive permanent magnet generator technology providing high reliability and availability in renewable energy converters.



The differentiating design features of the patented C-GEN design include:

- Axial flux topology with C-shaped rotor core
- Air-cored stator arrangement
- Generator divided into several axial generator stages that are electrically independent
- Modular generator build to ensure low O&M costs

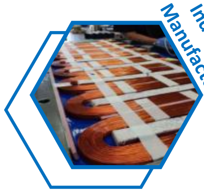
C-GEN PMG technology has the following USPs over existing generator technologies used for direct drive PTO

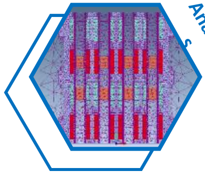
- No Magnetic Attraction Forces within Airgap
- No Cogging Torque
- High Degree of Modularity
- Affordable with low CAPEX
- Easy Integrated into various Renewable Energy Device Types
- High efficiency across full operating range

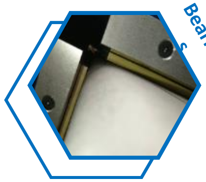
Current C-GEN Technology Status

- TRL level 5 for Rotary
- TRL level 3 for Linear
- Patent Granted in USA, China, Japan, Canada, Australia & Europe
- Numerous C-Gen Machines built from 10kW to 1MW
- Marinised Flooded C-Gen Generators have been tested for Submerged Offshore Operation

"The C-Gen system is highly versatile and can be applied in linear, rotary and part-rotary arrangements"







Availability, Reliability And Survivability

- MTBF – target 5 years
- 5 x electrical & mechanical overload capability
- Modularity provides redundancy
- Maintenance on vessel – low MTTR
- Flooded operation provides inherent overload capability

Project Neptune Objectives

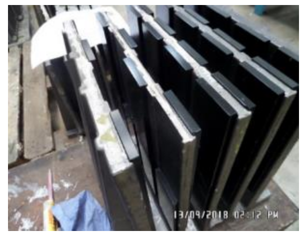
- Demonstrate C-GEN in a real Environment, at a Relevant Scale and under Realistic Load Profiles.
- Industrialise the Design and Manufacture of C-GEN for Marine Renewable Applications.
- Obtain Qualification from an Independent Body.
- Align the Commercial Strategy with Device Developers for a Full-Scale Stage 4 Demonstrator.

Project Neptune Build & Flooded Operation

- Epoxy Potted Air cored Coil Blades
- Polymer Bearing Modules
- Cast iron PM translator modules
- 4 Stage C-Gen Linear Design
- Modular Stator and PM Translator
- Fully flooded operation.
- Controllable test rig – linear motor-generator back to back system.
- Power conversion into the grid.
- Demonstrate O&M procedures.

Component Manufacture


Stator module


Cast iron PM module


Bearing Pad

Component Testing


Wet Stator Blade Test

Assembly Process

Completed:

- Design, Build and Test a Linear Generator at scale.
- Back to Back Linear Motor-Generator Test rig
- Dry Tests for commissioning

To do :

- Operate fully flooded in Leith Docks, Edinburgh.
- Demonstrate Operation and Maintenance Process.

FIND US LATER TO WATCH THE VIDEO

Thank you for listening

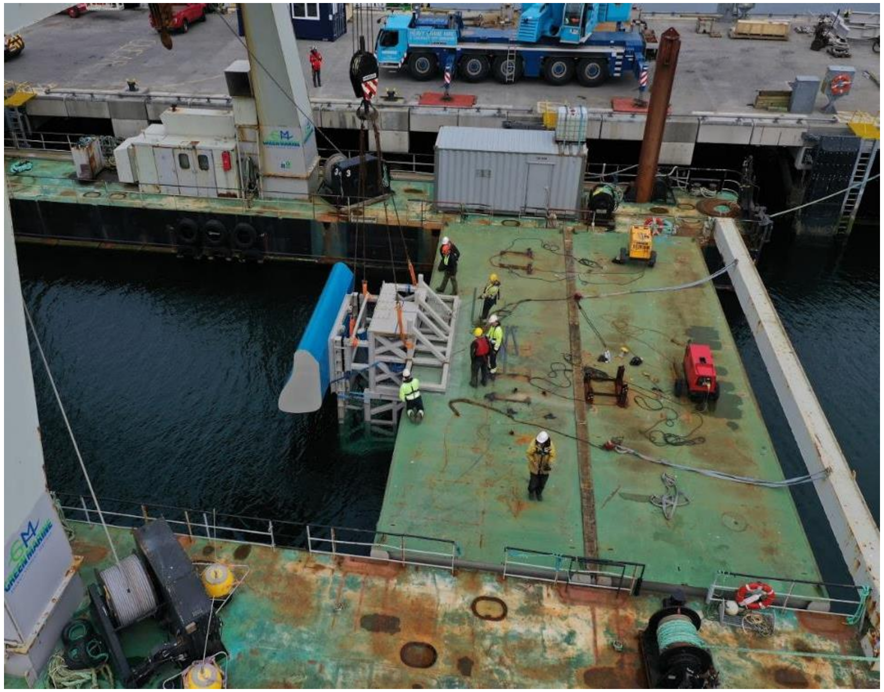
Contact: Markus.Mueller@ed.ac.uk

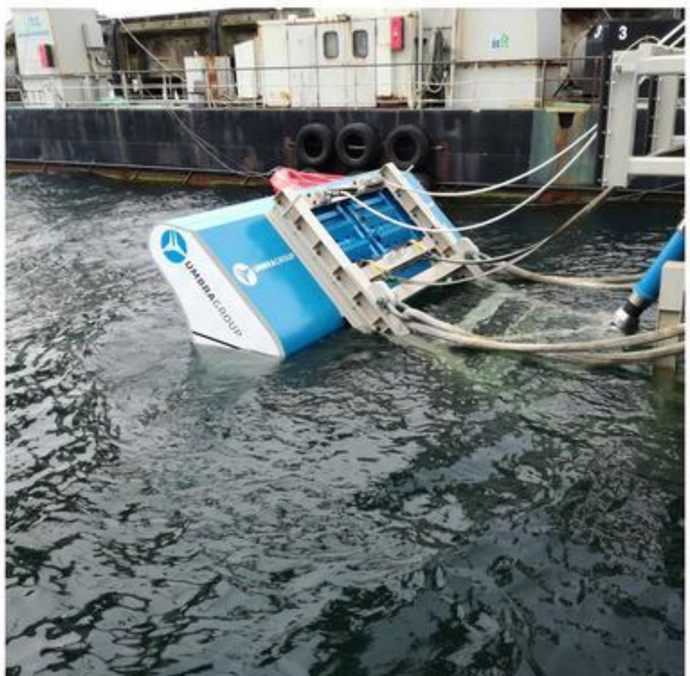
Website: www.cgen.eng.ed.ac.uk

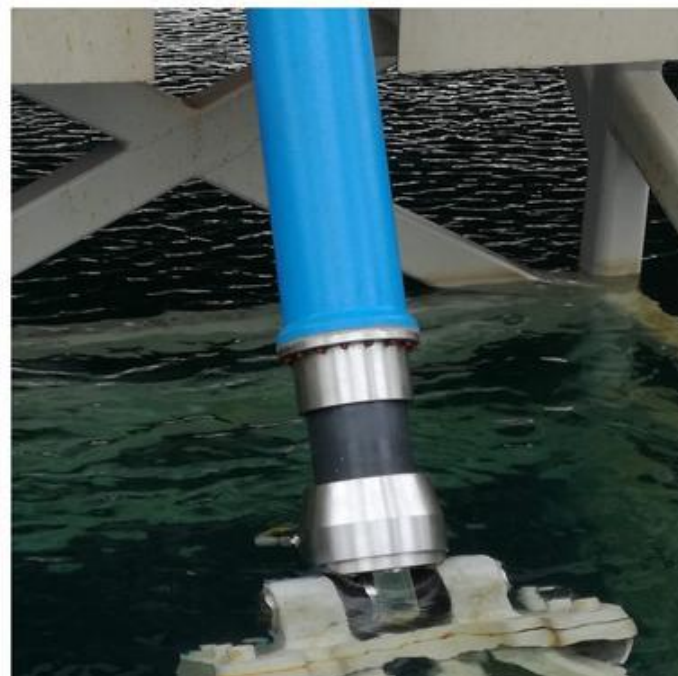
Umbra (PTO Stage 3)

Luca Castellini

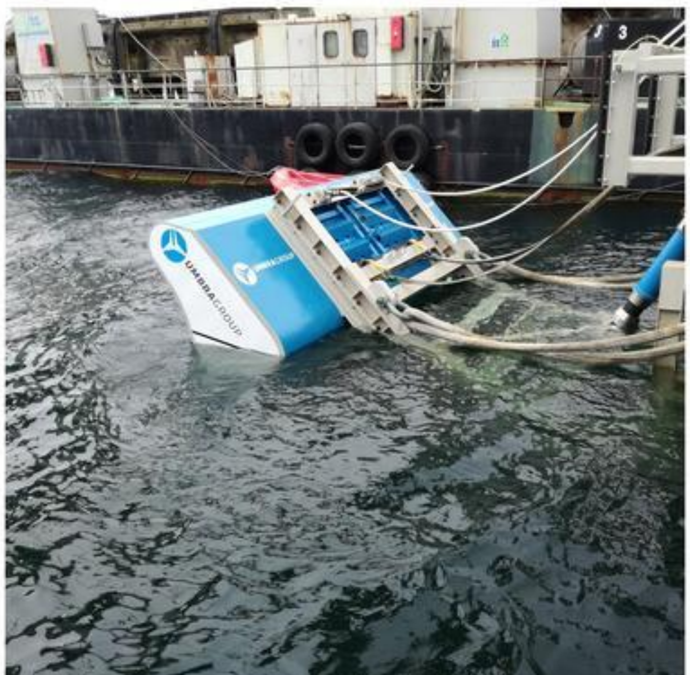
Umbra Orkney Testing

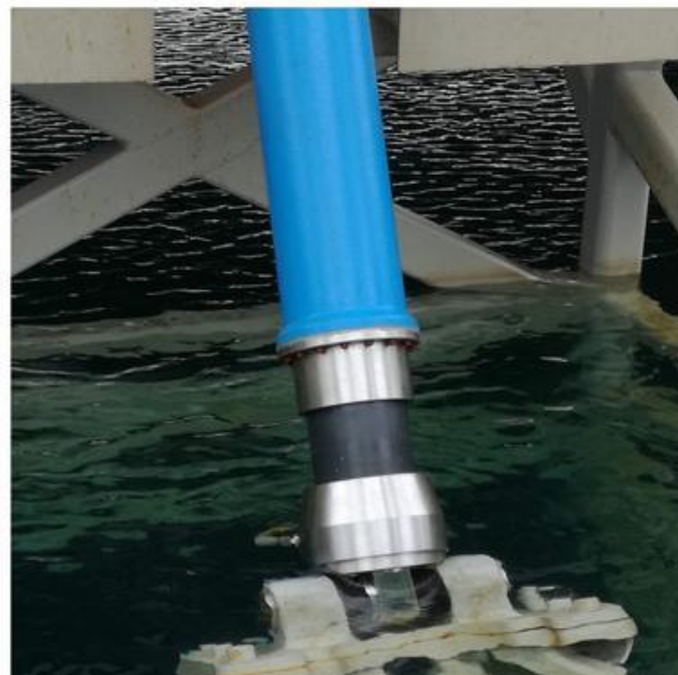



UMBRAGROUP



HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean





IMPACT & WEC-Sim (SgurrControl continuation)

Nathan Tom

Efficiency, Force and Phase – Practical Considerations for Controller Design of Point Absorber Wave Energy Converters

Nathan Tom (NREL), Adam Stock (UoS), Edward Hart (UoS)

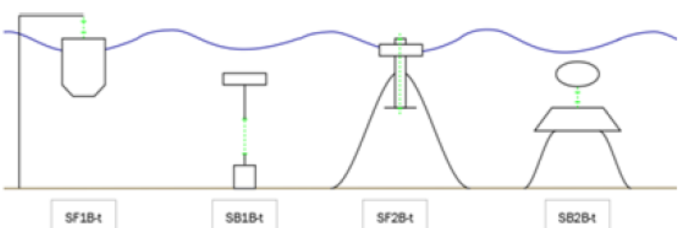
EWTEC Wave Energy Scotland Side Event

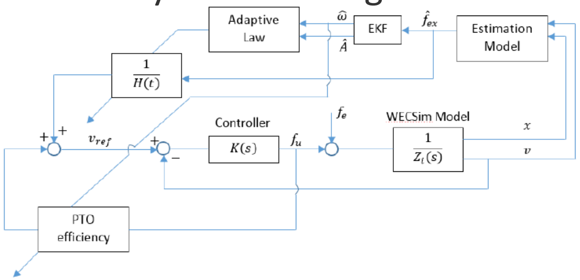
Monday 2nd September 17.30-19.00

What is IMPACT?

The Integrated Marine Point Absorber Control Tool (IMPACT) is a control toolbox that quickly and easily generates control models for point absorber WECs.

- Designed by Dr. Adam Stock and his team at SgurrControl Ltd (part of Wood) as part of WES's control call.
- Tool can be used to design an optimal velocity tracking (OVT) controller which are suitable for simulation in WEC-Sim.
- Simulations using the control methodologies provided by IMPACT have demonstrated improved energy capture in Scottish waters.
- IMPACT can be found in the WES Library
  - Library->Development Programmes -> Control Systems -> Stage 2





What are the goals of our project?

Previous work in IMPACT undertook a preliminary investigation of the following issues and potential solutions, but a more detailed investigation is needed:

- Issues restricting the energy capture of WECs using the OVT methodology are predominantly the PTO efficiency, and the PTO force, which are driven by the phase of the WEC dynamics.
- Limitations of the PTO, particularly with regards to force output and efficiency at low speeds reduces the effectiveness of the controller significantly.
- Without remedial action to ameliorate the efficiency and force issues OVT controllers do not provide increased energy capture and increase loads.

The collaborative project between UoS and NREL aims to provide actions to improve IMPACT via the following approaches:

- Additions to the controller algorithm to take into account PTO efficiencies
- Potential switching between OVT and linear damping methodologies in extreme conditions
- Suggesting practical and technically feasible alterations to the PTO design to better match the PTO to reactive control approaches such as OVT
- Explore the possibility of incorporating IMPACT into the WEC-Sim code

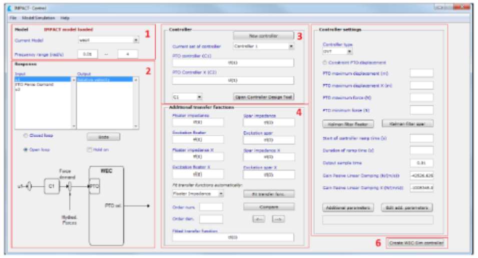
Project Funding Support and Timeline

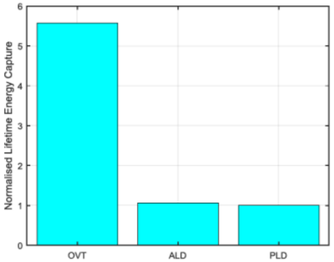
➢ Funding Sources

- *International Network of Offshore Renewable Engineers (INORE)*
  - Ocean Energy Systems Blue Energy Collaborative Scholarship (OES-BECS)
- *University of Strathclyde*
  - Global Engagement Fund

➢ Project Timeline

- July-Aug '19: Award notification,
- September 8 – 20 '19: Collaborative meetings at the University of Strathclyde
  - Finalize work scope, division of labor, initial results generation
- Oct.-Nov. '19: Continued remote work and model development
- Dec. '19 – Jan '20: Writing of conference paper to present preliminary results
- Feb. – March '20: Finalize work and development of application cases
- April '20: Journal publication presenting final project results





Thank You

www.nrel.gov

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Water Power Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

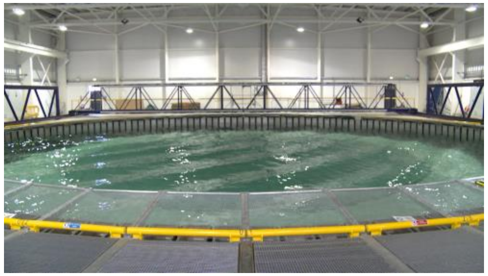
NREL Transforming ENERGY

SUPERGEN (Marine) FlexFund

Norman Morrison

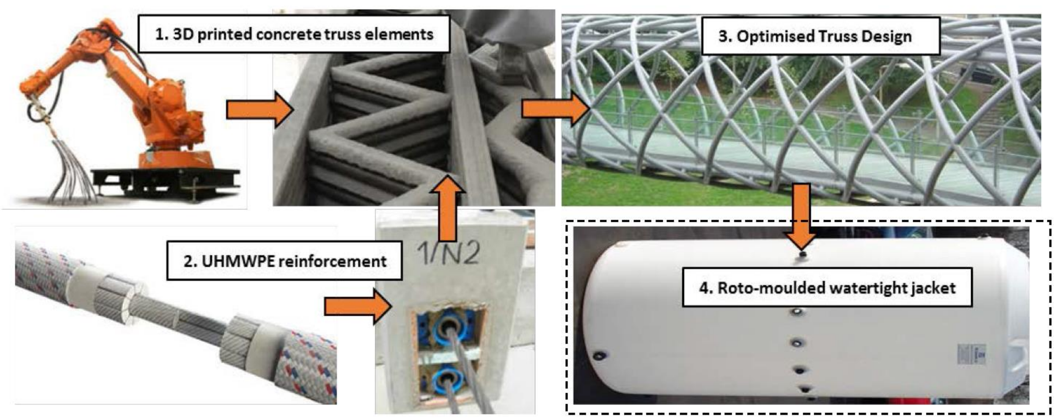
Background

- Supergen UKCMER was a consortium of marine energy researchers from across the UK (20003-2019)
- WES matched the UKCMER "Flex-fund" to fund short research projects; including test time at FloWave
- Six projects were supported in total, across wave and tidal energy



University of Dundee

- Digital Design and Additive Manufacture of UHMWPE-Reinforced Concrete Composite Structures (AD-CON)
  - PI – Prof. Rod Jones
- Moving from a shell to a truss

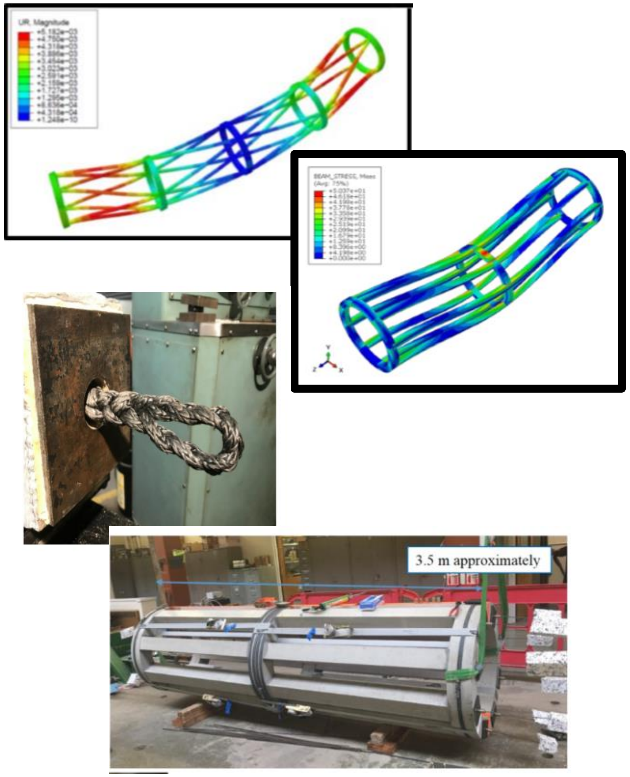


University of Dundee

- Aligned Steel Fibre Reinforced Concrete (SFRC)
  - No falsework/formwork required
- Corrosion resistant materials
  - High durability
- Optimising use of materials
  - Creating a kit of replaceable parts
- Lower cost material/manufacture

University of Dundee

- Different truss designs considered
- 1.5m beam element printed and post tensioned with UHMWPE rope
- Good resistance to deflection
- Truss manufactured and tested; deflections in line with model predictions

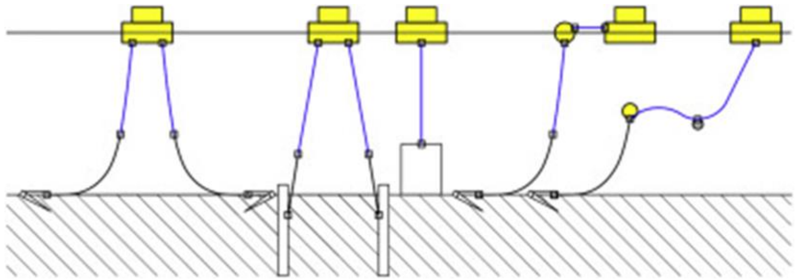


University of Dundee

- Conclusions
  - Aligned steel fibres capable of replacing conventional rebar, although not possible to achieve the same area of reinforcement
  - UHMWPE is capable of replacing steel (standard jacks and clamps not suitable)
  - The elastic load/deflection behaviour closely followed that from the analysis initially carried out, verifying the model developed
  - Elimination of bespoke rebar cages is good for CAPEX reduction and better suited to additive manufacture.
- Contact
  - Rod Jones m.r.jones@dundee.ac.uk

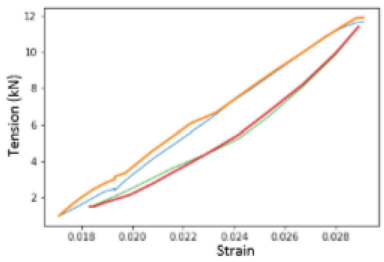
University of Exeter

- Synthetic ropes for Marine Renewable Energy mooring systems (SynMaRE)
  - PI – Dr Sam Weller
- Development of a detailed analytical model to simulate time dependent, non-linear behaviour of synthetic ropes.



University of Exeter

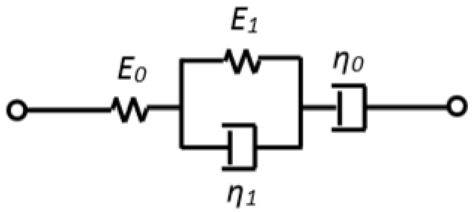
- Synthetic ropes display complex viscoelastic, viscoplastic and time dependent behaviour when loaded and unloaded; modelling is therefore challenging
  - Assess different rope models to allow more detail without computational overhead of FEA
  - Consider several parameter estimation methods
  - Implement the model and parameter in Orcaflex

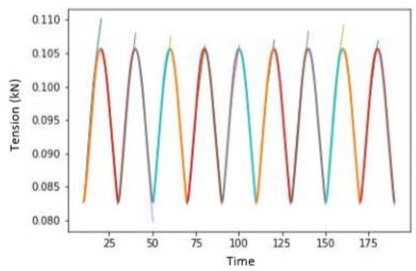


Orcina

University of Exeter

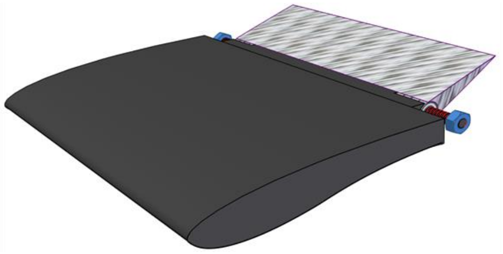
- Conclusions
  - Two springs – two dashpots model is better able to predict the behaviour of analysed ropes
  - Differential evolution algorithm provides best fit parameters
  - Approaches for Orcaflex implementation trialled. Unable to alter lumped mass model directly, so further work required.
- Contact
  - Sam Weller weller@tensiontech.com
  - Helen Smith H.C.M.Smith@exeter.ac.uk





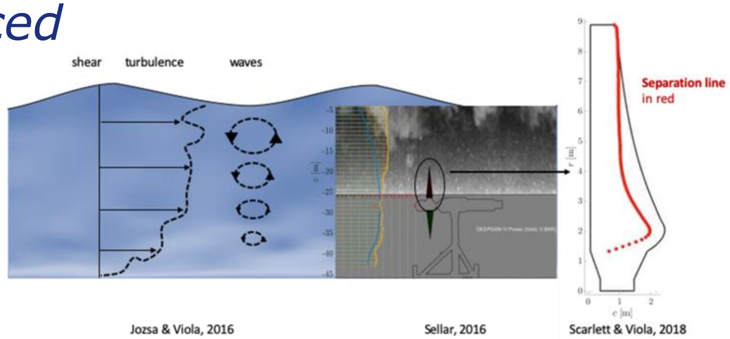
University of Edinburgh

- MetaTide: A New Meta-Material for Enhanced Fatigue Life of Tidal Energy Converters
  - PI – Dr Ignazio Maria Viola
- Prove that a morphing blade with a flexible trailing edge can reduce load fluctuations experienced by the blade.



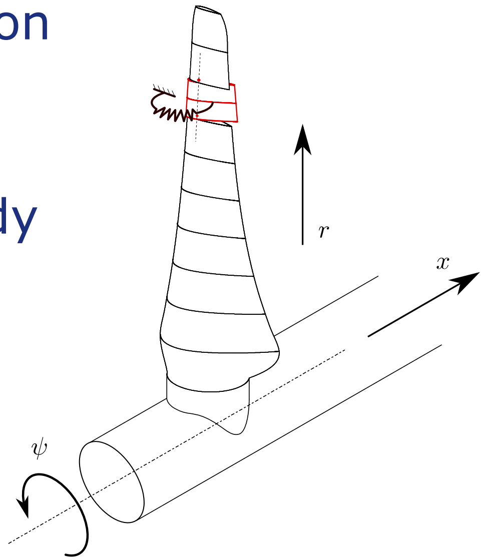
University of Edinburgh

- Tidal blades experience large flow fluctuations that result in load fluctuations that are transmitted to the whole turbine and can result in failures. Blades and many turbine components are over-dimensioned leading to unnecessary weight and costs.
  - *Study the morphing blade concept across the range of flow conditions experienced by a tidal turbine*
  - *Prove the fatigue loading reduction in these conditions through physical experiments*



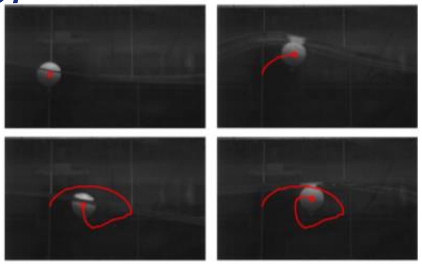
University of Edinburgh

- Conclusions
  - Model to predict load fluctuations and mitigation allowed by morphing blade developed
  - Results validated on model scale turbine
  - Morphing blade can mitigate >99% of unsteady loads while preserving mean loads
- Contact
  - Ignazio Maria Viola I.M.Viola@ed.ac.uk



University of Oxford

- A Robust Framework for Nonlinear Probabilistic Extreme Wave Loading Design and Testing: from Buoy to WEC – *Dr Ton van den Bremer*
  - *Develop model for semi-Lagrangian motion of a buoy*
  - *Validate model in FloWave*
  - *Perform random simulations to investigate effect of buoy motion on wave measurements*
  - *Develop software analysis tool*



- Contact

  - Ton van den Bremer ton.vandenbremer@eng.ox.ac.uk

University of Oxford

- Tidal Stream Turbine Fence Technology Demonstrator– *Prof Richard Willden*
  - *Demonstrate superior performance of single high blockage turbine designed for a multi-rotor fence*
  - *Demonstrate performance enhancement achievable from constructive interference for a short fence of two turbines*
  - *Demonstrate reduction in the LCOE of rotor fence design relative to conventional single-rotor designs.*

- Contact
  - Richard Willden richard.willden@eng.ox.ac.uk

University of Southampton

- Tidal Array Control and Optimisation of Energy (TACOE) – *Dr Luke Myers*
  - *Experimental campaign at Flowave*
  - *Heavily instrumented turbines installed and tested*
  - *Investigate the tuning of capture efficiency of devices in an array to increase total array power generation*
- Contact
  - Luke Myers L.E.MYERS@soton.ac.uk

DTOceanPlus

Ben Hudson

DTOceanPlus

- EU's Horizon 2020 programme
- 3-year project (May 2018 – April 2021)
- Total budget of €8m

- An advanced **open source** suite of tools for the **selection**, **development**, **deployment** and **assessment** of ocean energy systems

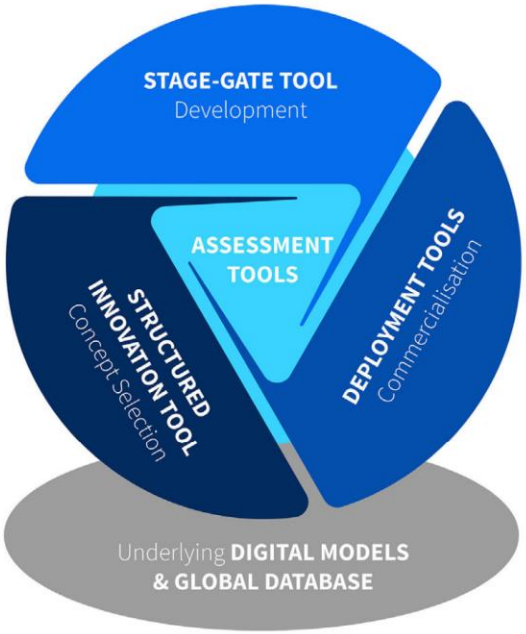
- 2nd generation
- Continuing the development of **DTOcean**

Objectives

- Support the entire technology innovation process, from concept to deployment
- Advanced design tools applicable for sub-systems, devices and arrays
- Enable tools to reach TRL6 through real world demonstration scenarios
- Open source and available to the entire ocean energy sector
- Develop an integrated suite of tools that will be a professional and user-friendly product

Integrated suite of tools

- **Structured Innovation** design tool
- **Stage Gate** design tool
- **Deployment** design tools
  - Site characterisation
  - Energy capture
  - Energy transformation
  - Energy delivery
  - Station-keeping
  - Logistics and O&M
- **Assessment** design tools
  - Performance and Energy Yield
  - RAMS
  - Lifetime Costs
  - Environmental and Social Acceptance



Stage Gate Design Tool

- Draws on Wave Energy Scotland's expertise in running a stage gate programme

- Objectives
  - Facilitate the objective assessment of ocean energy systems
  - Guide the development of technologies from concept to commercial deployment
  - Provide the framework within which the *Deployment* and *Assessment* design tools can be applied
  - Allow funders, investors and technology developers to select the most appropriate technologies

Current Progress

- Software development ongoing
  - Python 3
  - Application programming interface (API)
  - Graphical user interface (GUI)
  - Business logic

- Stage Gate Metrics Framework
  - WES expertise
  - Collaboration with 18 international partners
  - Strong links with IEA-OES Task 12

Further information

- https://www.dtoceanplus.eu/
- Contact us
  - Jillian Henderson; *jillian.henderson@waveenergyscotland.co.uk*
  - Ben Hudson; *ben.hudson@waveenergyscotland.co.uk*

DTO+ presentations @ EWTEC

- *Capability Assessment of DTOcean Array Design Tool for Ocean Energy*
  - T. Bloise Thomaz, L. van Velzen, H. Jeffrey, E Medina Lopez, and T. Wills
  - Wednesday 4th 09:00, Room Calipso

- *A novel framework for the Digital Representation of physical and functional characteristics of Ocean Energy Systems*
  - Vincenzo Nava, Pablo Ruiz-Minguela, Jonathan Hodges
  - Wednesday 4th 14:40, Room Agave

What is success?

Jillian Henderson

Why do we need metrics?

- Measure success
- Manage competitive innovation calls
- Allocate funding appropriately
- Demonstrate progress
- Gain confidence of investors and stakeholders
- Cross funder comparisons

- Cost per install/removal cycle
- Installation/MW

- Capture factor
- Capture width

- % Availability
- Mean Time Between Failures
- Mean Time to Failure
- # single point failure modes
- Fatigue life

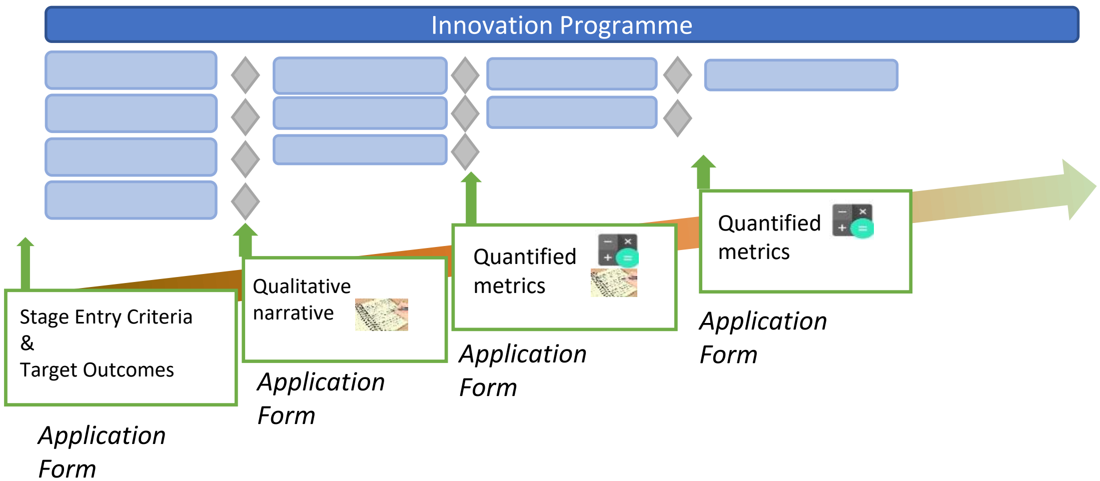
- Rated Capacity
- Capacity factor
- Annual Average Yield
- Conversion efficiency
- ACE

- Mean Time to Repair
- Time to Replace
- # interventions/ year
- Overhaul/refit period

- LCOE
- CAPEX/MW
- OPEX/MW
- Cost/Device
- Cost per annual MWh

Application of Metrics to WES' Stage Gate Programme

- All stages assessed according to technical and commercial merit, and impact on cost reduction
- Demonstrate progress against Target Outcomes – *Affordability, Reliability, Survivability….*
- Success measures qualitatively at early stage and quantitatively at later stages



Collaboration on metrics

IEC Standards e.g. IEC/TS 62600-101:2015: Wave energy resource assessment and characterization IEC/TS 62600-100:2012: Power performance assessment of electricity producing wave energy converters	**IEA-OES Task 12** IEA-OES Task 12 has 25 contracting parties from different countries around the world including USA, Japan, Mexico… aim is to achieve consensus on method to evaluate ocean energy technology
Workshops • February 2016 WES and US DoE • September 2016 EERA Ocean Energy Joint Programme, Ocean ERA-NET and the International Energy Agency OES, and facilitated by WES • November 2017 workshop delivered by Wave Energy Scotland on behalf of and funded by the Ocean ERA-NET	**DTOceanPlus** DTOceanPlus Stage Gate design tool work package of DTOceanPlus and working with 18 organisations around the world in defining metrics for the whole technology development process (TRL 1-9)

Challenges of defining metrics

Metrics which can apply to all technologies:
- Comparison of very different technologies
- Assessing the unknown: Mature & proven with known values vs. New and high risk with optimistic values
- Wave and tidal energy
- Site non-specific metrics

Technology specific Metrics
- Developers adaptation: metrics which remain unbiased and are comparable
- Relative vs. absolute metrics e.g. Capture Width Ratio

Early stage metrics

Lack of quantitative data at early stage = Mainly Qualitative

Events

- PLEASE REGISTER SO WE HAVE YOUR NAME

http://tiny.cc/EWTEC

- Scottish Renewables Marine Conference
  - Sept 9/10, Inverness
- Ocean energy Europe
  - September 30, Dublin

- WES Annual Conference

  December 5, Edinburgh

Related talks/ side events this week

Day	Session	Time	Speaker	Title
Tuesday	WDD	14:40	Domenico P. Coiro, Giancarlo Troise, Nadia Bizzarrini, Luca Castellini and Guido Lazzerini	Numerical and experimental test on a large scale model of a pivoting wave energy conversion system
Tuesday	WDD	16:00	J. Cameron McNatt, and Christopher H. Retzler	The performance of the Mocean M100 wave energy converter described through numerical and physical modelling
Tuesday	WDD	17:00	Niall D. McLean, Matthew A. Holland, Ruairi D. Maciver and Elva B. Bannon	Site selection for scaled open water testing of a wave energy converter
Tuesday	Side Event (Perseide)	17:30	Chair: Jochem Weber	Wave-SPARC - Structured Innovation Experience
Wednesday	TDD	09:00	T. Bloise Thomaz, L. van Velzen, H. Jeffrey, E Medina Lopez, and T. Wills	Capability Assessment of DTOcean Array Design Tool for Ocean Energy
Wednesday	WDD	09:00	Nathan Tom, Yi-Hsiang Yu, and Alan Wright	Submerged Pressure Differential Plate Wave Energy Converter with Variable Geometry
Wedneday	GPG	14:00	Sarah Acheson, Ross Henderson, Daniil Dumnov	Simulation of Digital Displacement Hydraulic Power Take-Off for Wave Energy Converters
Wednesday	ESP	14:40	Vincenzo Nava, Pablo Ruiz-Minguela, Jonathan Hodges	A novel framework for the Digital Representation of physical and functional characteristics of Ocean Energy Systems
Wednesday	GPG	16:00	Simon Robertson, Donald R. Noble, Henry Jeffrey, Luca Castellini, and Michele Martini	Progress update on the development and testing of an advanced power takeoff for marine energy applications
Wednesday	GPG	16:20	J. Burchell, I. Barajas-Solano, M. Galbraith, N. Ahmed, O. Ubani, & M. Mueller	The Design and Build of a 75 kW Linear C-Gen Generator Prototype for Wave Energy Power Conversion
Wednesday	Side Event (Perseide)	17:30	Chair: Giuseppe Giorgi	INORE WORKSHOP Bursting the bubble: crossing the boundary between academia and industry
Thursday	SMM	10:40	J. Cruz, M. atcheson, T. Martins, L. Castellini, M. Martini	Preliminary Load Assessment: UMBRA's 250kW EMG Power Take-Off