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Physical model testing of a large array of fully representative scale wave energy converters.

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Oregon State University

TEAMER
Testing & Expertise for Marine Energy

U.S. DEPARTMENT OF ENERGY

Company Overview

Oscilla Power aims to offer one of the first commercially attractive ocean wave energy converters

☑ Low cost ☑ High Efficiency ☑ Survivability

2009
Founded

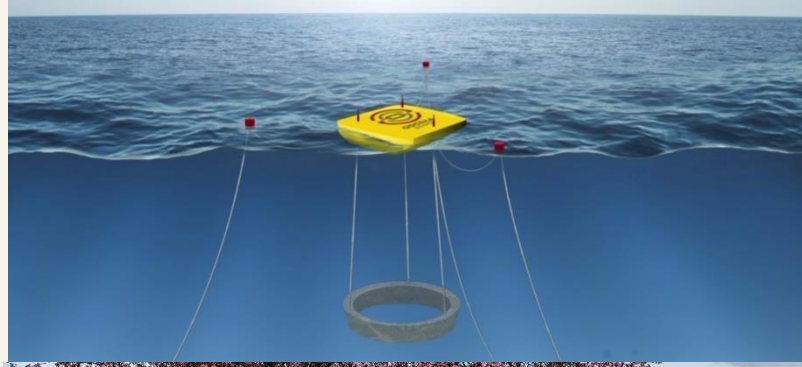
Seattle, WA, USA
HQ and lab

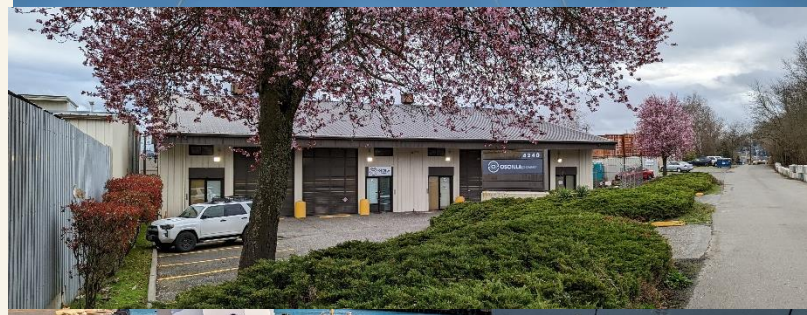
$25+ Million Raised
>80% through competitive grants

DOE Wave Energy
Challenge prize finalist[1]

Development supported through competitive awards from:

National Science Foundation WHERE DISCOVERIES BEGIN · NOAA · U.S. DEPARTMENT OF ENERGY · wave energy SCOTLAND





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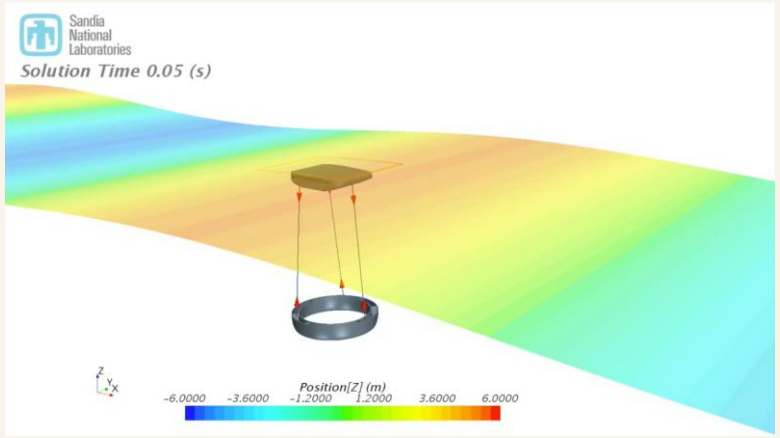
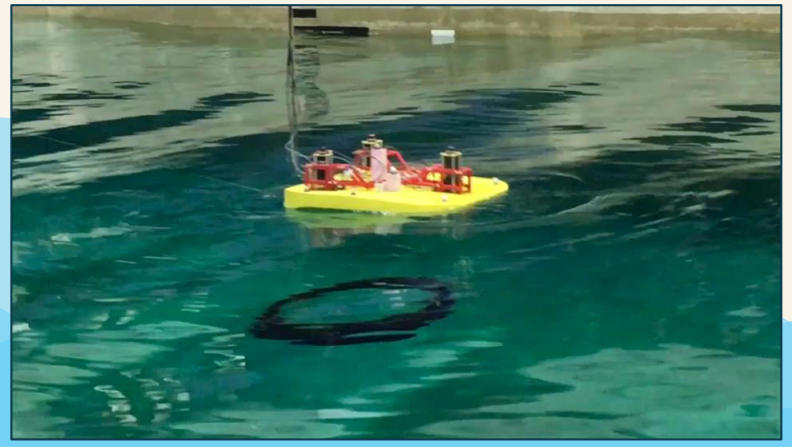
Source: https://www.energy.gov/eere/water/articles/us-department-energy-s-wave-energy-prize-announces-finalist-teams

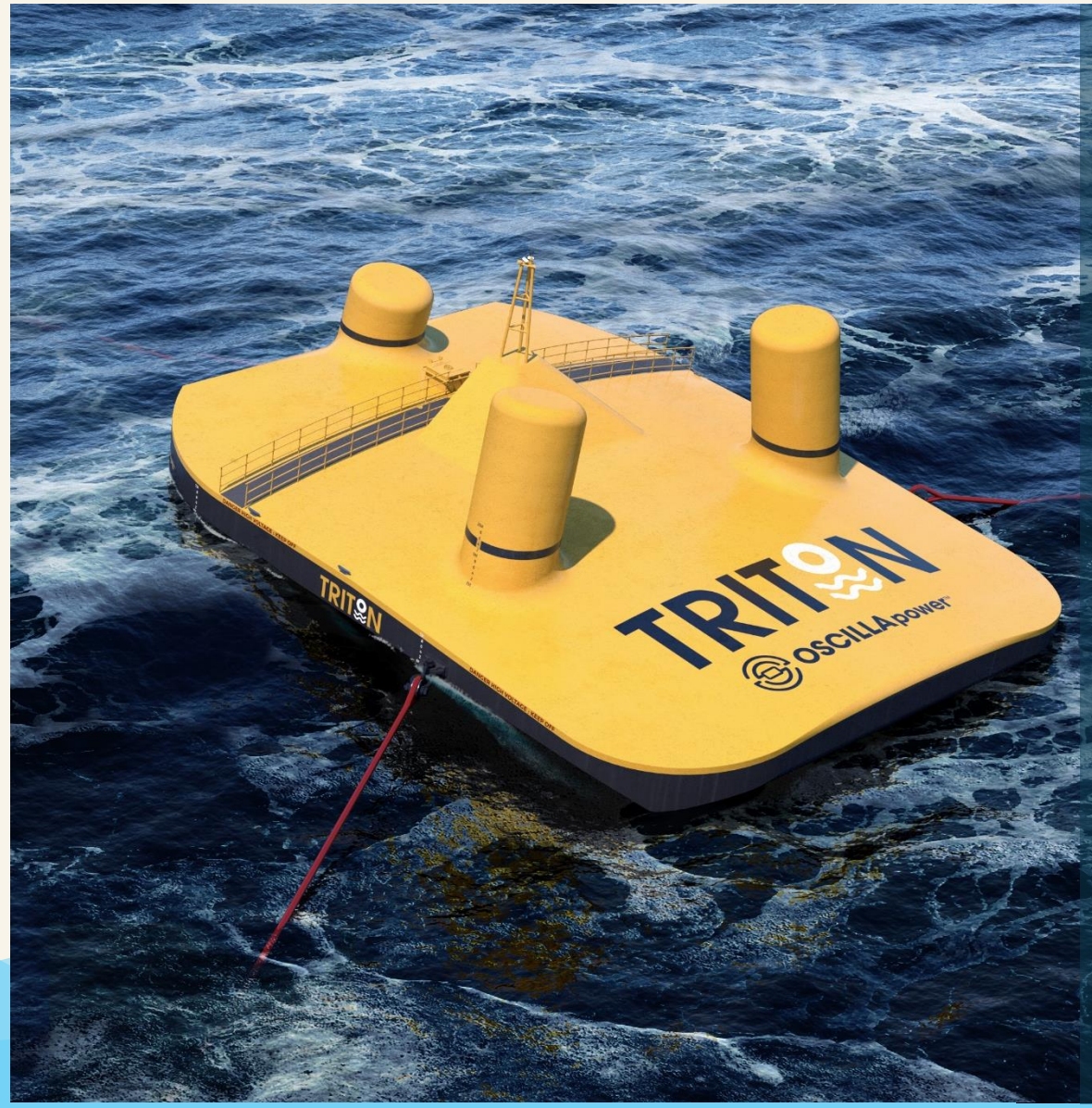
Our Breakthrough Solution – The Triton WEC

Architecture optimized through extensive hydrodynamic modeling



Optimized geometry and configuration:
Highly efficient energy capture

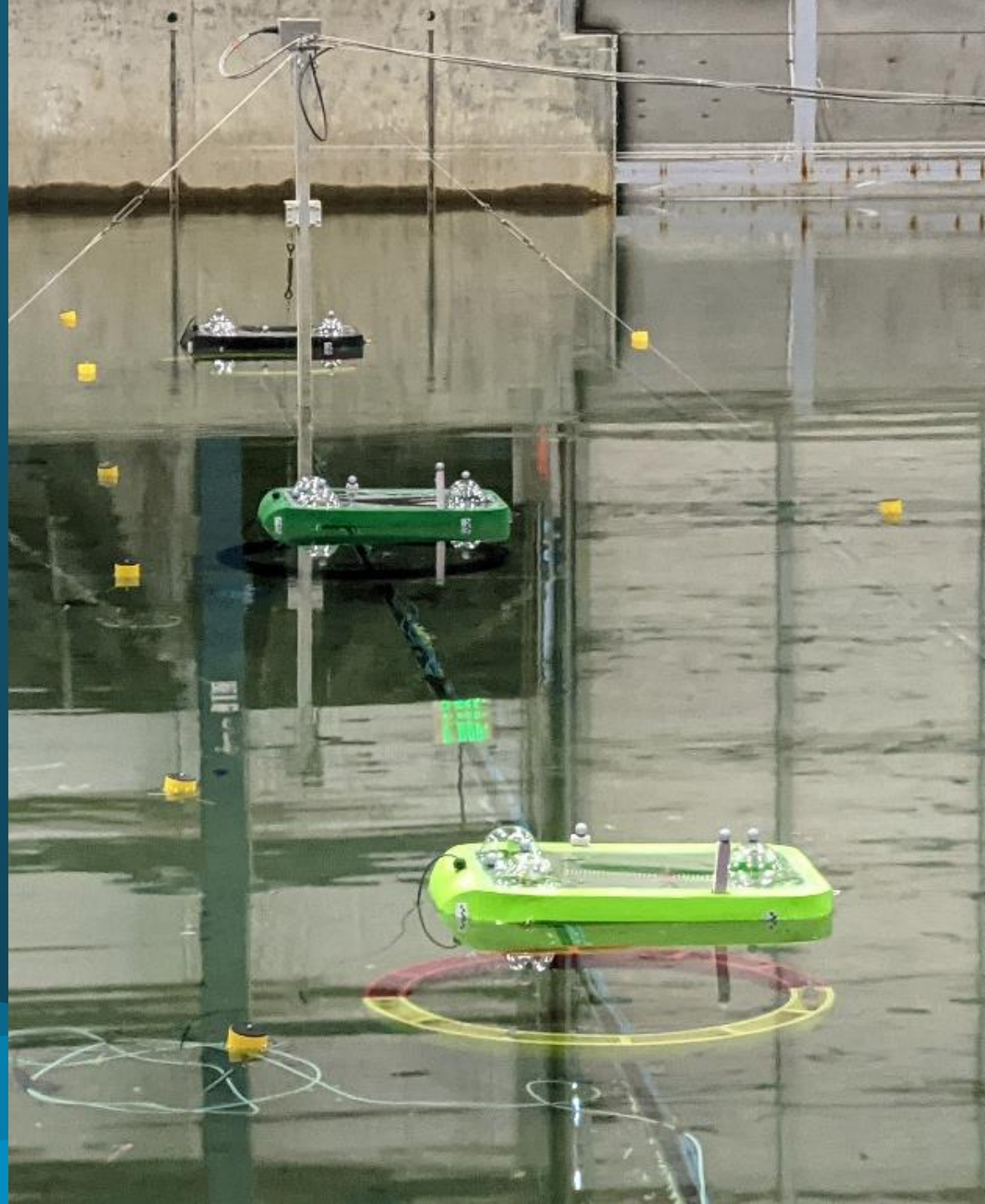




- **Highly Survivable:** Designed to submerge and survive the most extreme conditions.
- **Externally validated by DoE:** One of only 4 (out of 90+ companies) to meet DOE's technical targets
- **3X performance improvement:** over state-of-the-art and continuous development.

Motivation & Objective

- Part of larger project to develop the electrical design for a 50MW array.
- Aim to understand how the power varies throughout an array in order to size electrical equipment.
- Physical models used to validate numerical results. especially with regards to interaction effects.
- Array optimization was not the primary goal.



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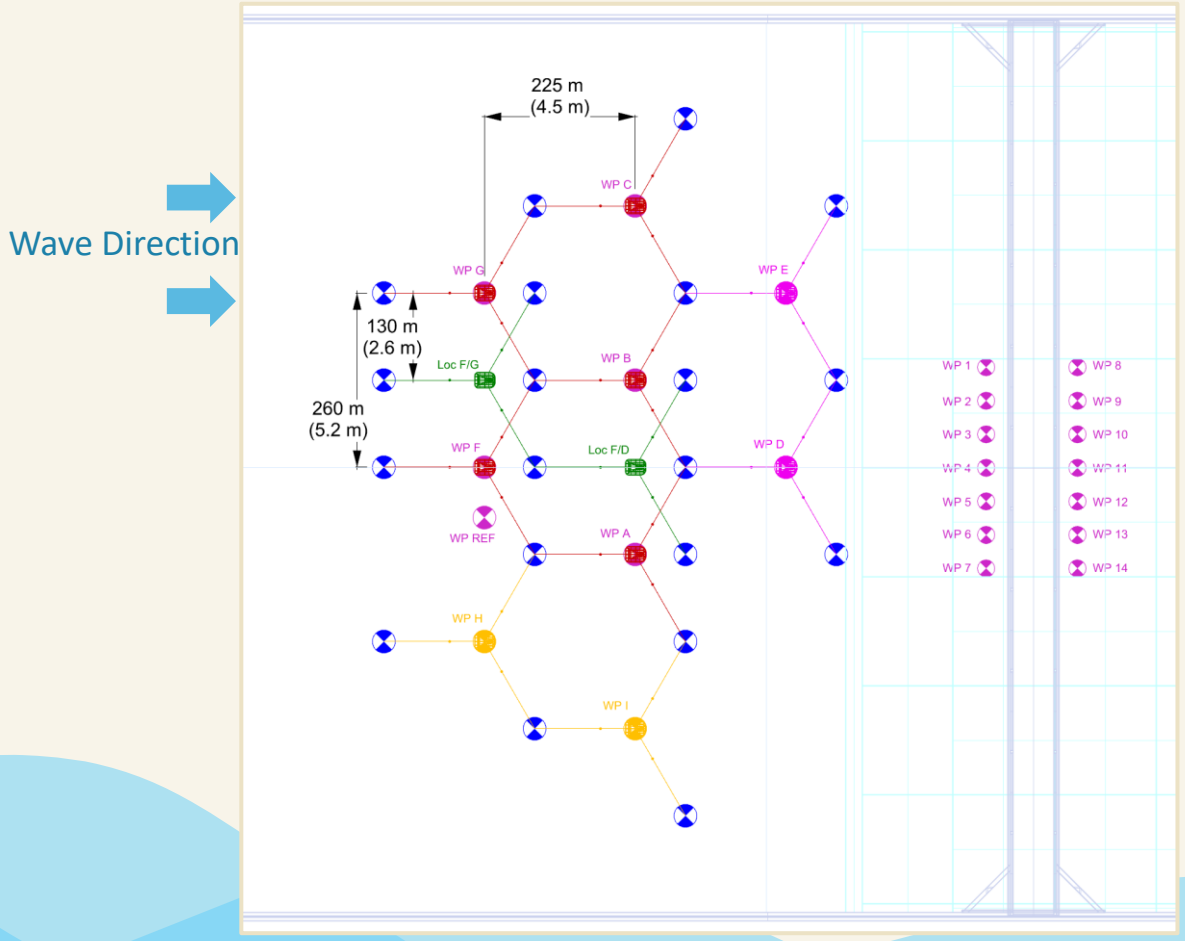
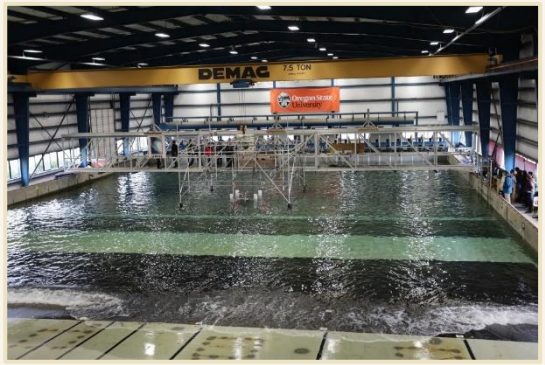
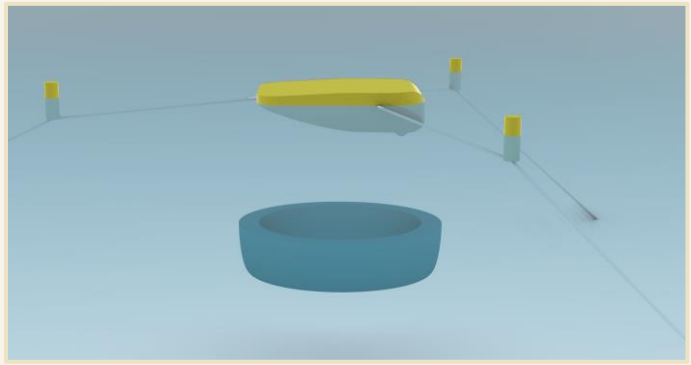
Experimental Approach



- Oregon State University Hinsdale Directional Basin
  - 48.8 m x 26.5 m x 1.3m
- Evaluate array spacing of 225 m x 260 m
- 7 devices in 4/3 or 2/3/2 arrangement
- Fully representative physical models ensure power extraction effects.
- 1:50th scale optimum balance between model fidelity and maximum array size.





- Representative mooring & power export included.
- Model data was captured concurrently with 6DOF motions
- Mixed mooring grid allowed devices to be added or removed to create different spacings or arrangements.

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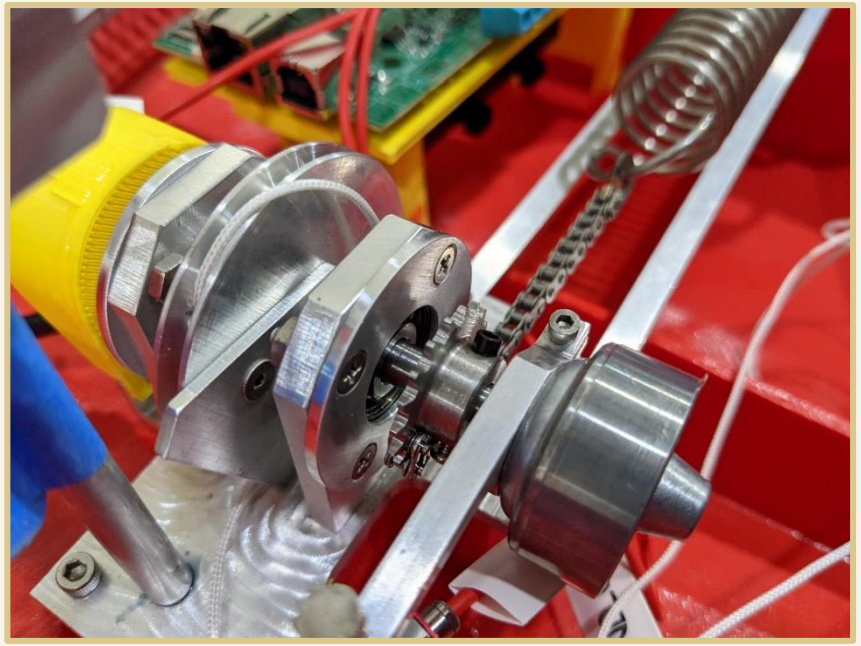
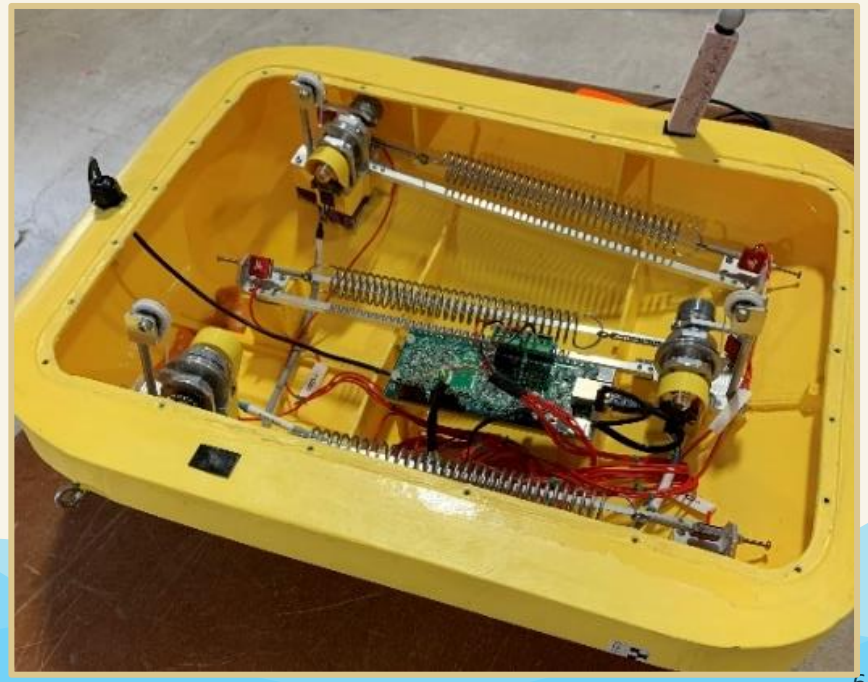
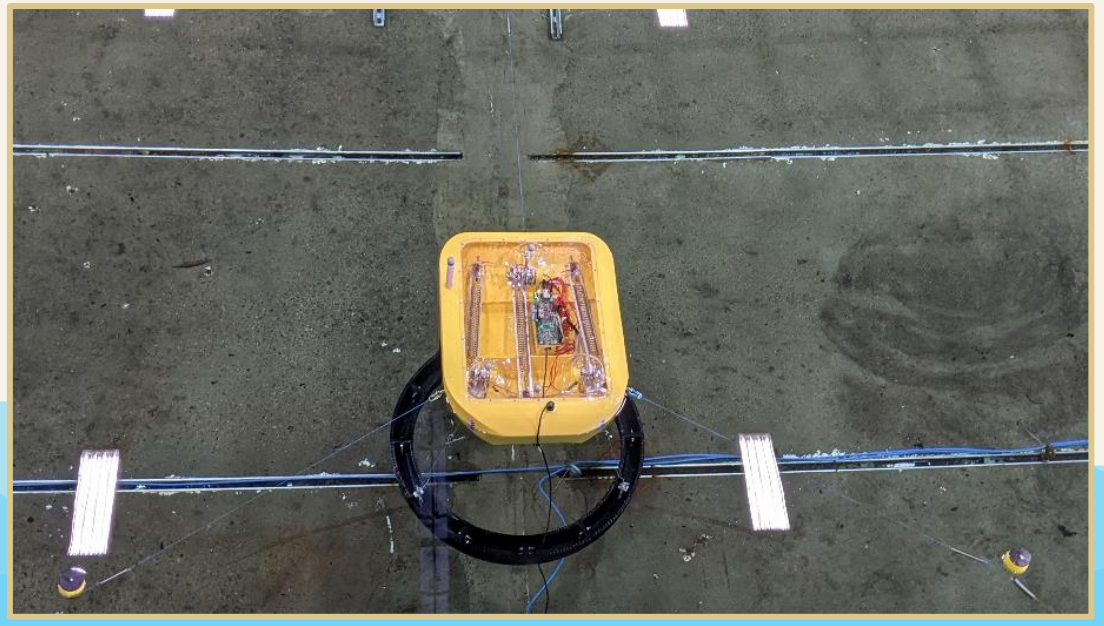
Physical model (1:50 scale)

- 7 complete models were constructed.
- Size allowed each model hull to be 3D printed in-house (0.6 m x 0.46 m)
- Onboard DAQ solution with single POE cable to eliminate umbilical contamination
- Used a passive dashpot style damper to represent generator
- Each drivetrain had displacement, damper torque and spring force instrumented (9 channels per model)







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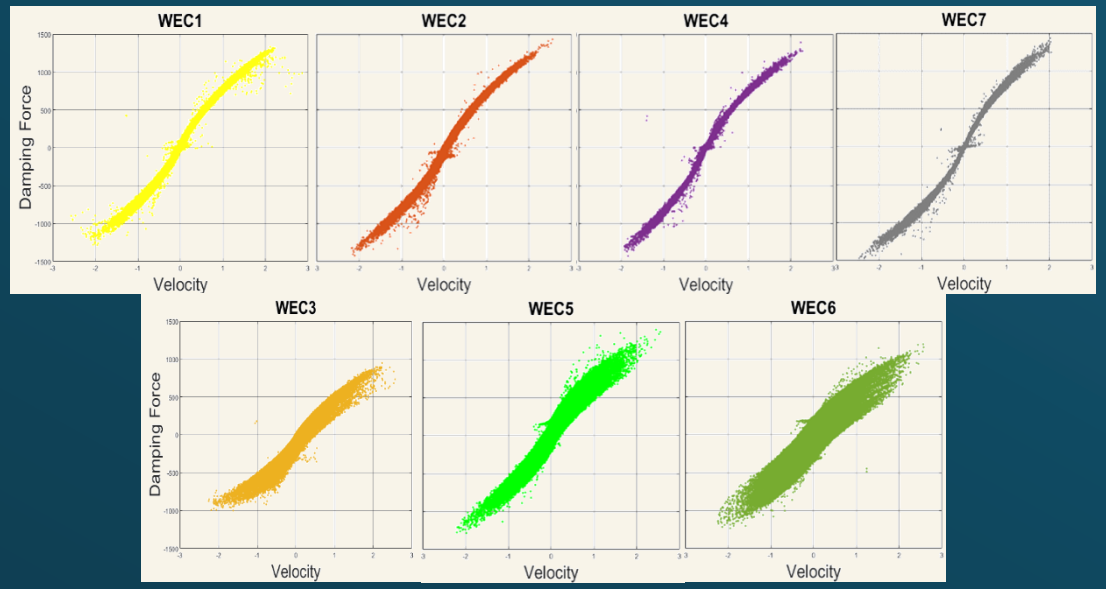
Physical model challenges

Ideal Performance – Low friction



Impaired Performance – Increased drivetrain friction

WEC	Power (kW)	Pk-Av Ratio
1	253.2	12.8
2	253.7	14.2
3	***172.3***	***13.1***
4	218.0	13.9
5	***197.4***	***17.8***
6	***178.4***	***18.7***
7	235.0	16.3

- Models were built using identical components, however friction variability resulted in differences between model performance
- Models bench-tested & calibrated in advance: To quantify the consistency of each model, each model was tested in the basin in isolation**
- 1:50 scale at the lower limit of practicality for this system
- Onboard DAQ worked extremely well, but underwater connectors slightly unreliable for PoE ethernet

7 complete models with transportation cases.

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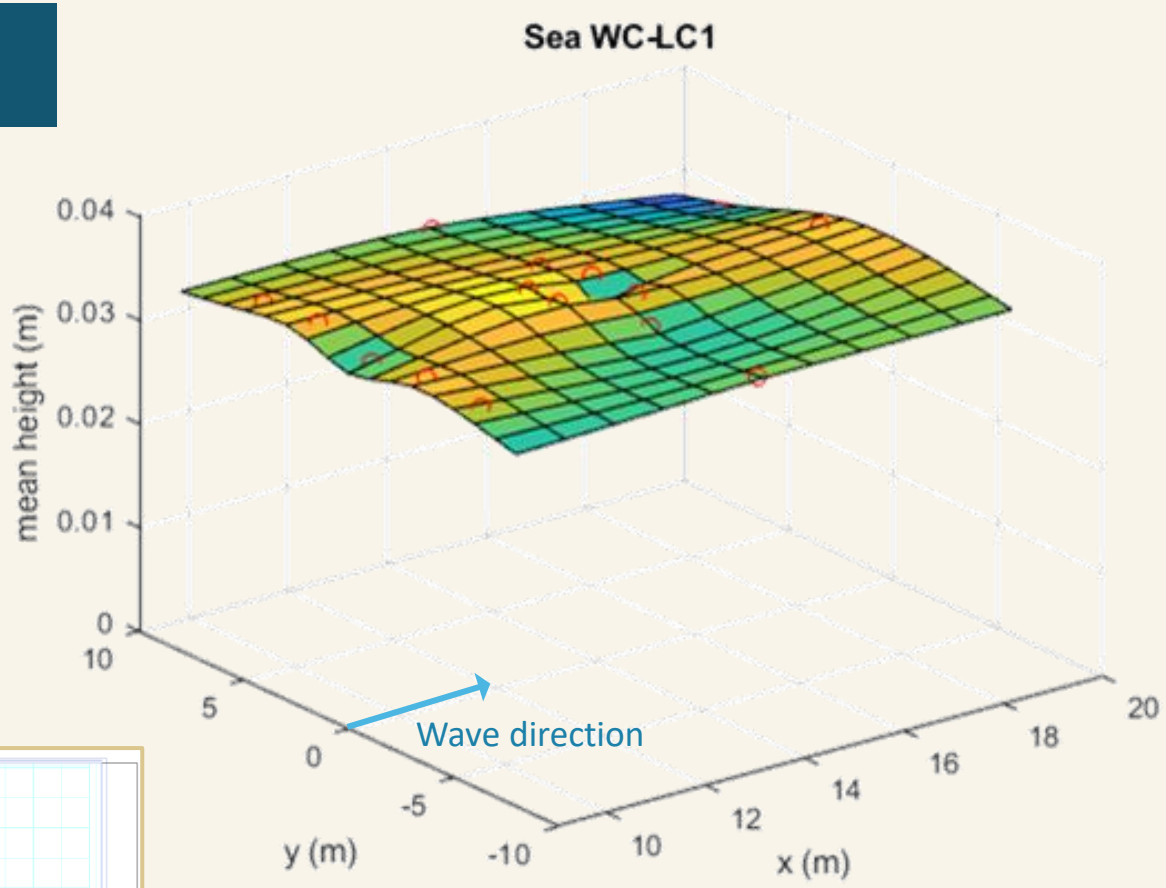
***Some models were tested concurrently, but in a single horizontal row spread out as far as possible so there would be no interactions*

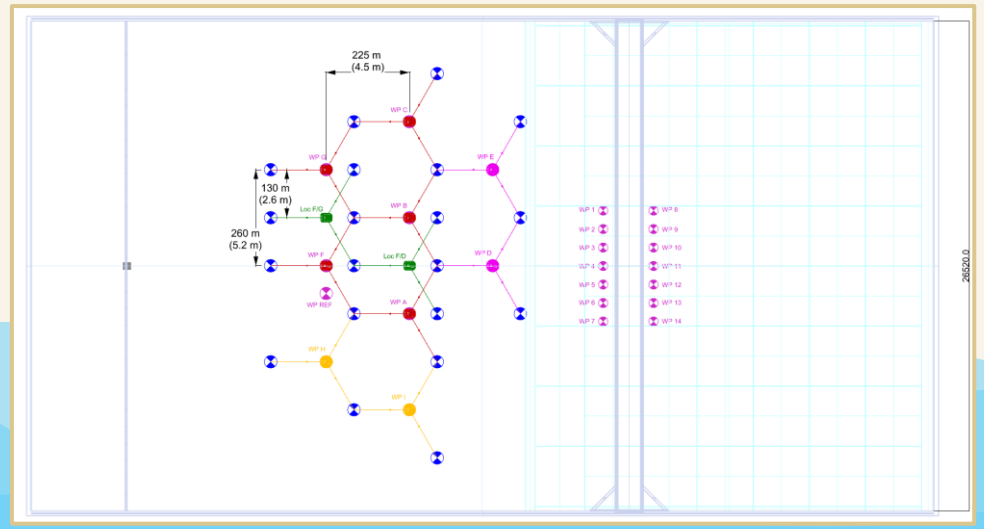
Basin calibration

- Basin was calibrated to determine the spatial variability of the wave field.
- Calibrations performed with a reference wave probe at each device location (and other locations)
- Measurements used to correct wave field with devices in place.

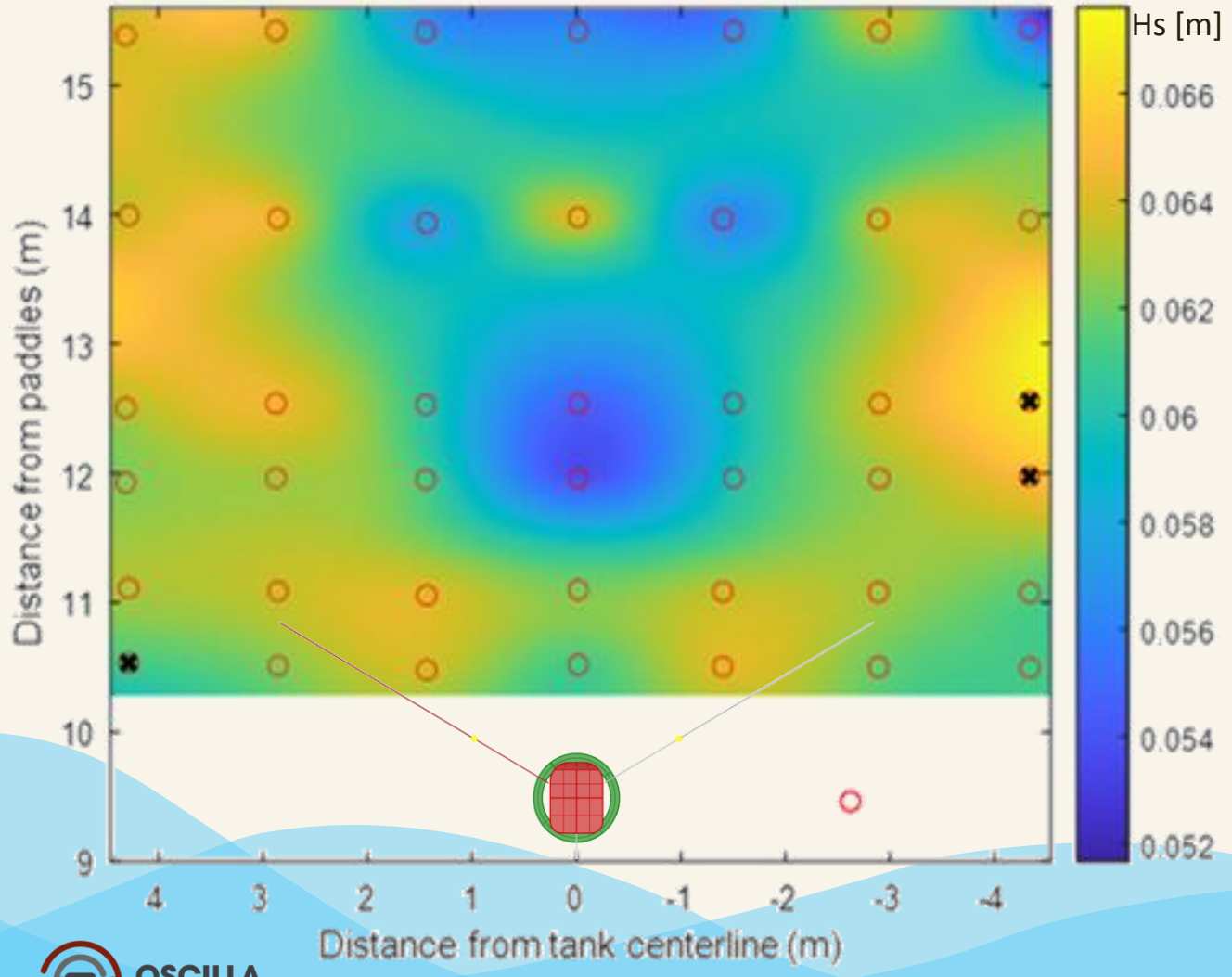


Calibration wave (Hs 1.75m, Tp 9.2s) – variation of mean Hs
Approx 4% variation mean Hs (~8% variation in energy flux

waves



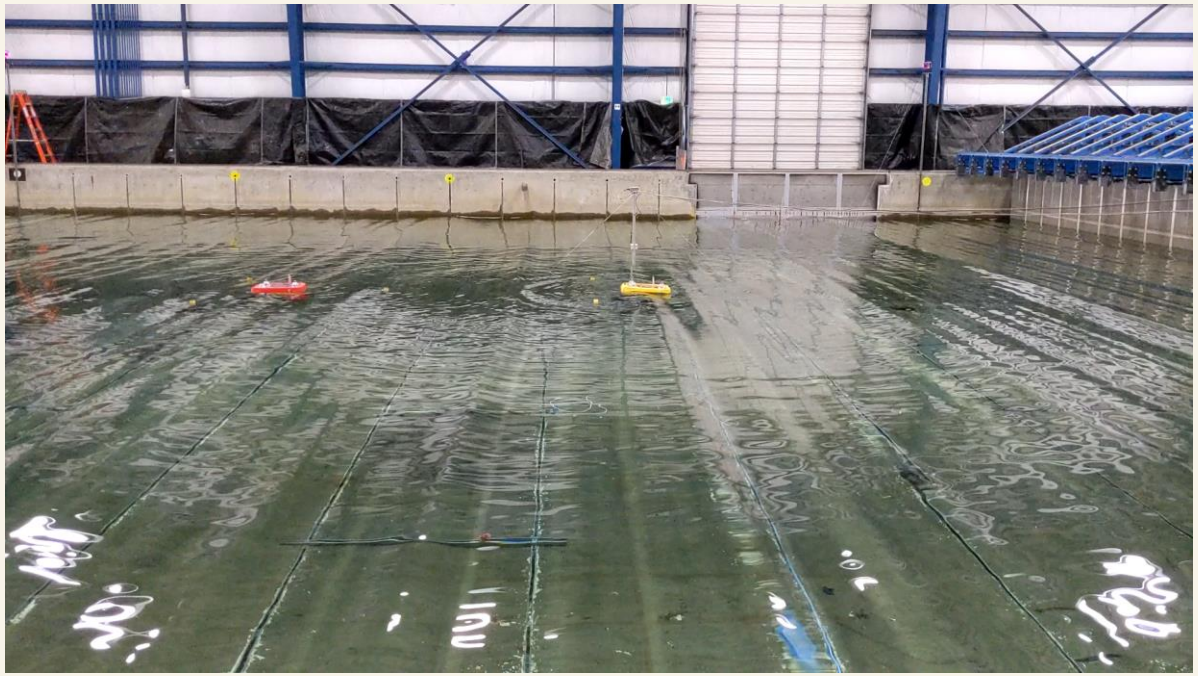
Wake testing – single device measurements

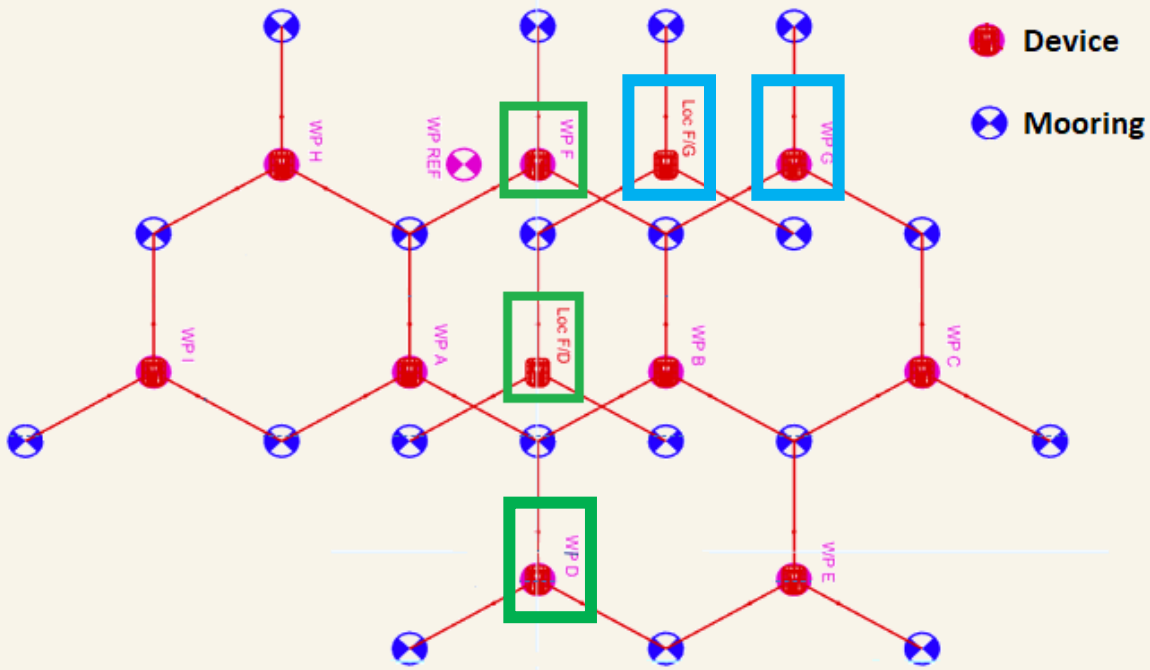


- Wake was measured by repeating tests with a probe array in different locations
- There is a clear wake effect in the surface elevation behind the device
- Reduction in Hs takes approx. 1 wavelength to develop
- Some recovery appears to happen in one specific location**
- Basin calibration used to correct measurements

*** Single probe - possible measurement error?*

Interactions between two WEC





WEC placed behind each other (Green boxes on right)

Half spacing (110m):

- No significant change in performance for the front device
- An average 20% reduction in power for the back device

Full spacing (225m) :

- *Average 25% reduction in power for the front device***
- No significant reduction in power for the back device

WEC placed side by side (Blue boxes above)

Half spacing (120m):

- *13% increase in performance is observed in both devices***

Full spacing (240m):

- No significant change in the performance of the devices

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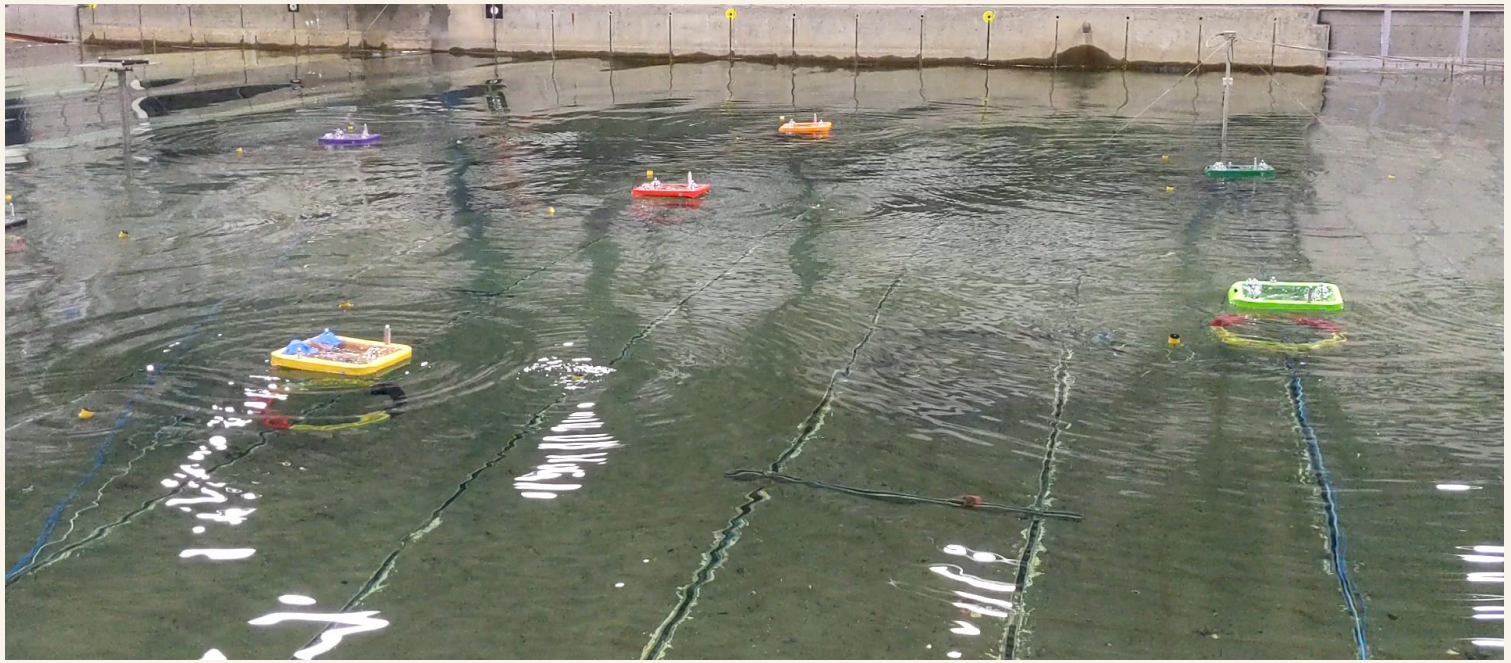
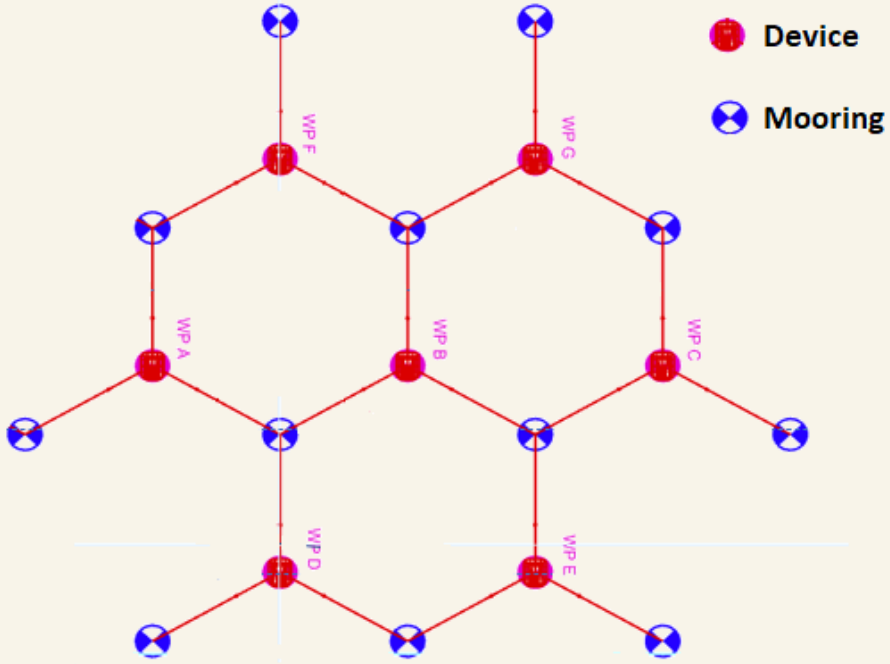
Full array test results (three rows)



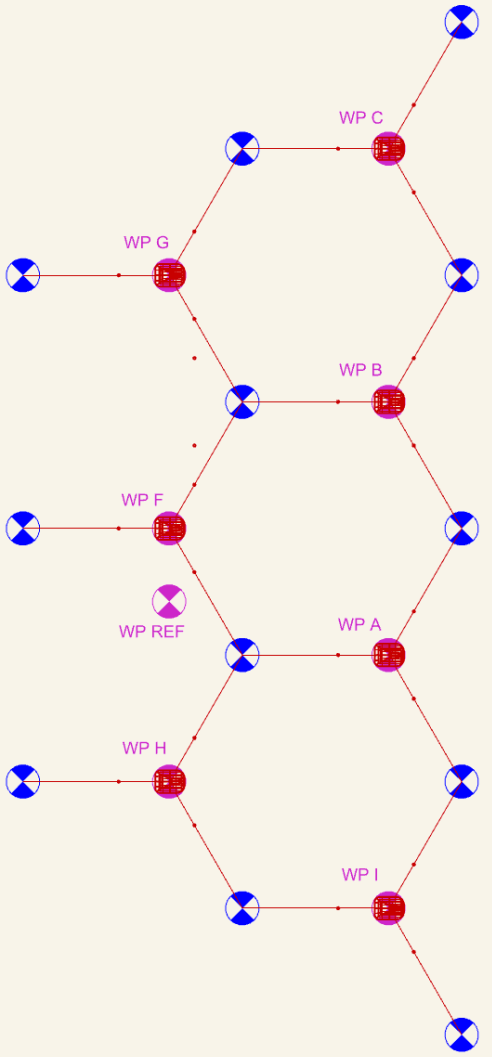


Compared to model performance in isolation:

- The front row performs on average 5% better
- The middle row performs on average 20% worse
- The back row performs similar

Realistic arrangement for larger array

Full array test results (two rows)



Experienced some challenges with model performance & repeatability. 2 row testing results were less reliable than the 3 row

- Devices on the front row appear consistently 5% higher compared to isolated tests with the same models
- Devices on the back row appear ~20% lower compared to isolated tests**

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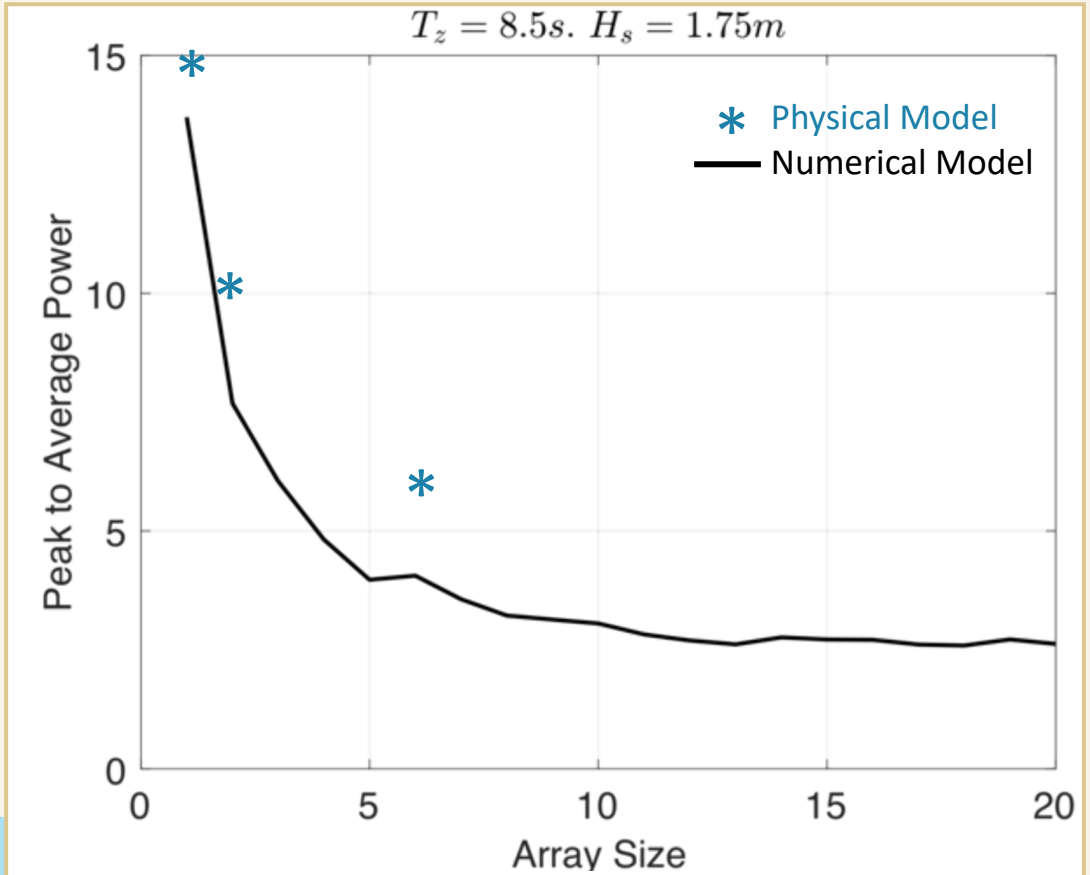
*** except for 1 device but this appeared to be a problem with the particular model (WEC3)*

Impact on peak to average ratio



Mechanical power in uncorrelated waves obtained using OPI's Triton model (OrcaFlex) compared to Physical model data

- Peak to average power is critical for sizing electrical aggregation equipment
- Results show good agreement between physical and numerical results.
- Results presented only for long crested zero-degree waves. Short crested and off-axis waves show increased reduction, but data not yet fully processed.

Future Work:

- Complete analysis of short crested and off axis waves
- Repeat physical model tests again to confirm results and measure interactions with different power absorption and improved model PTO

Conclusions & observations

- Power absorption of devices on the front row is broadly similar to that of devices on their own, although some constructive and destructive effects were seen for special array configurations of 2 devices.
- While WEC's will produce radiated waves, results suggest little radiated interaction at the proposed device distances.
- *Absorption and diffraction* by the front row produces some shadowing effects that affect the performance of devices on the second row negatively.
- Surprisingly, the same shadowing is not seen for the third row, where performance of the devices is similar to the front row

A number of findings presented here are based on single tests, which means they could partly be due to non-perfect repeatability. However, results were cross-checked, directly and indirectly, as much as possible

Most results are based on tests in a single sea state (Tp = 9.2s, Hs = 1.75m). More seas were used, but the large number of array configurations made it difficult to run multiple iterations. This, combined with acquisition problems in certain cases, meant that a single sea state gave the most opportunities for comparison. Effects may be different for different sea states

While short crested and off axis waves were also tested, only long-crested, head-on waves have so far been examined

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Questions?

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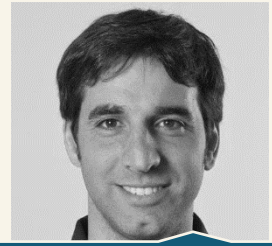

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