Accelerating Hydraulic PTO Design and Validation through the HAWSEC Platform

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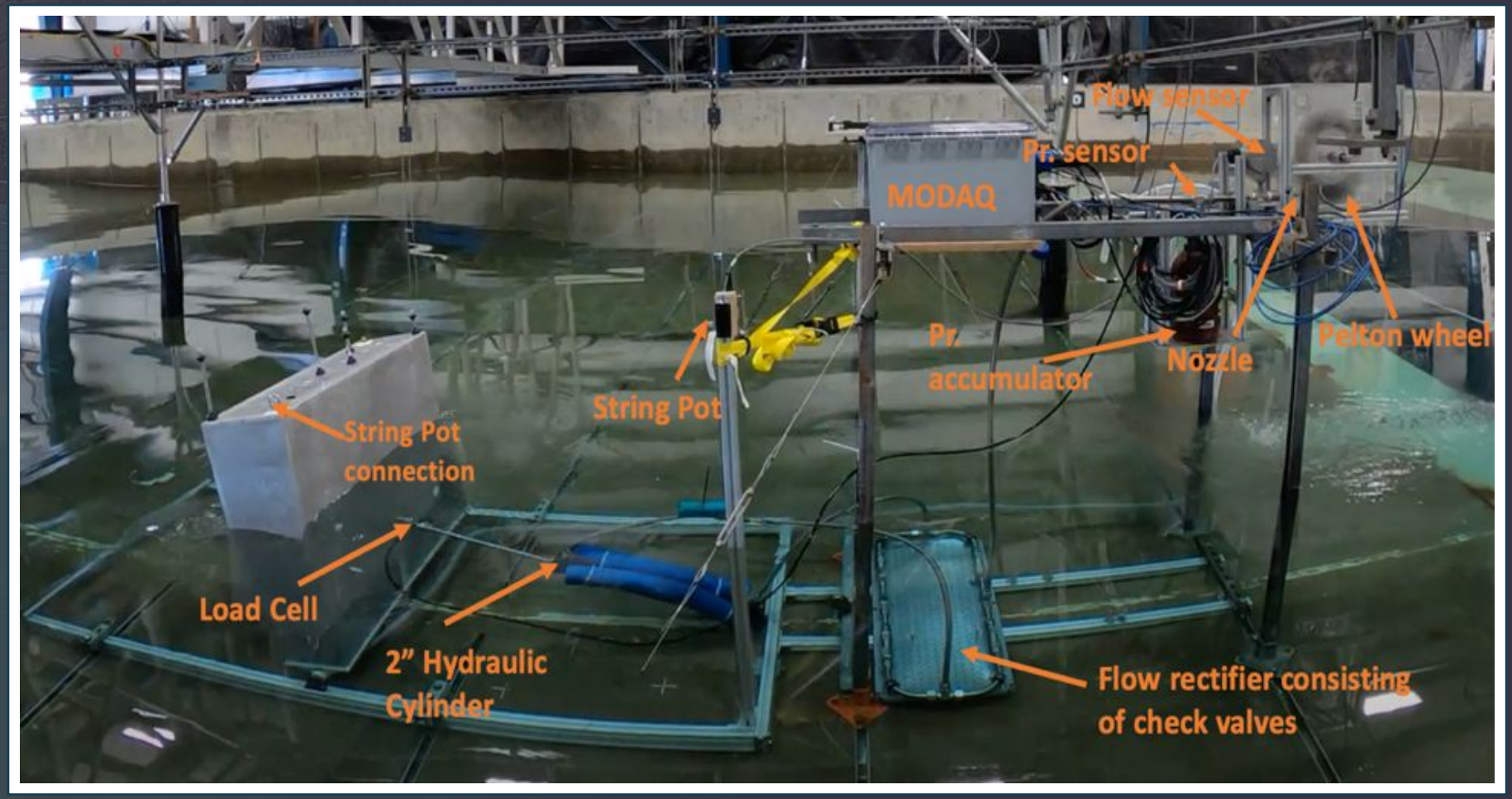
“Hawai‘i Wave Surge Energy Converter”



DOE Water Power Technologies Office (DE-EE0008629)

Background

Inspiration

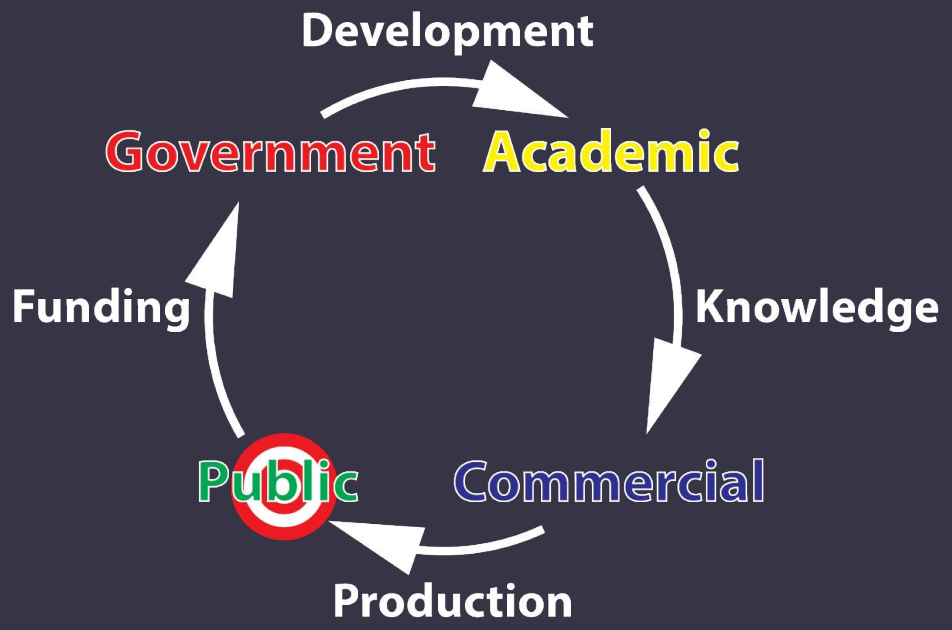
- Oyster (figure)
- WaveRoller

} Europe

- Resolute Marine Energy

Public funding

- Open design and data dissemination
- Knowledge persists independent of funding



Scaling

- Select target depth = 9m (~30ft)
- Experimental scale: S = 1/9
- Nominal 1m x 1m characteristic area

Device	Depth (m)
Oyster	10-12
WaveRoller	8-20
Resolute Marine Energy*	5-7

* Estimated from photos

Finite Depth

Deep to shallow water

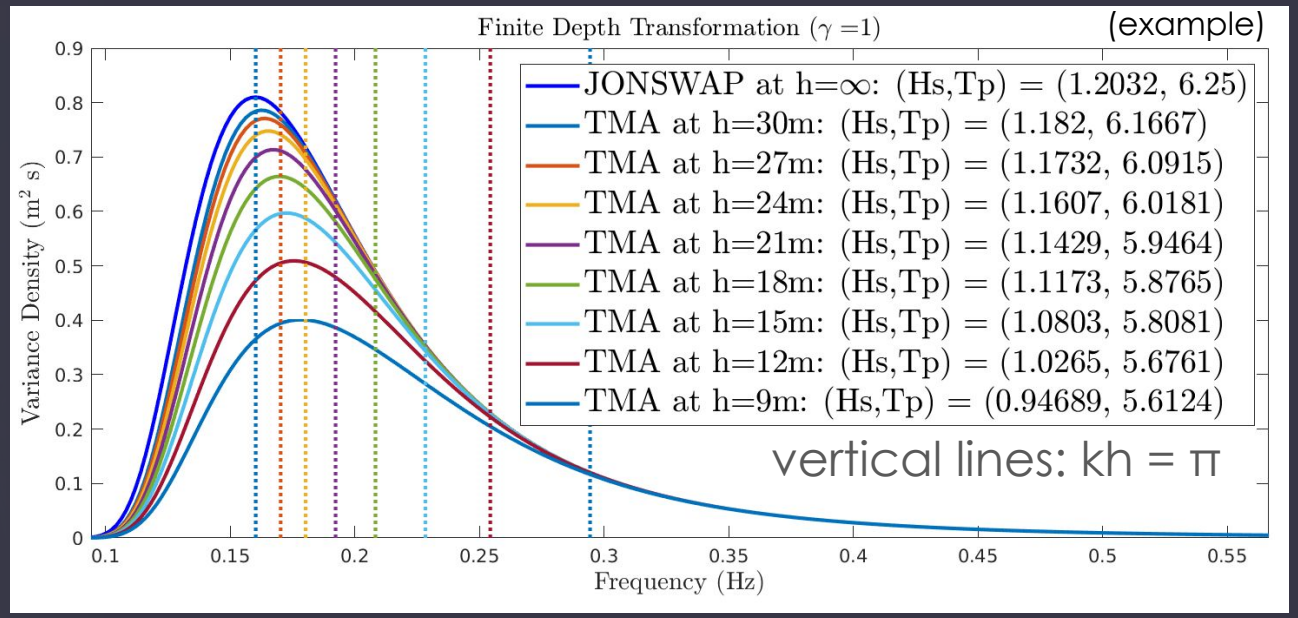
- JONSWAP □ TMA (Texel, MARSEN, and ARSOLE)

Full to model scale

- TMA □ Froude

Frequency x $S^{-0.5}$

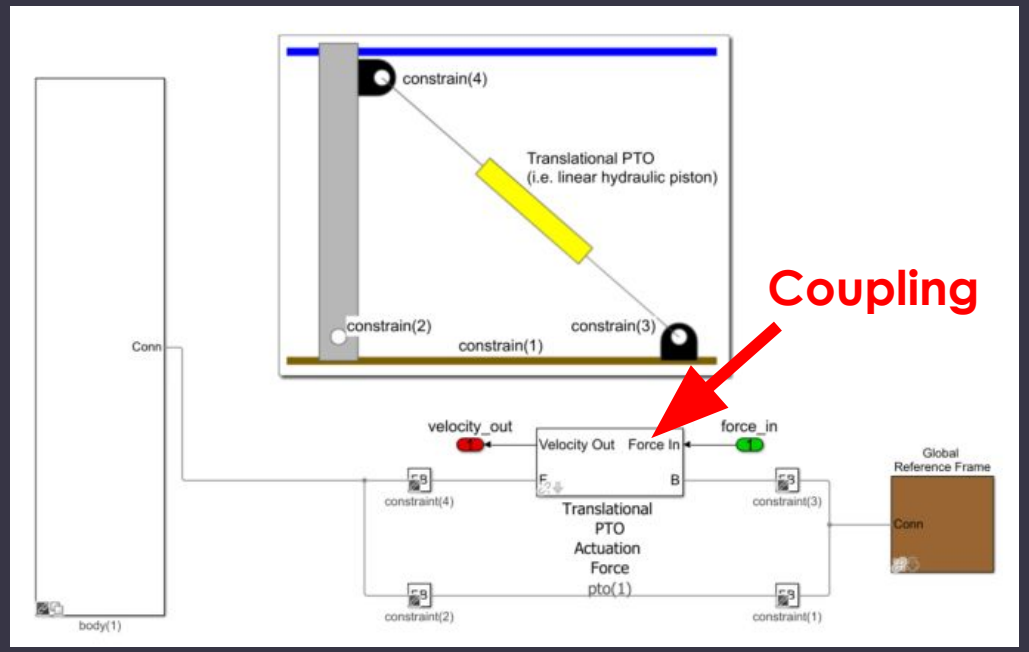
Variance Density x $S^{2.5}$



Methodology

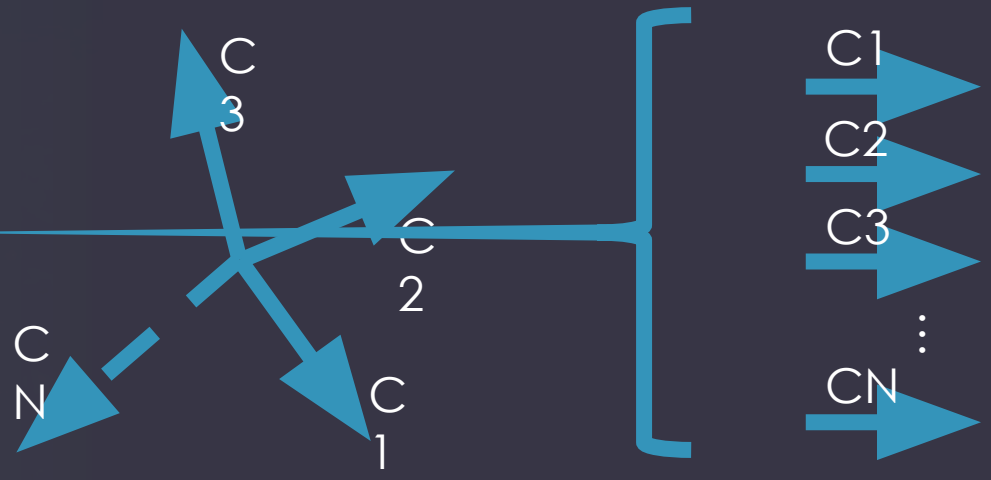
Problem: Many (constant) coefficients.

Question: What are the coefficient values?

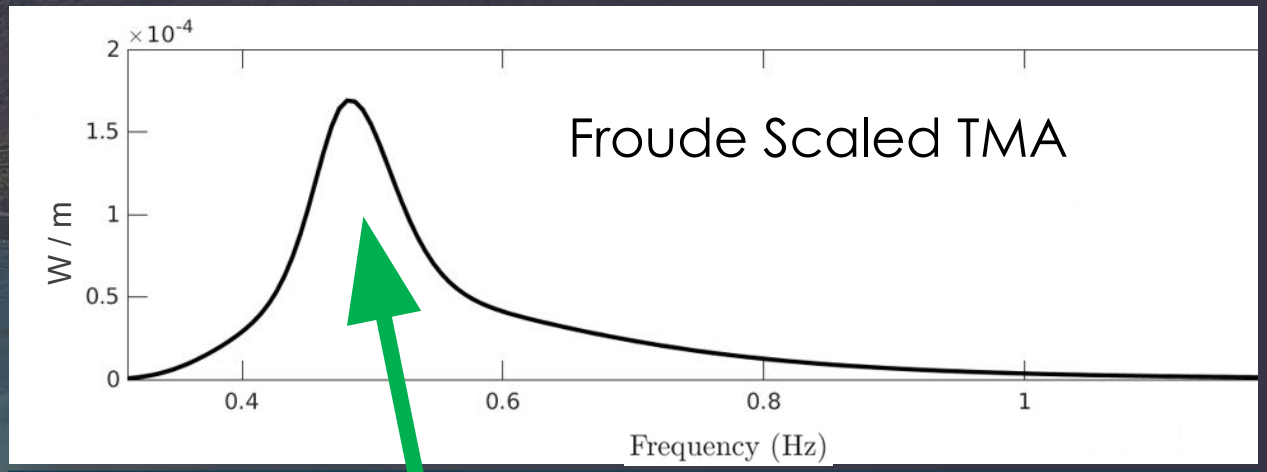


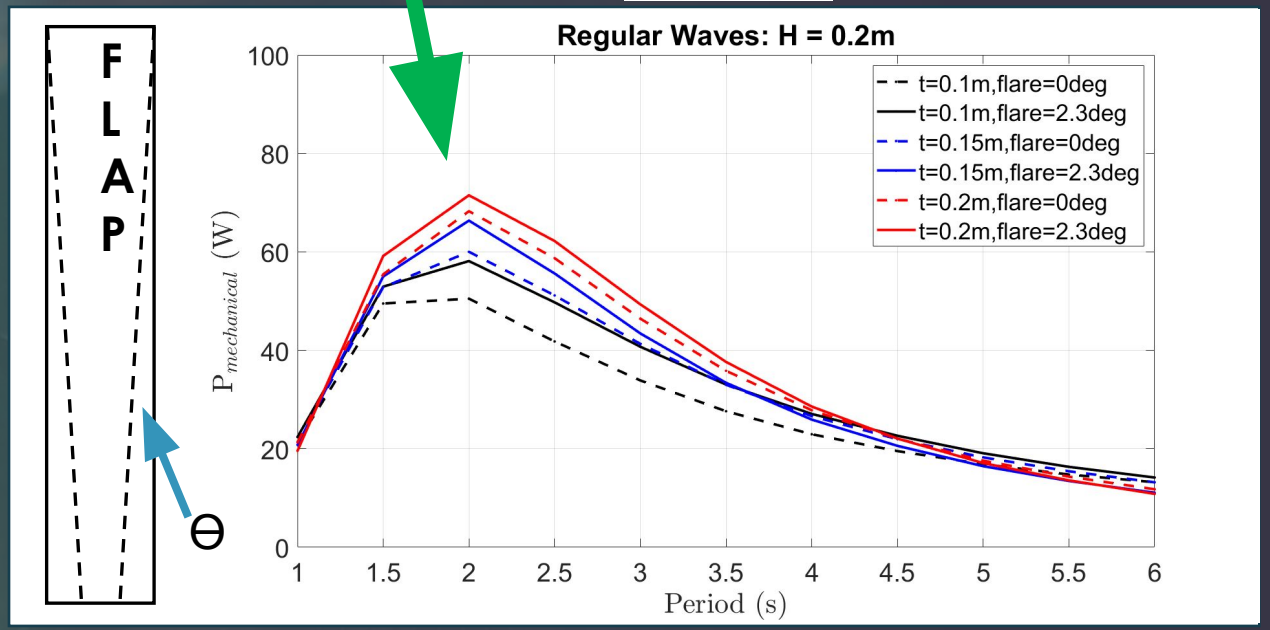
Top-down approach…

- **Break the coupling**
- **Systematic calibration**
- **Stitch back together**
- **Validation**

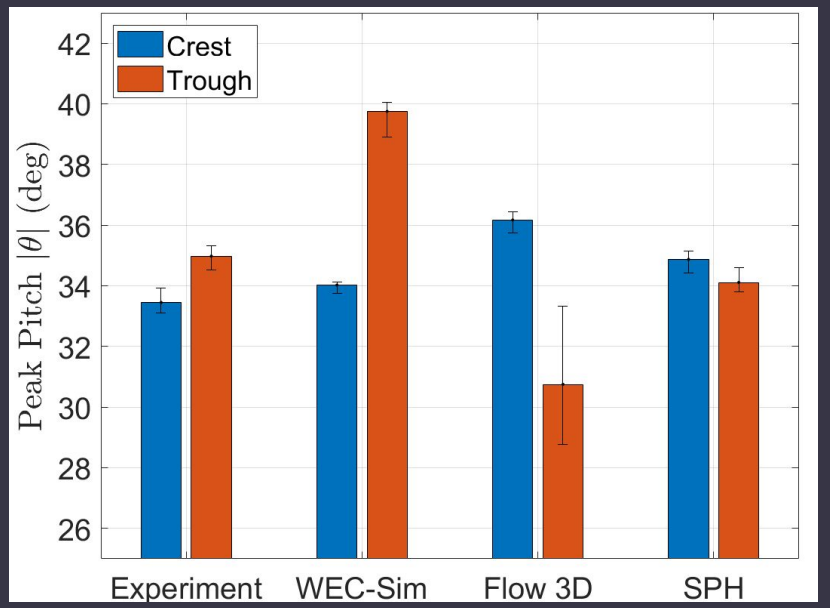


Hydrodynamics: Design and OSU Basin



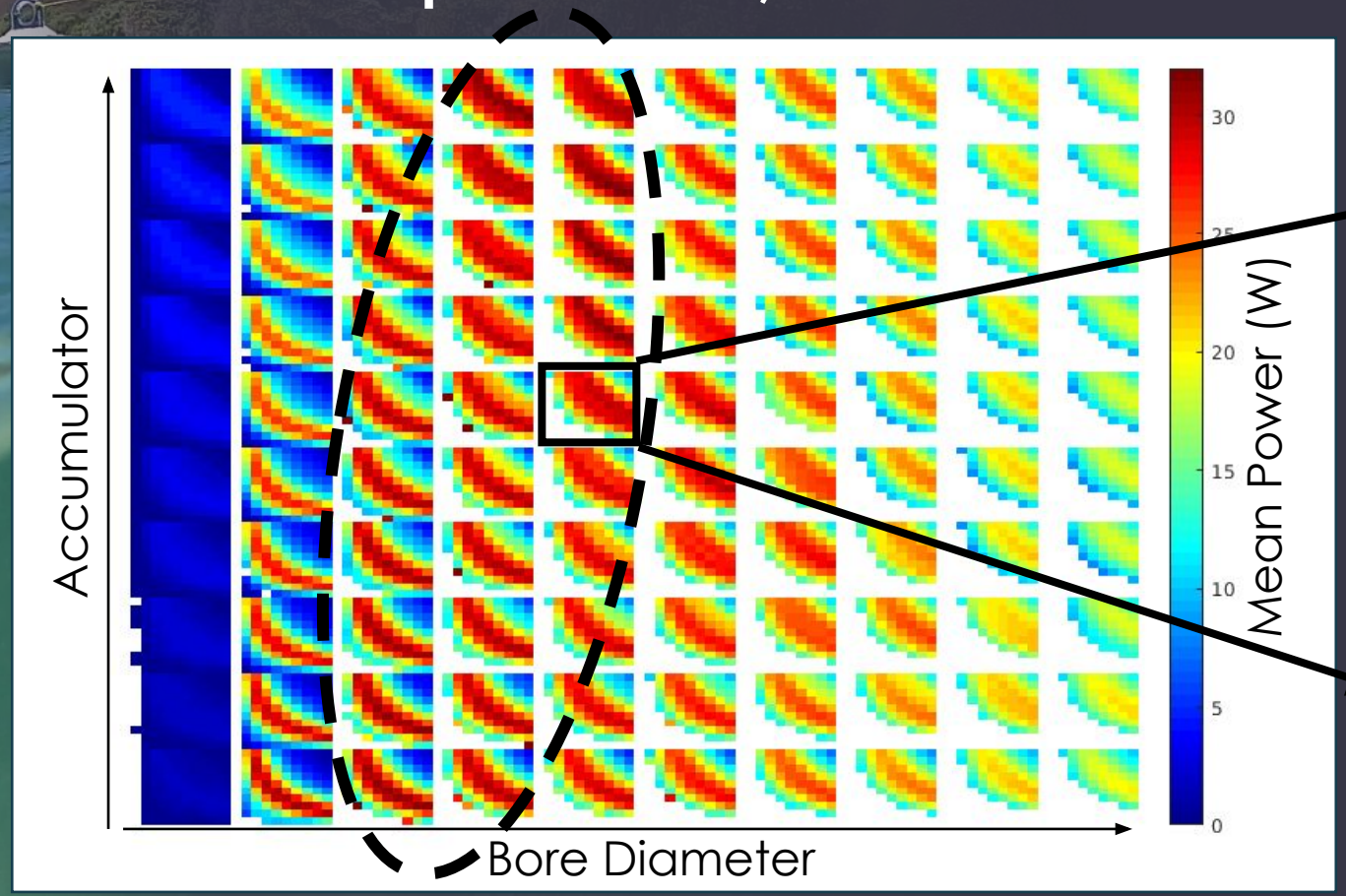


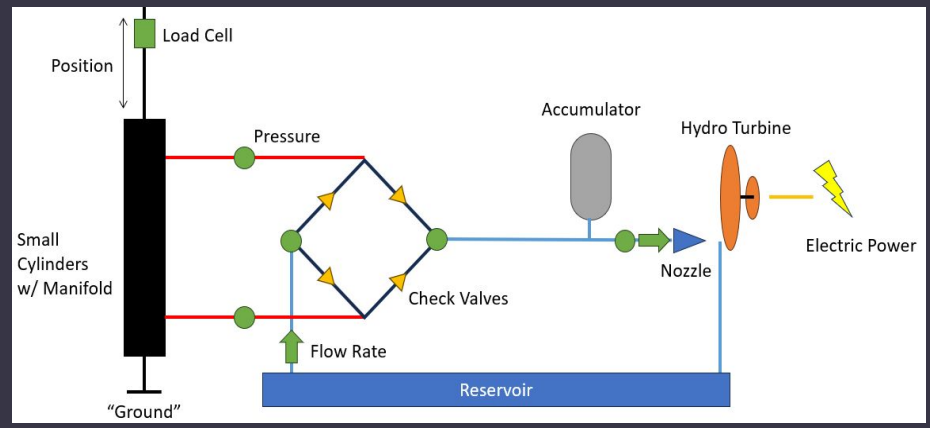
- Spectrum defines target
- Profile design
  - ANSYS AQWA, WEC-Sim
  - Scaled linear PTO
- Viscous damping

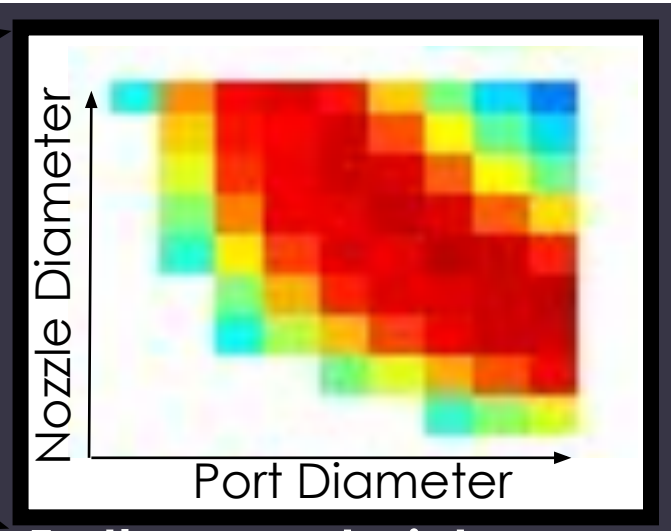


Hydraulics: Design

- Simscape Fluids: 8,100 simulations







Further constraints

- Standard Deviation
- Off-the-shelf

Hydraulics: Bench

- **Testing Equipment**
  - Electric Actuator
  - MODAQ
  - Sensors
- **Calibration**

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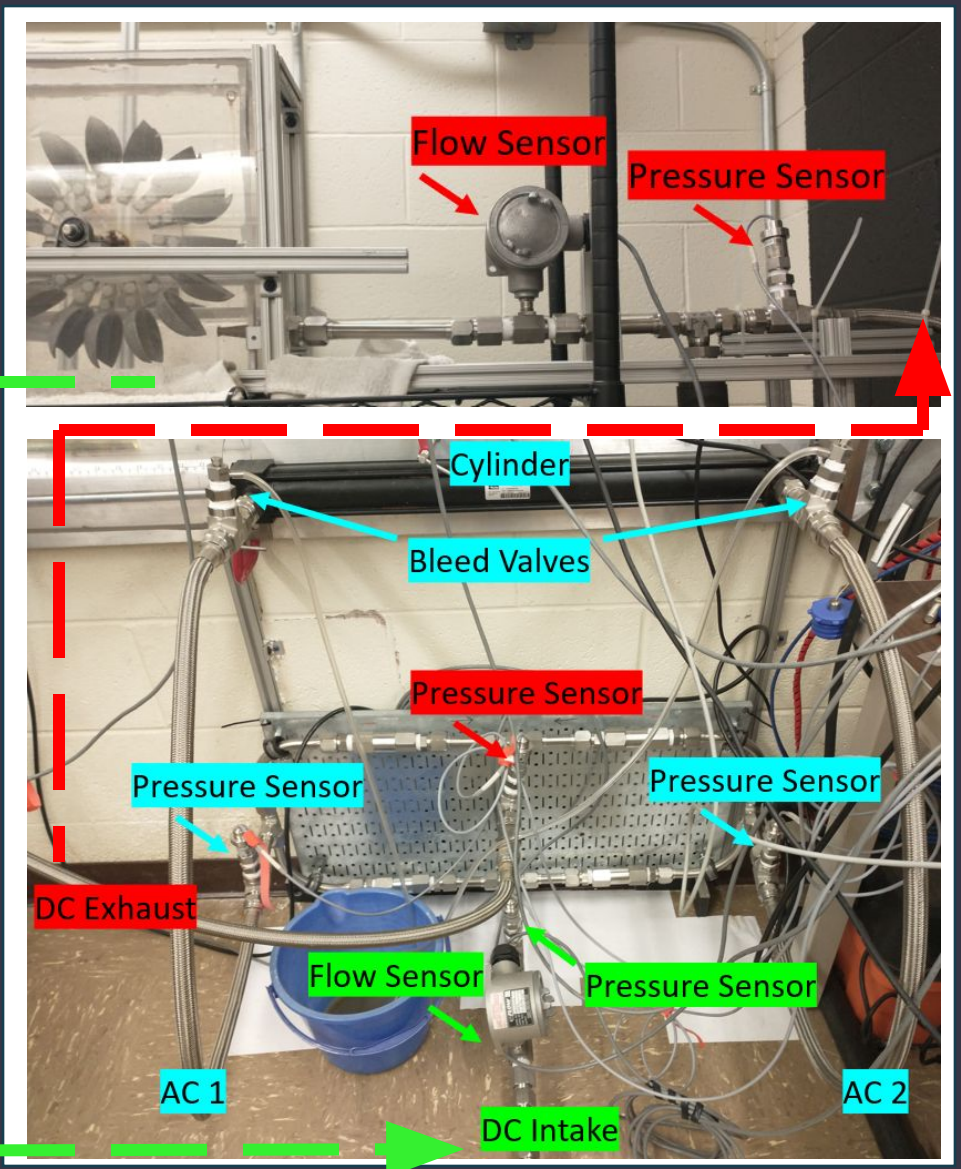


Coupling: OSU Basin

(video)

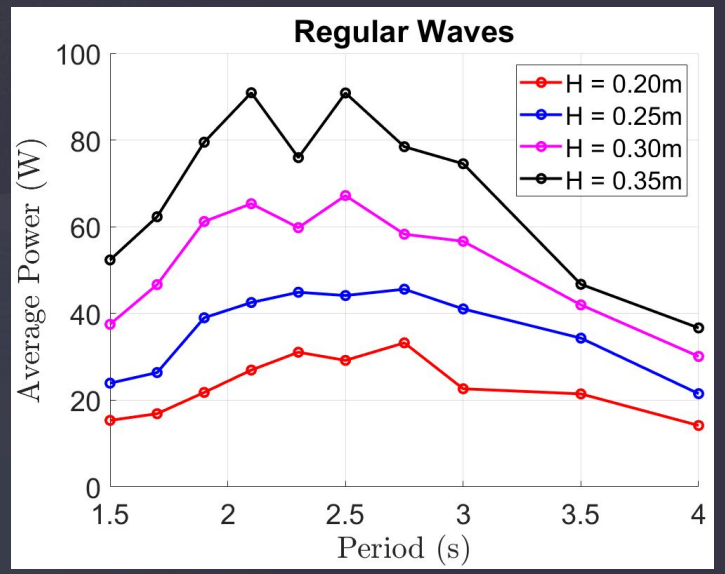
Coupling: Validation

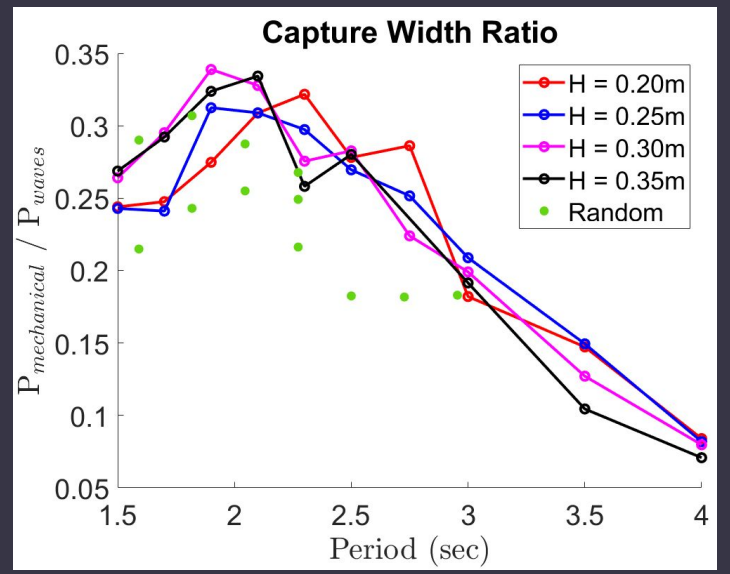
Experimental results

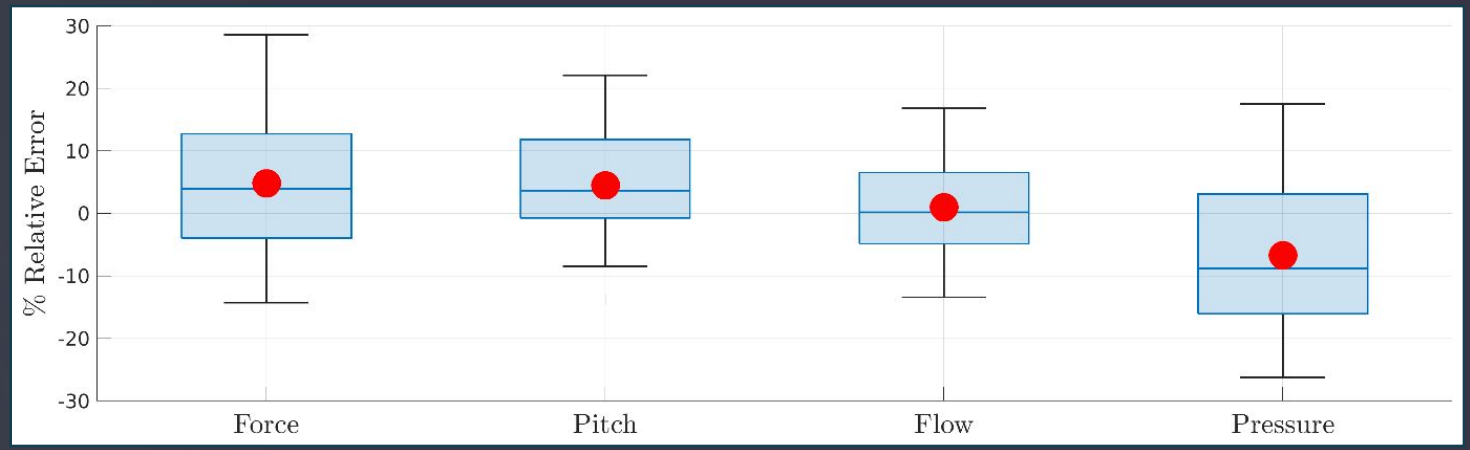
- Mostly agrees w/ hydraulic study
- Regular agrees with random

WEC-Sim with Simscape Fluids

- Driven by OSU observed free surface elevation
- 40 experiments







Conclusions

- Tapered profile improves hydrodynamic performance at small scale.
- High head hydraulic performance does have optimal solution, but solution space is broadband.
- Mechanical efficiency agrees with existing technology ~ 30%
  - Design is consistent
  - Max mechanical power observed ~ 90W
- Mean diagnostic parameters within +/- 10%
  - Systematic calibration approach works

Closing Remarks and Future Work

- Developed an open source hardware platform
  - Bench top hydraulic testing: O(100W) & O(1,000W)
  - Year-round ocean testing: Makai Pier and Kilo Nalu Observatory
    - Utilize HAWSEC hydraulic PTO to test your flap design
    - Utilize HAWSEC flap to test your hydraulic PTO
      - Friday morning in the "WEC PTO and Operations" section, Jackson Wills to present "Comparison of Hydraulic Power Take-Offs With and Without Continuous Control Force Capabilities"

TEAMER

- Publications
- Experimental datasets soon to be released on MHKDR
- Scaling up to S = 1/3 and focus on:
  - PTO hardware selection and model validation
  - Quantify electrical-mechanical hydro turbine efficiency
  - System controls (HMEC)

Thank You!

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