DE-EE0008629 - Hawaii Wave Surge Energy Converter (HAWSEC)

Patrick Cross
University of Hawaii

pscross@hawaii.edu
19 July 2022

Project Overview

Project Summary

- Develop an oscillating wave surge energy converter (OWSC) concept through numerical modeling and wave tank testing at two scales – 1/9th and 1/3rd.
- Utilize off-the-shelf, or readily fabricated, proven hydro turbine concepts for power takeoff – opportunity for LCOE reduction.
- Investigate both high head and high flow versions in BP1 (small scale), before down-selecting in BP2 (medium scale).

Intended Outcomes

- Final report to include results of small and medium-scale modeling and testing, as well as predictions of "full-scale" device performance, including assessment of the relative value of scaling up a single device, and/or deploying multiple devices in arrays.
- Robust understanding of head versus flow characteristics for hydro turbine optimization.

Project Information

Principal Investigator(s)

- Rajagopalan, Heitmann, Pappas, Gedikli

Project Partners/Subs

- Gerard Nihous Consulting – design oversight
- National Renewable Energy Lab – WEC-Sim support, MODAQ system design

Project Status

Ongoing

Project Duration

- 1 September 2019
- 30 September 2023

Total Costed (FY19–FY21)

$219K

Project Objectives: Relevance and Approach

Relevance to Program Goals:

- Project falls primarily in WPTO's Program Activity #1 – Foundational R&D, specifically:
  - Subactivity 1.3 (Numerical Modeling) – extensive use of WEC-Sim, AQWA, and CFD/SPH methods, integrated with tank testing to validate models
  - Subactivity 1.4 (Components) – careful analysis of key components, including hydraulic cylinders, check valves, and hydro turbines to optimize power performance
- Relevant progress in Program Activity #2 – Technology-Specific System Design and Validation
  - Specifically – "concept refinement, design, and small-scale prototype testing of new wave energy system concepts with high techno-economic potential"
  - Subactivity 2.1 – System Design and Laboratory Testing: Develop lower-energy and shallower wave system device designs, iteration on system designs through multiple phases
  - Subactivity 2.3 – Powering the Blue Economy: Emphasis on remote or island communities, with potential for conversion to desalination system. Adaptation to a floating version could be applied to Power at Sea applications.
- Some relevance to Program Activity #3 – Reducing Barriers to Testing, through creation of a robust hydraulic laboratory bench testing capability
- Potential application to grid-scale power needs for coastal communities – by scaling up and/or deploying arrays of systems

Approach:

- Develop concept through a modeling-testing-modeling-testing sequence, at increasing size/scale
- While OWSC WECs are not a new concept, we believe our full consideration of both high head and high flow versions, targeting proven hydro turbine technologies, will lead to efficient power generation and lower LCOE

Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- Lab-scale WEC and hydraulic system
- Flow, pressure sensors – other instrumentation for future projects
- Adaptable MODAQ system (NREL)
- Tools and lab setup for further OWSC (or other) investigations
- Pressure, flow, power datasets in wide-ranging wave conditions
- Final report
  - Small/medium scale performance analysis, and full-scale prediction
  - Robust assessment of flow/head characteristics for turbine optimization
- Journal publication focused on hydraulic analysis and turbine selection

Outcomes:

- Expertise in WEC-Sim and Matlab hydraulics toolboxes
- Expertise in lab and tank testing, design of instrumentation and data acquisition systems
- Masters thesis/degree for key team member
- Productive relationship w/NREL
- Readiness to propose future project to scale up and execute ocean deployment

Project Timeline

FY 2019

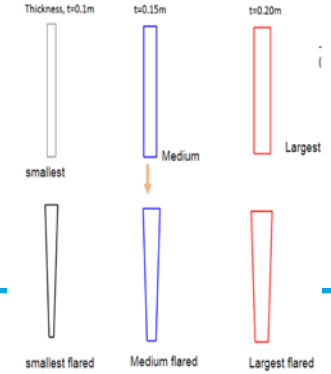
Project Initiation

(No funds expended)

FY 2020

Project/SOPO Reshape

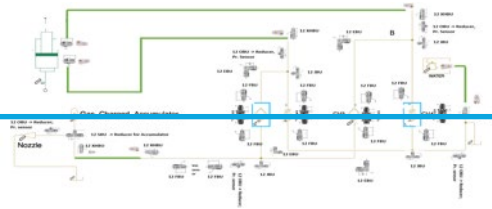
Early modeling steps



FY 2021

WEC-Sim modeling, system design

Procurement of hydraulic components/sensors



FY 2022

Complete procurement

Flap and base fabrication

Bench test assembly

Bench tests

In-ocean shakedown

- Project delayed nearly 1 year due to departure of key team member/loss of his IP
- Kept original focus on moving water through a hydro turbine, shifted to OWSC/hydraulic cylinder to pump water
- Approximately 6-month delay in receipt of linear actuator – key component needed for bench testing
- Go/No-go decision point scheduled for October 2022. Delay to spring 2023 in process.
- Next up is wave basin testing at OSU's Hinsdale facility – 13 June to 15 July 2022

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$1,162K	$331K	$1,653K

Includes $160K to NREL

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$0K	$5K	$213K	$219K

- Just beginning to spend when project put on hold in February 2020
- Spending resumed in November 2020 under revised SOPO
- Likely budget shortfall (order $50-70K) due to need for longer-than-budgeted wave basin testing (basin costs, travel), procurement-related project delays, and key test equipment lost in shipping (necessitating 2nd phase in BP1)

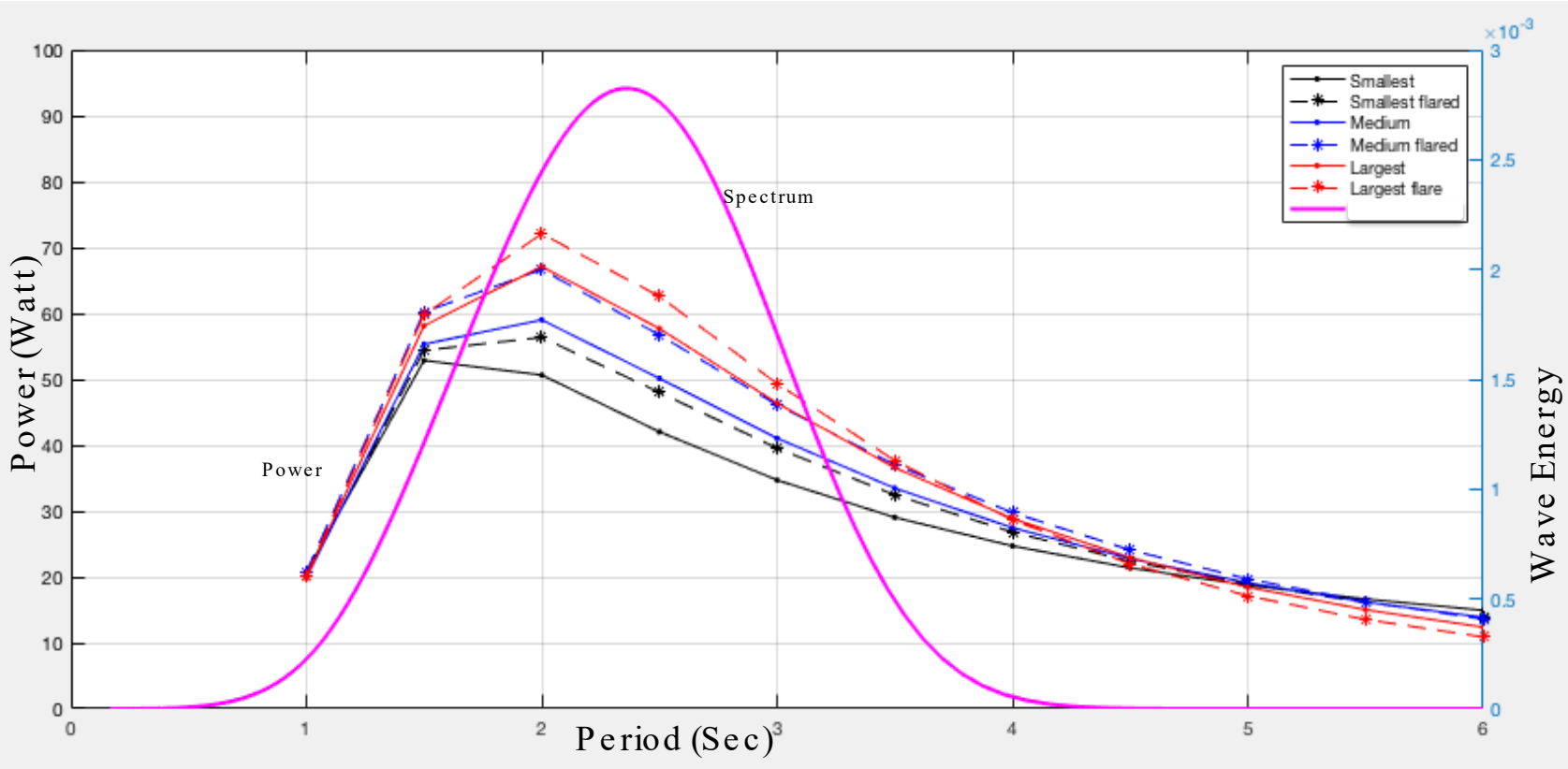
End-User Engagement and Dissemination

- Still in earlier stages of project – have not significantly engaged with potential end-users
- Project is largely academic in nature at this juncture, but with good understanding of practical, real-world challenges facing the maturation of wave energy conversion – obtained through extensive involvement in WEC deployments at WETS, and broad participation in the wave energy community as a whole
- Initial target of this technology is in the Resilient Coastal Communities category – including island and remote communities in need of diesel generation alternatives
- Technology will ultimately be scalable to a wide range of applications – through deployment at larger sizes or in arrays
- As concept matures in BP2, we intend to increase engagement
  - Identify potential end-user communities where this WEC archetype might be well suited
  - Seek potential industry partner to assist with commercialization – under future funds
  - Identify potential hydro turbine manufacturers
- Plan to publish key results in a peer-reviewed journal (*Ocean Engineering, Renewable Energy)*

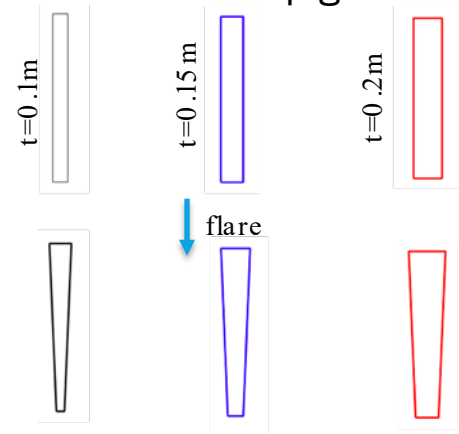
Performance: Accomplishments and Progress

Flap Geometry Selection Based on Device Hydrodynamic Performance

- 6 Geometries, varying in thickness and flare
- AQWA, FLOW-3D (drag estimation), WEC-Sim



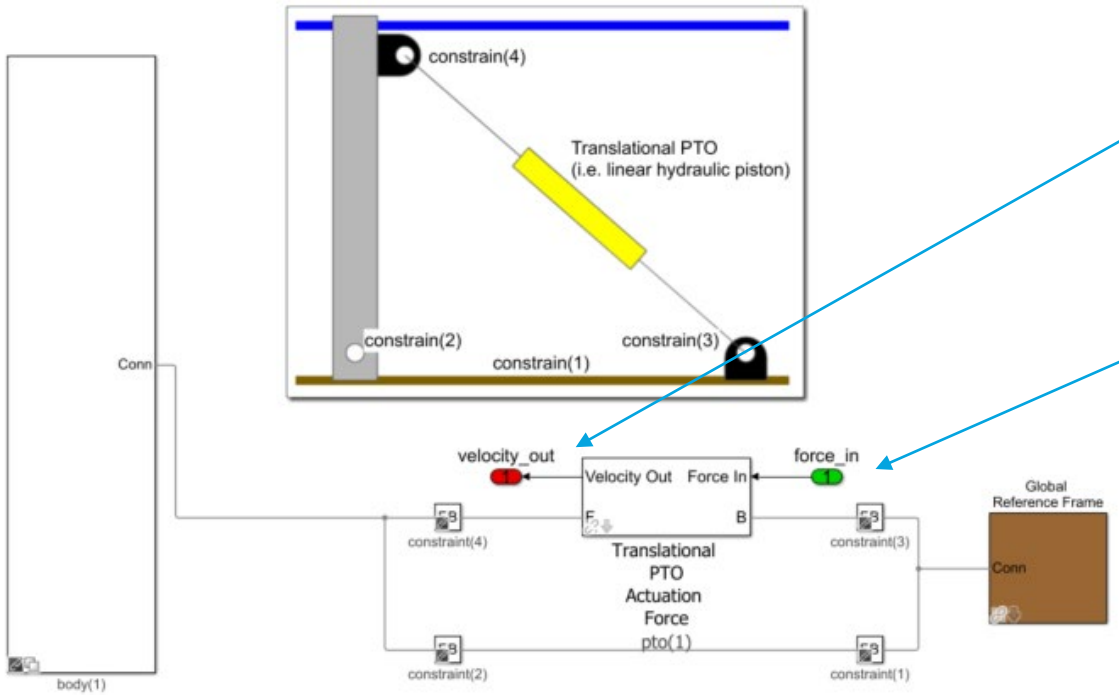
Profile view of 6 flap geometries



Performance: Accomplishments and Progress (cont.)

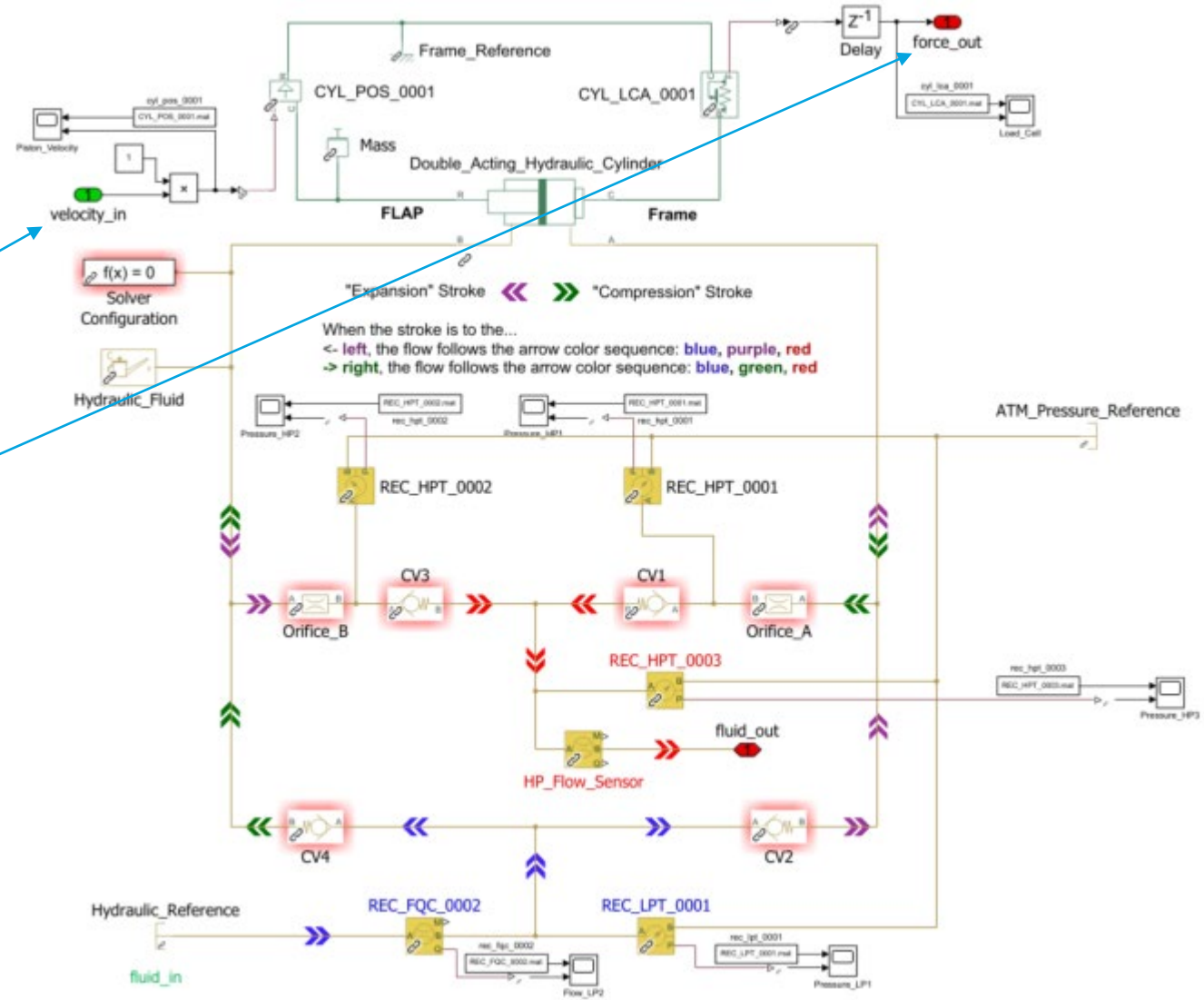
Computational Modeling

WEC-



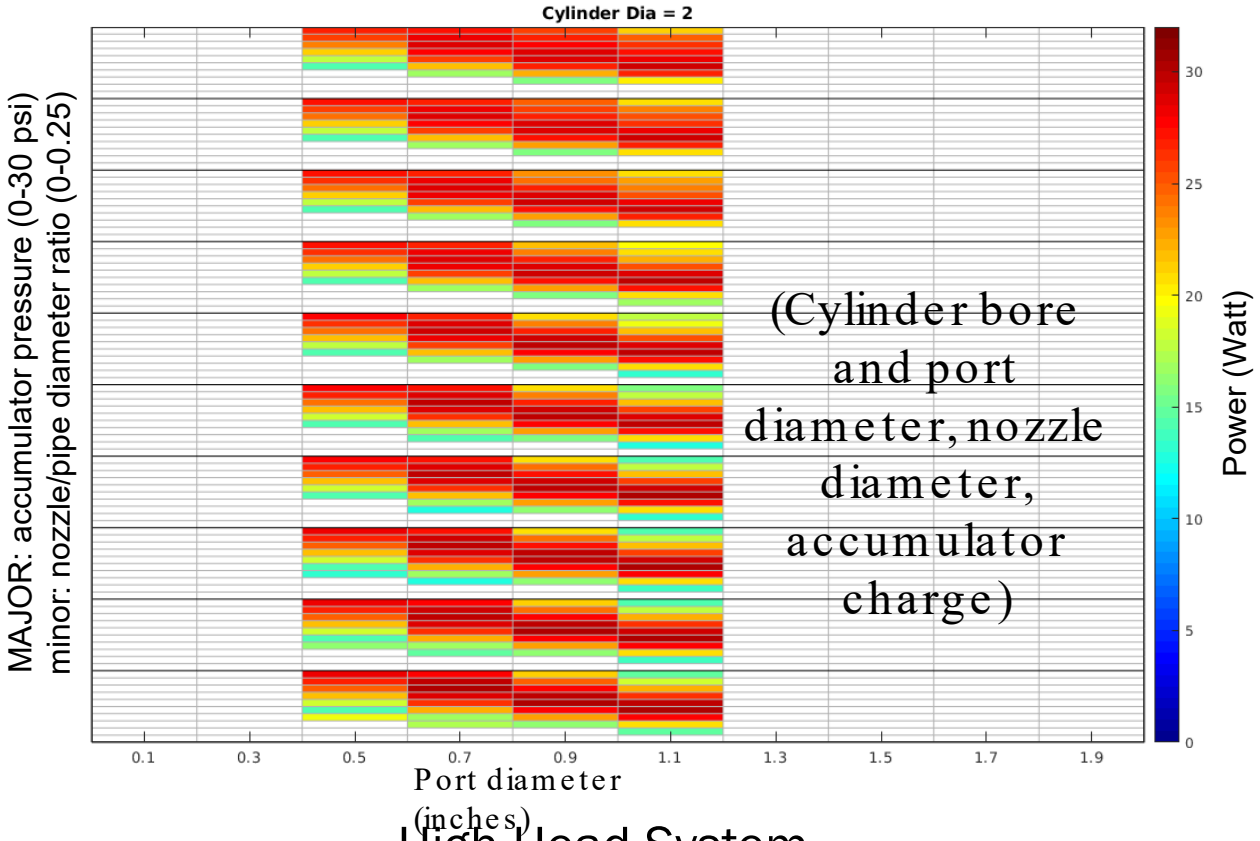
- Two-way coupling

Simscape/Simfluids

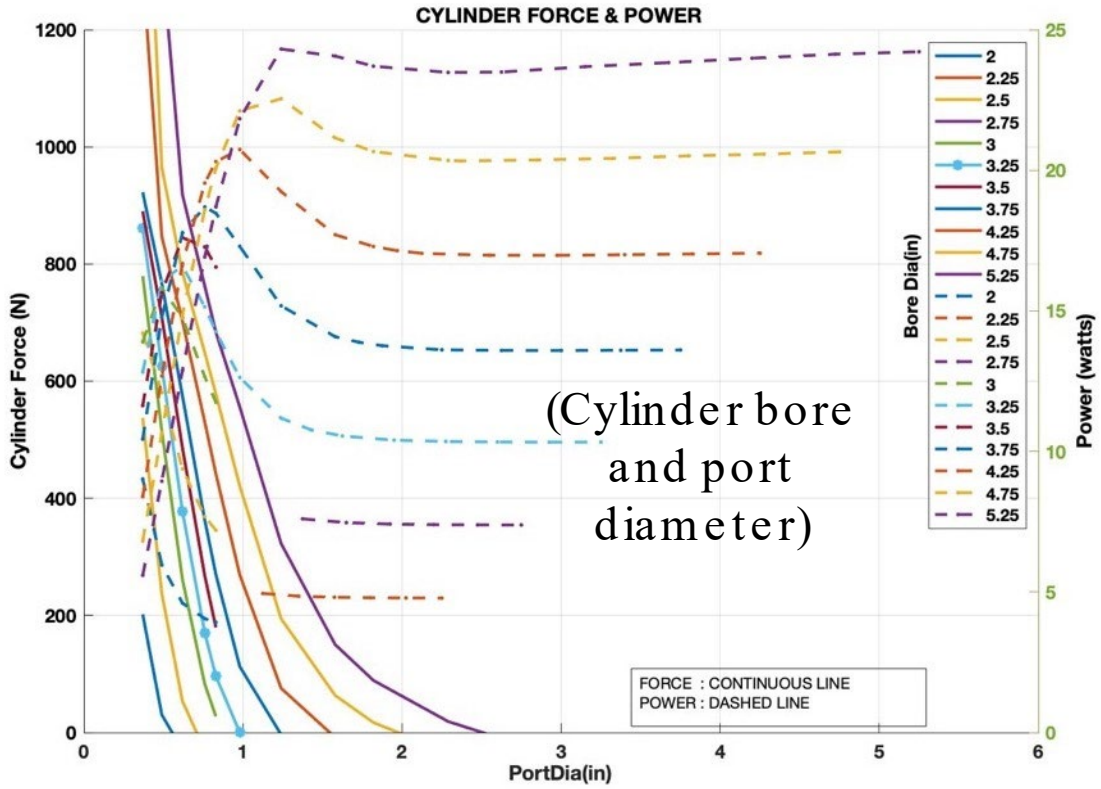


Performance: Accomplishments and Progress (cont.)

Parametric Study to Select Hydraulic Components

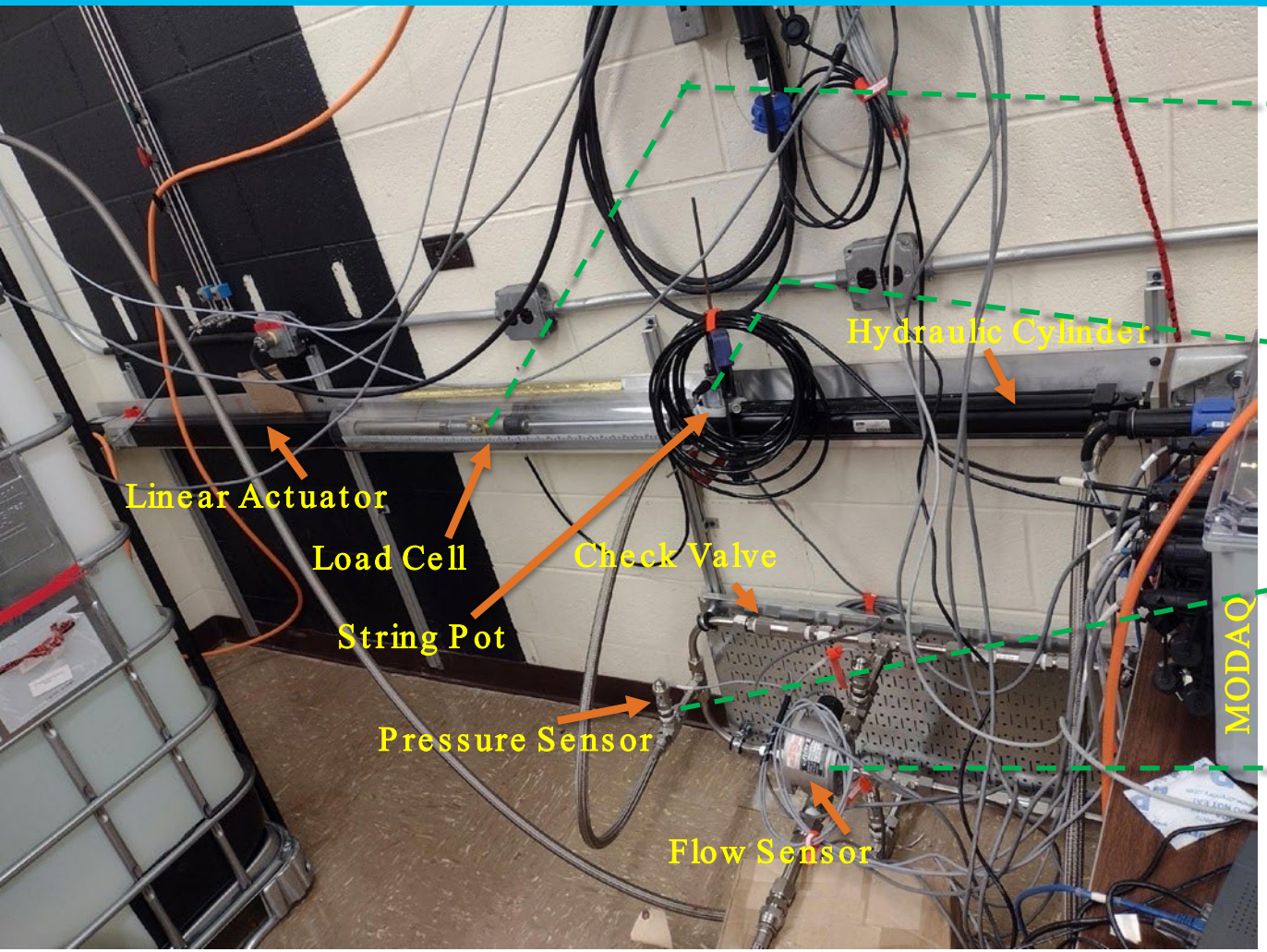


High Head System

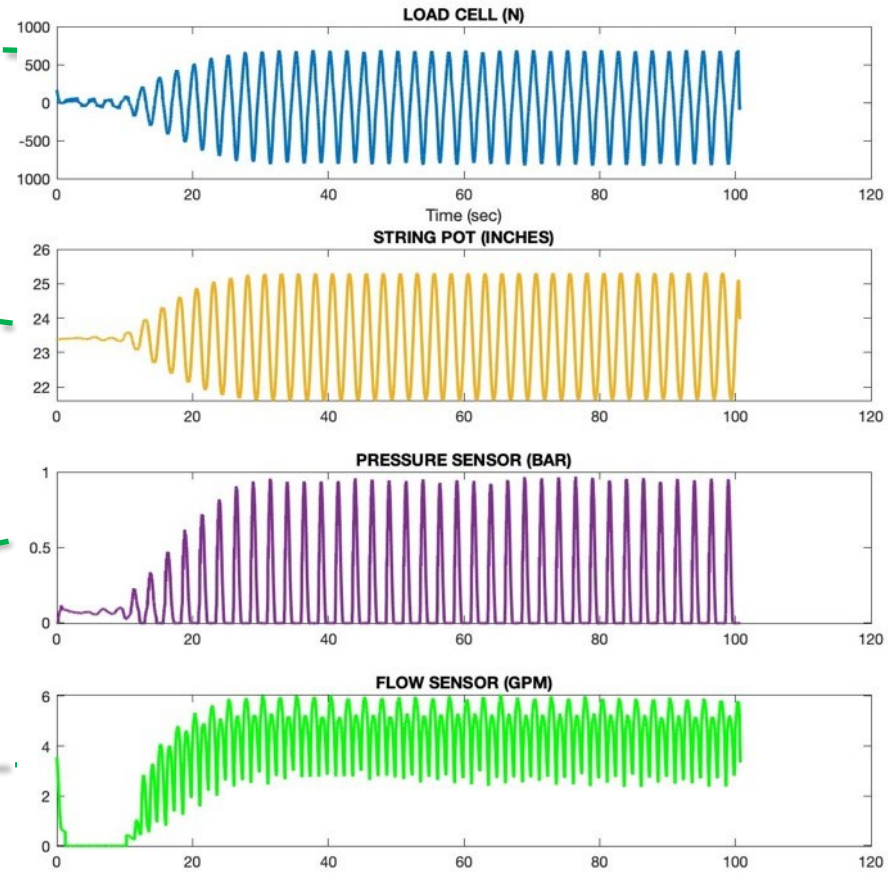


High Flow System

Performance: Accomplishments and Progress (cont.)



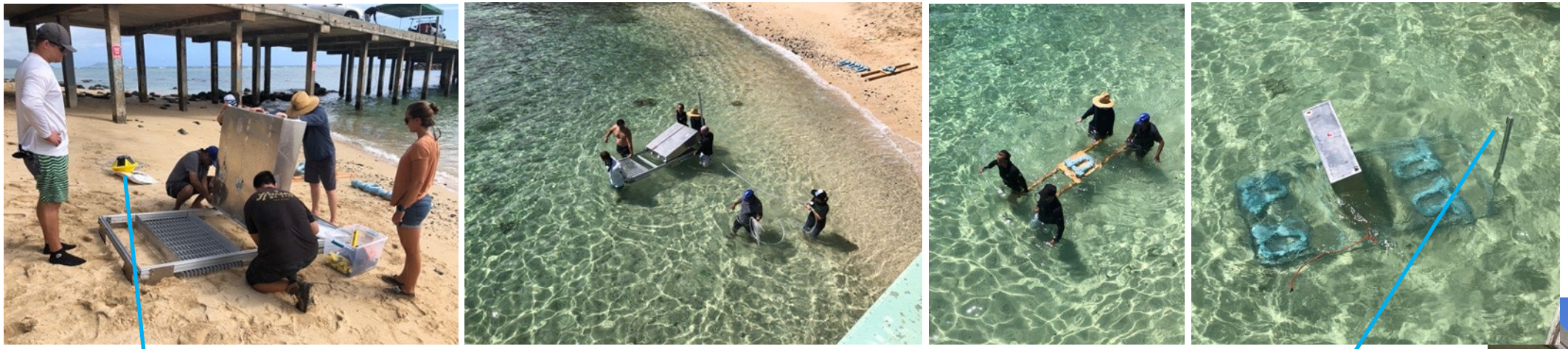
Bench Tests of Hydraulic System for Model Validation

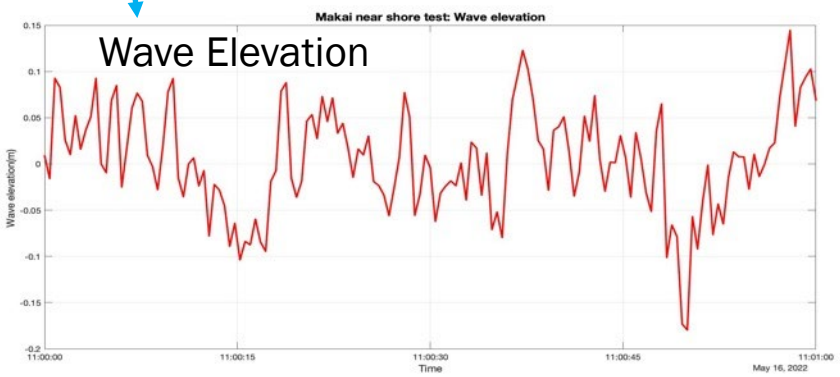


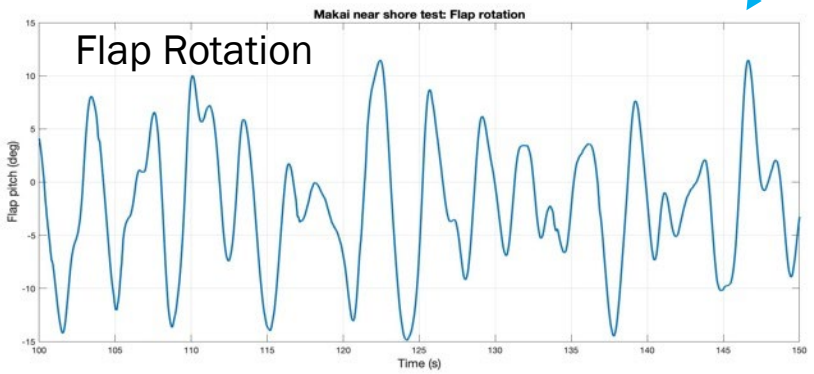
Results from initial WEC-Sim/Simscape model runs underdamped compared to measured data. Model validation ongoing.

Performance: Accomplishments and Progress (cont.)

In-ocean Shakedown Tests of Flap at Makai Research Pier – 13 May 2022

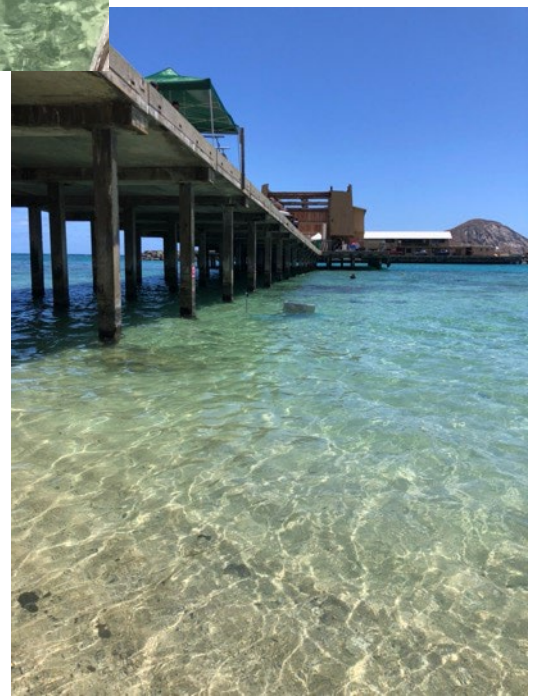






Objectives

- Deployment reality check
- Collect wave and flap motion data
- No hydraulics

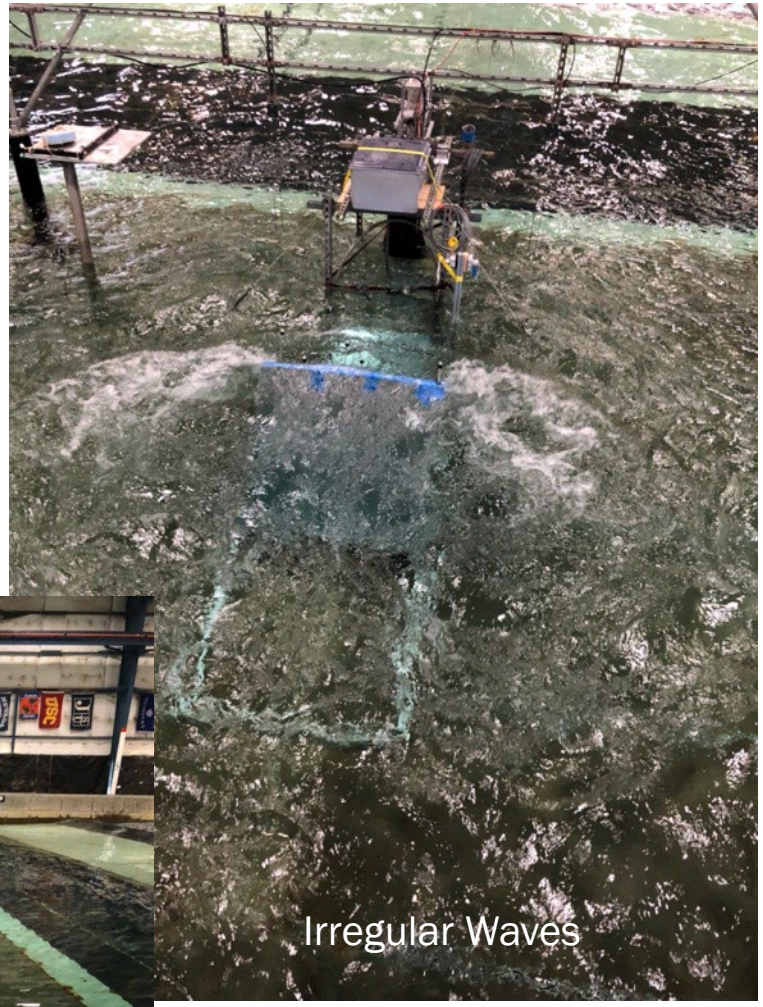


Performance: Accomplishments and Progress (cont.)

Phase 1 of OSU Hinsdale testing – 22 June to 1 July 2022

Issues

- Hydraulic cylinders lost in shipment
- No PTO testing possible
- Need to return early fall 2022



Objectives

- Free decay tests
- Behavior in regular waves
- Behavior in irregular waves
- CG and Moment of Inertia tests

Future Work

- Small-scale HAWSEC testing at OSU's Hinsdale wave basin – June 2022, and return in fall
- Model validation at small scale
- Scale up to medium scale (2.5 – 3x small scale) in model space
- Down-select device version, and complete design of medium-scale device
- Go/No-go decision – spring 2023
- Fabrication of medium-scale HAWSEC system
- Tank testing – nominally U of Maine, but may shift
- Model validation at medium scale
- Prediction of performance at "full-scale", including potential for deploying systems in arrays
- Anticipated project completion and final reporting – May/June 2024

Q&A