The Biggest Mistakes We Made with the LUPA WEC, and How We Tackled Them

Courtney Beringer, Bret Bosma, Bryson Robertson

Outline

- What is LUPA?

- How has LUPA been used?

- Lessons learned from
  - Design
  - Build
  - Test
  - Modeling

- Future directions

What is LUPA?

- Laboratory Upgrade Point Absorber

- Motivations
  - Open-source
  - Modular
  - Share lessons learned!

- Funding
  - DOE
  - Business Oregon
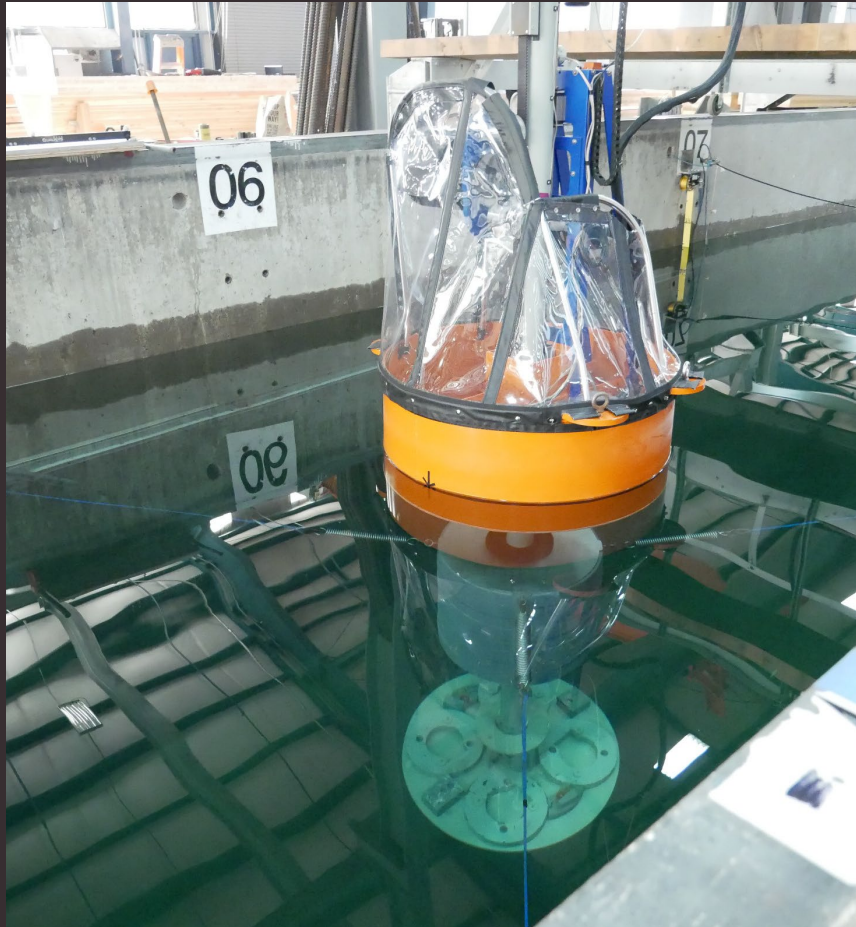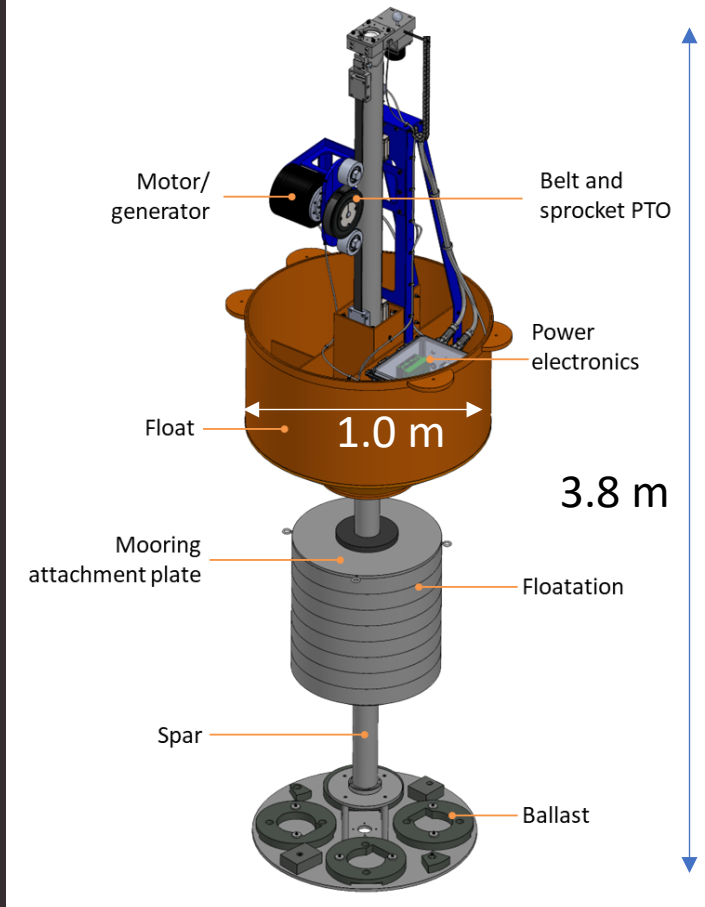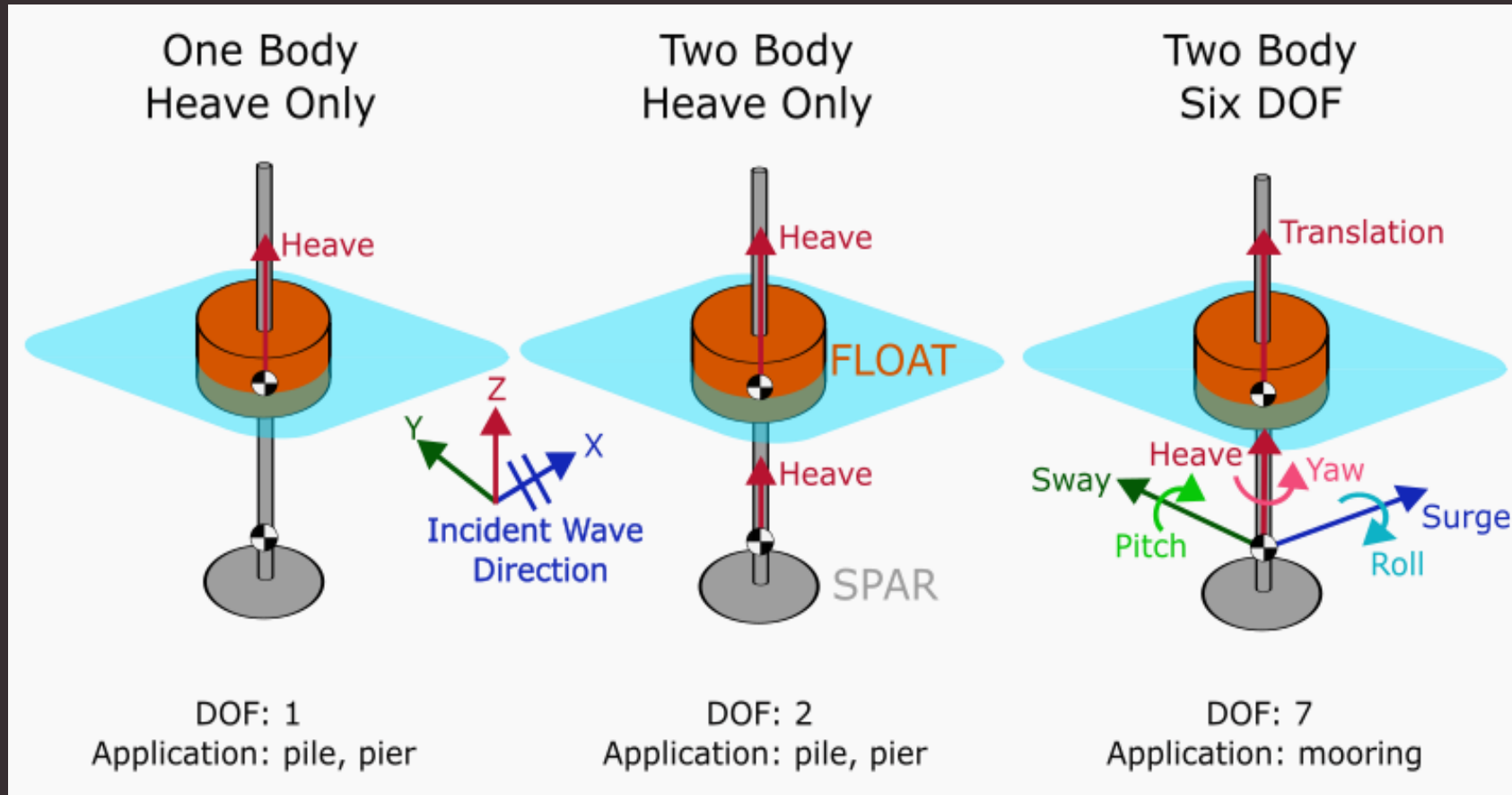 - TEAMER

- Project start: 2020

Photo by Samantha Quinn

O.H. Hinsdale Wave Research Laboratory
Large Wave Flume
Oregon State University
Corvallis, OR, USA

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Modes of Operation: simple to complex

- Actively controlled PTO with damping and stiffness control through MATLAB real-time interface

- WEC-Sim, WAMIT, ProteusDS, WecOptTool models

- TEAMER facility w/ Hinsdale

- Fully detailed CAD models

- Photos, videos

- Papers, presentations

Capabilities

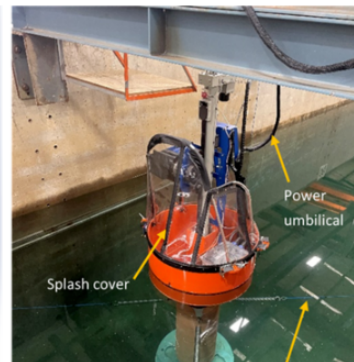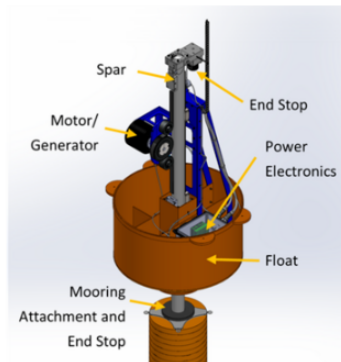# DOE WPTO: Signature Project

LUPA

Project Information

Project Purpose
The Laboratory Upgrade Point Absorber (LUPA) Project was designed to create an open-source, modular numerical and physical WEC system to create a common benchmark for WEC hydrodynamics, controls, mooring systems, and student learning.

Project Description
The Lab Upgrade Point Absorber (LUPA) project, sponsored by the U.S. Department of Energy (DOE), has developed open-source modular point absorber for WEC hydrodynamics, controls, mooring systems, and student learning. A visual of the experimental and numerical LUPA WEC are shown in Figure 1. The LUPA development team collaborated with the DOE National Marine Energy Centers (NMECs), Sandia National Laboratory (SNL), National Renewable Energy Laboratory (NREL), and private industry in the development of the LUPA WEC physical specimen and experimental device.

Status:	Ongoing
Start Date:	2020/04/01
Source:	LUPA Website
Organization:	Pacific Marine Energy Center (PMEC), Oregon State University (OSU)
Contact:	Bryson Robertson

LUPA
Laboratory Upgrade Point Absorber

PMEC — Pacific Marine Energy Center
Oregon State University

https://openei.org/wiki/PRIMRE/Signature_Projects/LUPA

Campaigns + Research

- Initial deployment Fall 2022

- TEAMER testing internal Fall 2023

- WEC modeling and controls workshop Spring 2024

- TEAMER testing external Spring 2025

- Over 100 deployment days

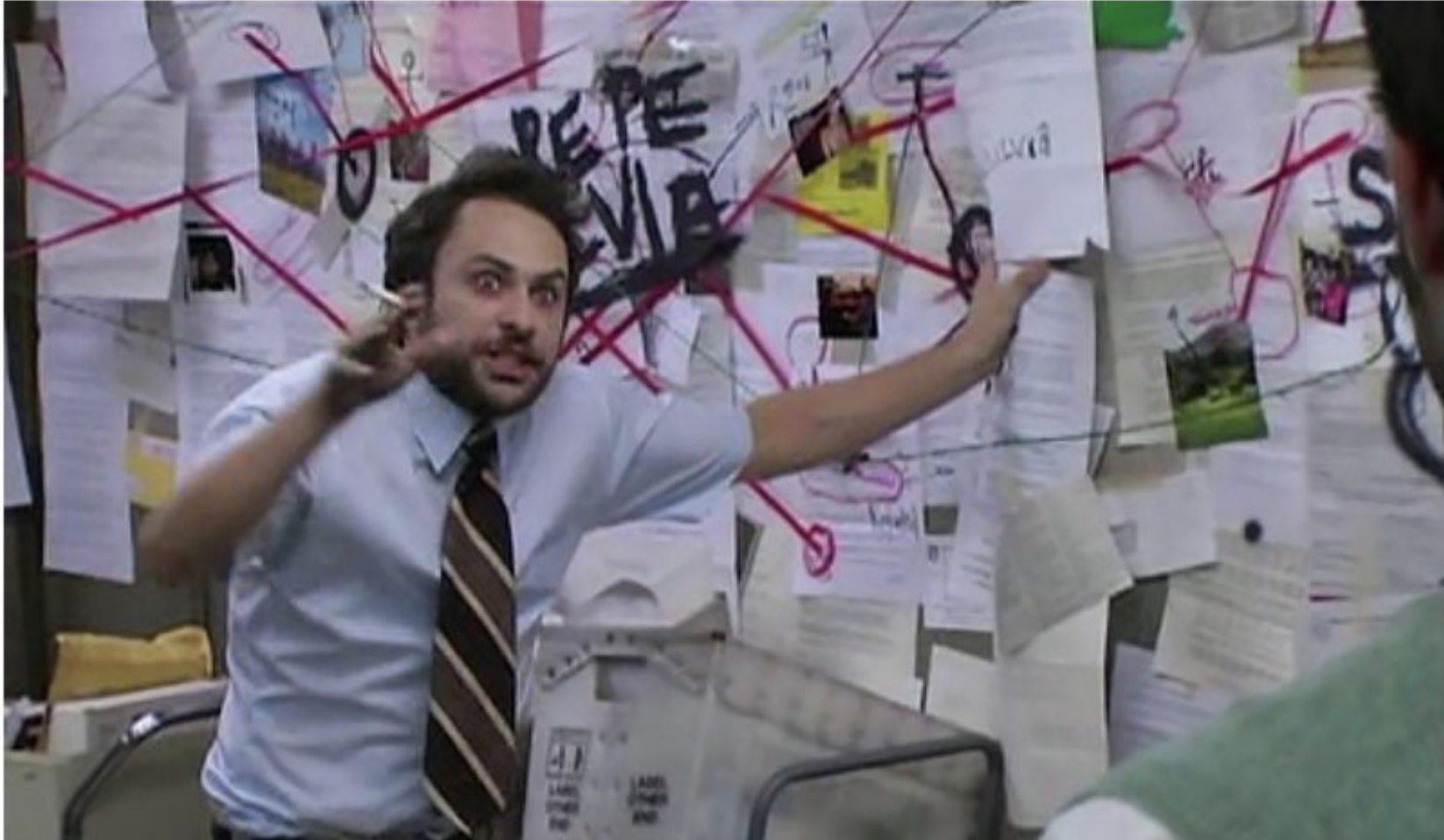- Through all this… we have successes and failures to share

Stability
Off the shelf
Safety
Configuration functionality

- Spar tube is hollow
- Spar positively buoyant
- Heavy generator high up
- Off the shelf steel pulleys
- **Problem: very unstable when deploying and recovering, high center of gravity**

Generator

Pulleys

Generator

Float

Mooring

Spar

Skewer

Us for the first hour of realizing this is a problem and we can't go on

Us for the next week

- Calling naval engineering friends
- Geometry, trigonometry, free body diagrams
- Brownies and good vibes to machinists
- Run wave calibrations so we don't waste precious tank time
- McMaster fast shipping
- Calling foam man
- CAD drafting
- MATLAB coding
- Undergrad errands
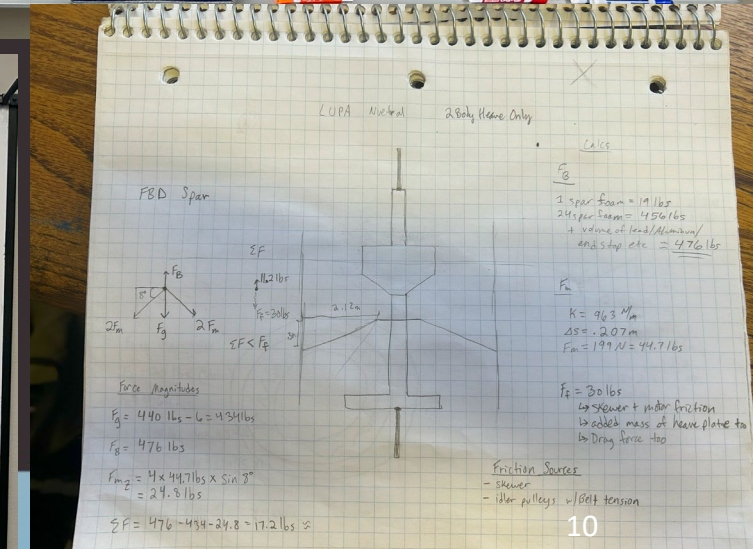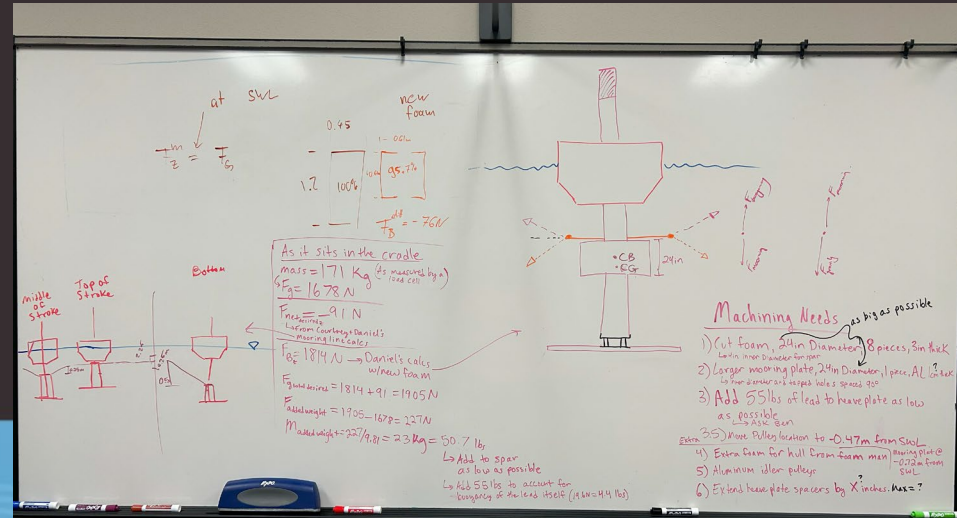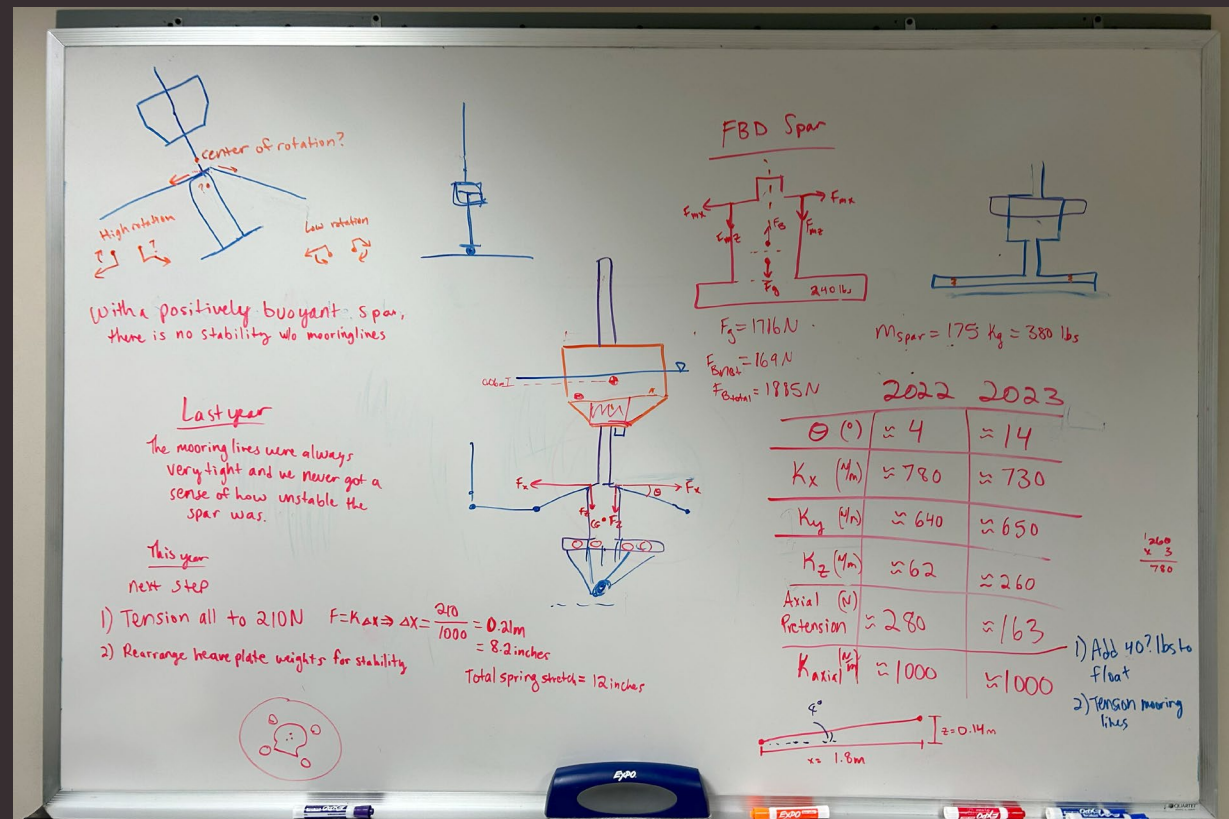
Improved LUPA

- Spar is now negatively buoyant
- Spar higher floatation, lower ballast = new CG
- Mooring pretension and angle changed
- Float lost a few pounds replacing steel pulley with aluminum
- Extended heave plate by 10 inches
- **Result: night and day stability**
- **Lessons learned**
  - **Out of the water and to the white board**
  - **Build good relationships with suppliers and machinists**

- 🔴 Center of Gravity
- 🔵 Center of Buoyancy

Difference = Metacentric Height

Fall 2022   Fall 2023 and Spring 2024
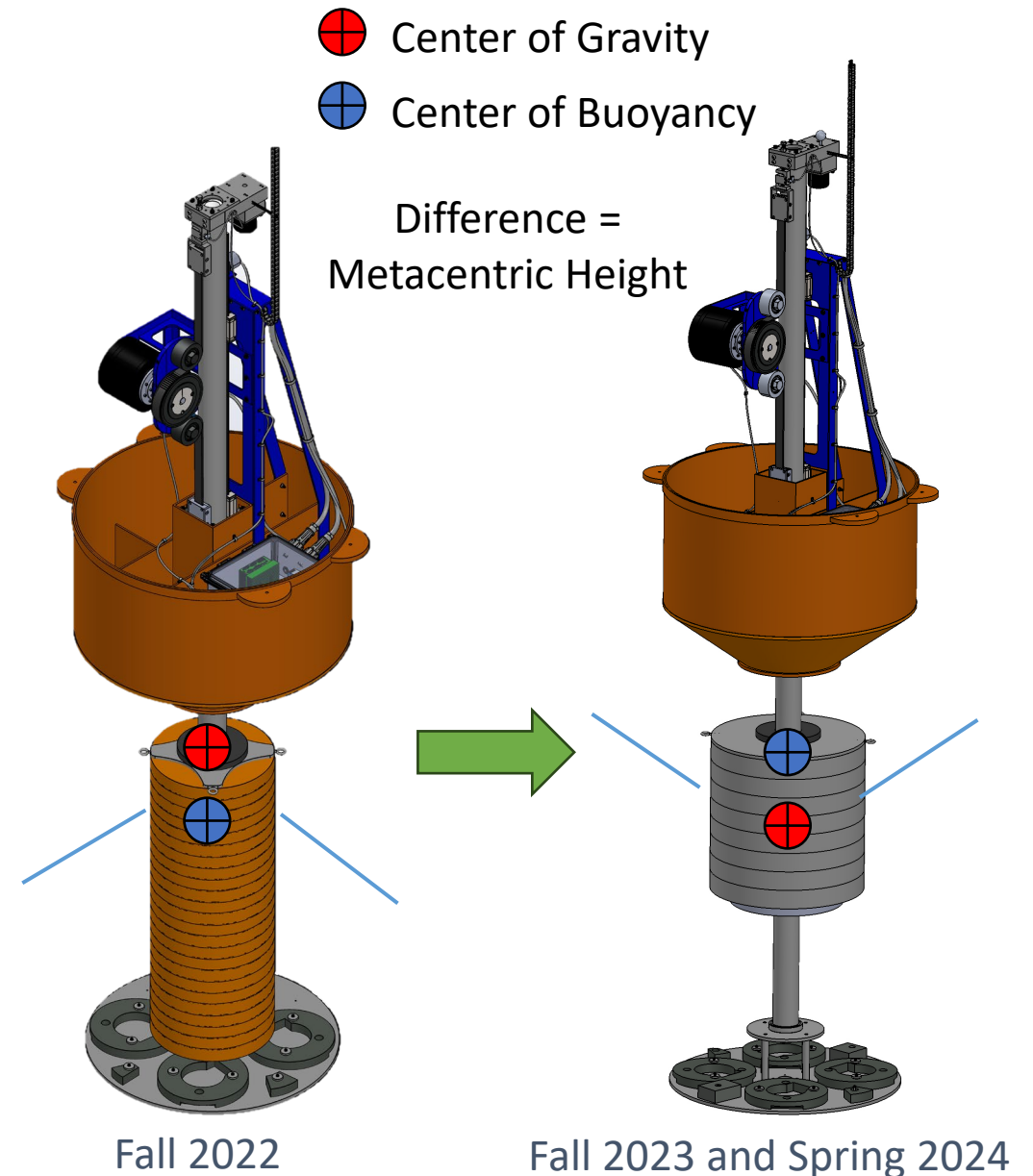
Build Lessons learned

- Mock up humans next to device in CAD
- First build: test fit and modify
- Disassemble everything
- Powder coating paint
- Second build: final assembly
- Cranes, forklifts, pallet jacks..
- LUPA weight?
- Cradle weight?

Assembly instructions

Step 18
Pulley and Sprocket Install

Parts	• Box 1: pulleys (2) , 3 sprockets (large, med, small), key (1)
Tools	• 5/16 Allen wrench
Instructions	• First decide what size sprocket you want • Insert sprocket onto drive shaft with shaft key inserted. Tighten the short, threaded, headless bolts into the holes across from each other. • Thread on pulleys into correct tapped hole depending on the size sprocket chosen • The exact location of the pulleys and sprocket needs to align with the belt.
Helpful Hints	• The sprockets have 3 threaded holes. The two across from each other are used to tighten the bushing. The one hole offset is used to loosen the bushing.

Test

- Issues with PTO control feedback loops
- High frequency PTO belt vibrations
- Violent! Broke load cell hardware
- First and only emergency stop use
- Solve: notch + low pass filter
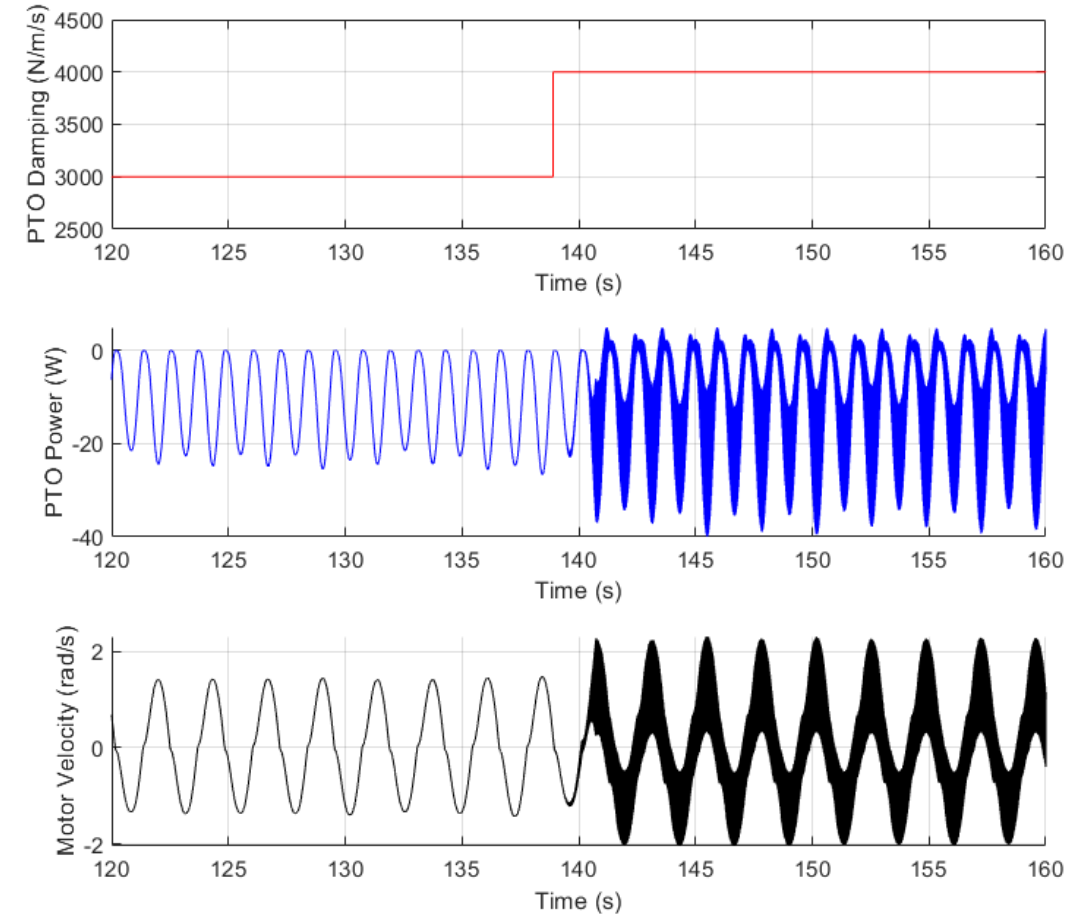
Test: Tank settling analysis

- Measure quiescent wave height (0.4mm)

- Run each condition of interest 1x

- Continue wave gauge data collection for ~20 min

- Analyze the wave height decay over time
  - 2 min to H=1mm
  - 4 min to H=0.4mm

Wave Height Decay
wg9

Observations
Least squares fit
Robust fit

1mm
0.4mm
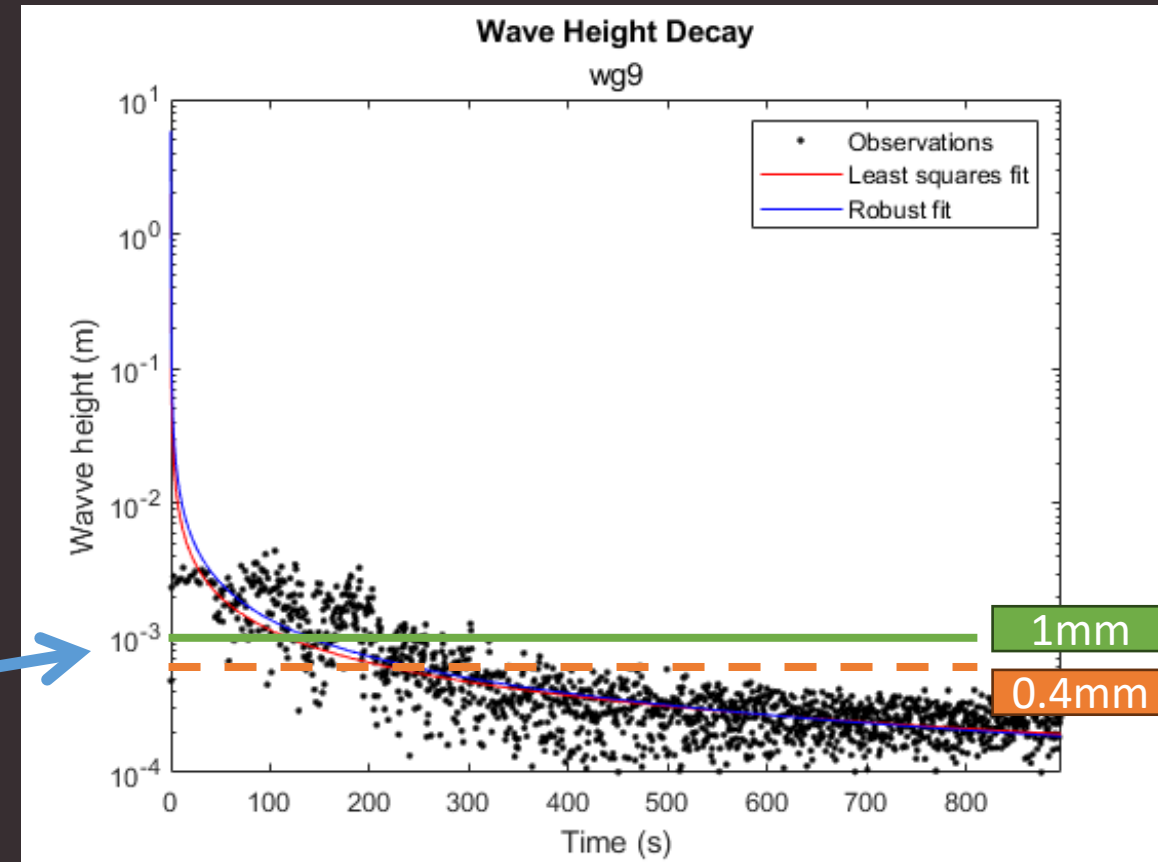
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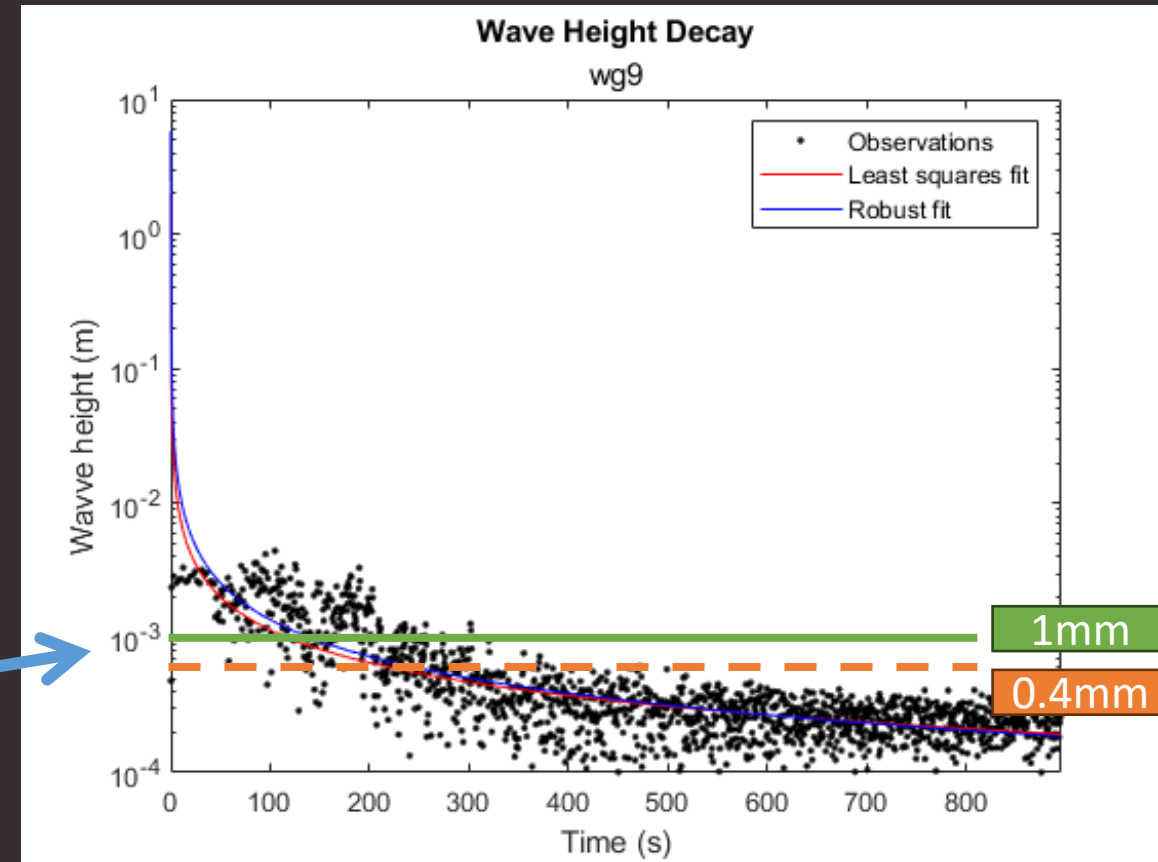
Lesson learned: saved 8 hours of test time ~$6K

We have all been here…

Shameless use of WEC-Sim issues page!!
https://github.com/WEC-Sim/WEC-Sim/issues

Future directions

- New motor drive to measure electrical power capture
- Adding battery charging capabilities and small load conditioning
- Lockout tagout on LUPA electrical box side
- Filters to prevent high PTO damping noise feedback loop

Future testing

- LUPA x Marine Carbon Dioxide Removal with NOAA / University of Minnesota
- LUPA x Autonomous Underwater Vehicle with WPTO / UW-APL + UH
- Codesign with WPTO / Sandia
- Reinforcement learning control with TEAMER/MTU

Many thanks and contributors!

- Bret Bosma
- Bryson Robertson
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- Rebekah Miller
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- Brian Johnson
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- Cedric LaPeyre
- Hannah Mankle
- Daniel Gaebele

Thank you! Questions?

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Extra slides

Mooring lines: Turnbuckle vs Winch

Turnbuckle

- Slow
- Heavy
- Limited stroke
- Operate from kayak in water

Winch

- Fast
- Solid mount
- Nearly unlimited stroke
- Operate from dry above flume
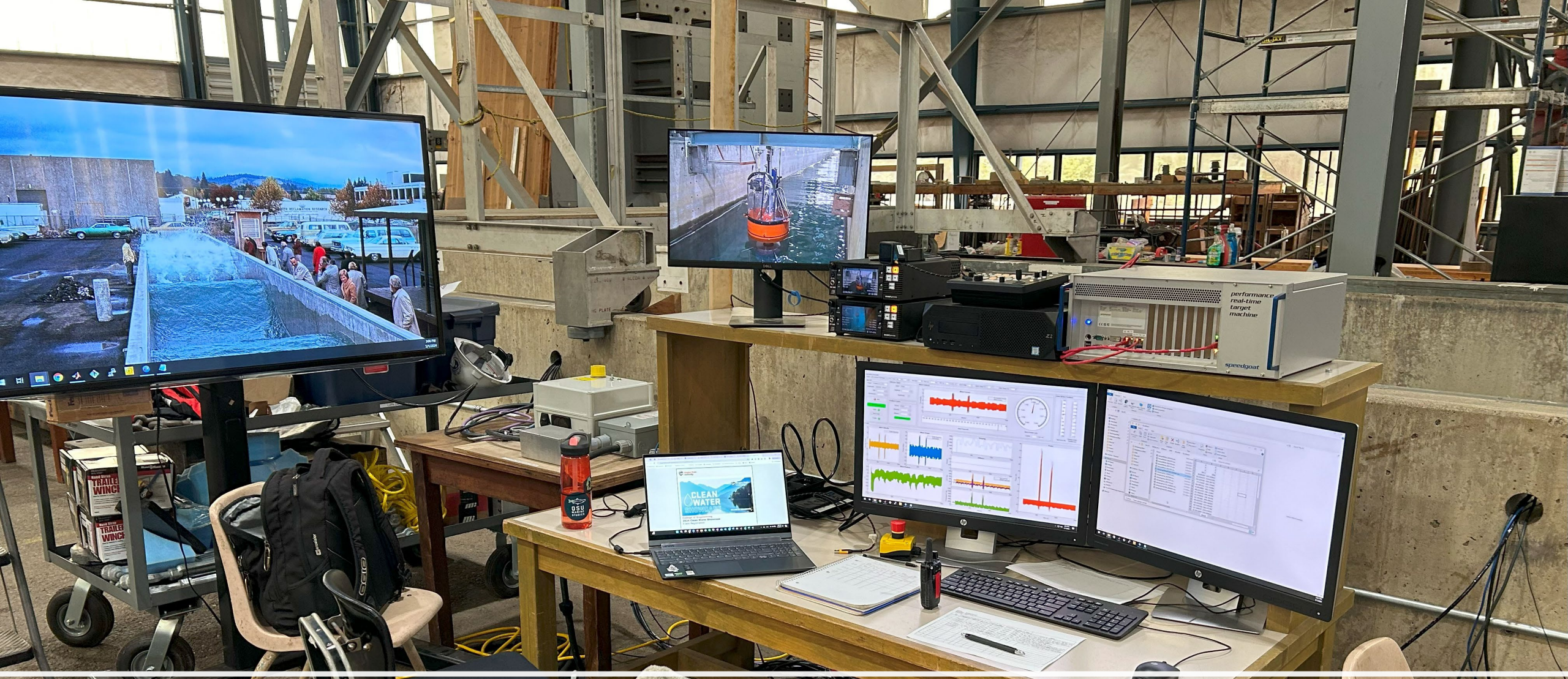
Human errors on motor current limit

Timeline
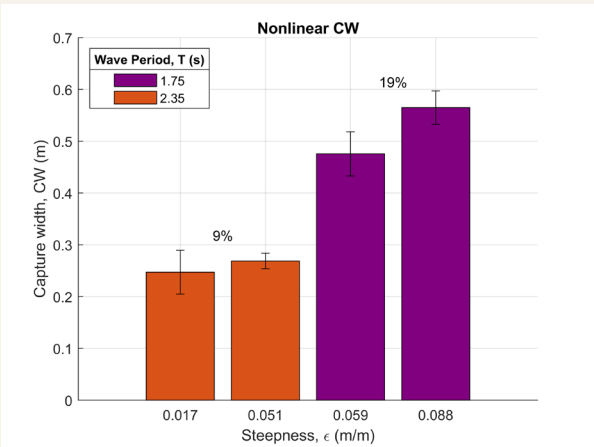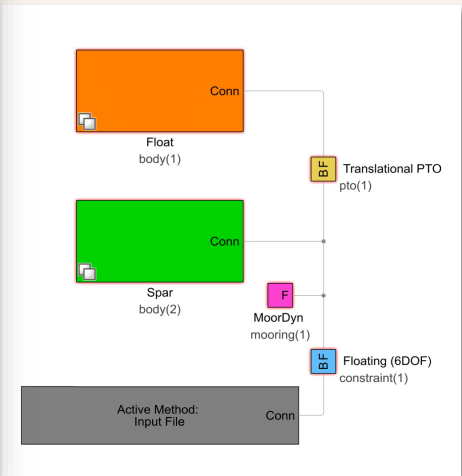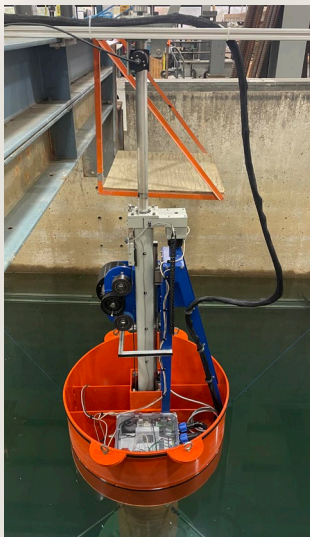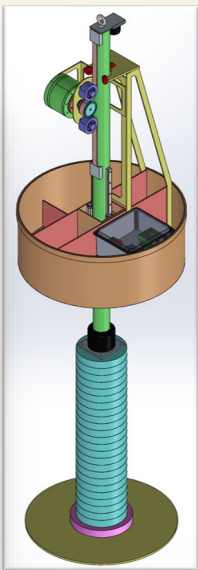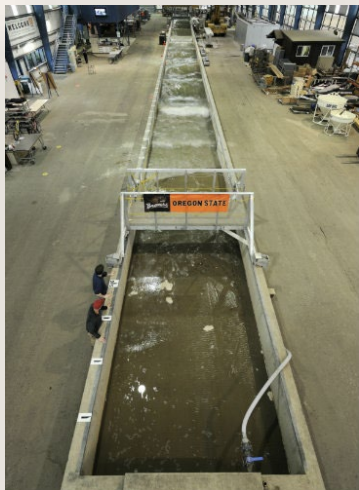
Concept development	Design iterations	Field expert feedback	Build device	Experimental testing	Numerical modeling & uncertainty	Publishing on controls, uncertainty, system ID, and DOF
2020	**2021**		**2022**		**2023**	**2024-25**

Flume drawings to communicate with wave lab team
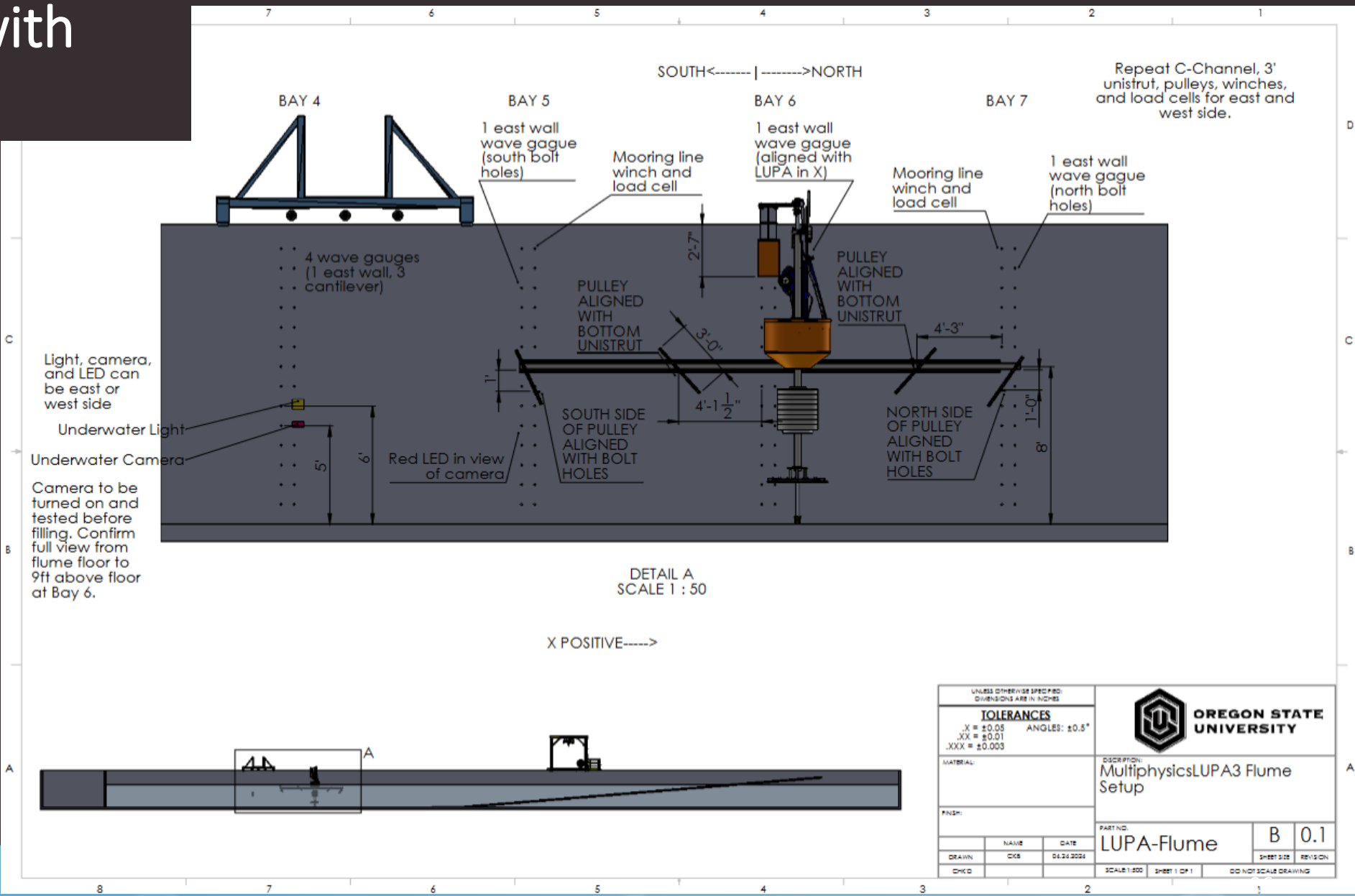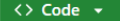
Control Code Management on GitHub

https://github.com/PMEC-OSU/LUPA

GitHub for WEC-Sim model control