



## Advanced WEC Dynamics and Controls

2.1.2.701

Marine and Hydrokinetics Program

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Sandia National Labs

# Project Overview

## Project Summary

- Wide body of research has shown **massive potential for control to improve WEC performance** (more power & reduced loads)
- This projects focus is **realizing those benefits for WEC developers** by creating a tractable engineering workflow

## Project Information

### Project Principal Investigator(s)

Ryan Coe & Giorgio Bacelli  
Sandia National Labs

### WPTO Lead

Bill McShane

### Project Partners/Subs

US Navy  
Michigan Tech.  
Oregon State University

### Project Duration

- Oct. 2016
- Sept. 2019

## Project Objective & Impact

The goal of this project has been to deliver actionable methods for WEC developers to apply in order to improve the performance of their devices via control. This goal has been achieved and extended upon as our research has led us to better understand the need to incorporate the knowledge available from WEC control design into the large WEC design process.

## Marine and Hydrokinetics (MHK) Program Strategic Approaches

### Data Sharing and Analysis

Foundational  
and  
Crosscutting  
R&D

Technology-  
Specific  
Design and  
Validation

Reducing  
Barriers to  
Testing

## Foundational and Crosscutting R&D

- Drive innovation in components, controls, manufacturing, materials and systems with early-stage R&D specific to MHK applications
  - Develop, improve, and validate numerical and experimental tools and methodologies needed to improve understanding of important fluid-structure interactions
  - Improve MHK resource assessments and characterizations needed to optimize devices and arrays, and understand extreme conditions
  - Collaboratively develop and apply quantitative metrics to identify and advance technologies with high ultimate techno-economic potential for their market applications
- Sandia leverages expertise from aerospace, defense, and robotics control to deliver methodologies for WEC device and control design capable of delivering dramatic improvements in performance and economic viability.
  - To deliver a robust framework for WEC device and control testing and design, Sandia has developed and validated numerous methodologies and experimental techniques. The methods provide WEC developers with a tractable path for WEC and control design. Experimental methods have increased the effectiveness of wave tank testing, enabling WEC developers to accomplish more in less tank time.

## Technology-Specific Design and Validation

- Validate performance and reliability of systems by conducting in-water tests of industry-designed prototypes at multiple relevant scales
- Improve methods for safe and cost efficient installation, grid integration, operations, monitoring, maintenance, and decommissioning of MHK technologies
- Support the development and adoption of international standards for device performance and insurance certification
- Evaluate current and potential future needs for MHK-specific IO&M infrastructure (vessels, port facilities, etc.) and possible approaches to bridge gaps


- Sandia's Advanced WEC Dynamics and Controls project has produced the most popular dataset on MHK-DR.
- Sandia's improved testing methods are being used heavily for the update of IEC 62600-103 (*"Best practices and recommended procedures for the testing of pre-prototype scale devices"*).

# Project Budget

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget (FY17–FY19 Q1 & Q2)	
Costed	Costed	Costed	Total Costed	Total Authorized
\$1,381K	\$1,132K	\$470K	\$2,983K	\$3,528K

- ***Leverage synergies/funding from***
  - *MARINET2*
  - *Sandia internal funding (SWEPT Lab)*

# Management and Technical Approach

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- **Problem:** Clear potential for improvements based on WEC control since 1970s, but limited real-world benefits
  - **Goal:** Holistic approach to realize these gains and provide a basis for co-design
  - **Strategy:** Leverage methods and tools proven successful in other applications to provide a tractable work flow for WEC control design



# End-User Engagement and Dissemination Strategy

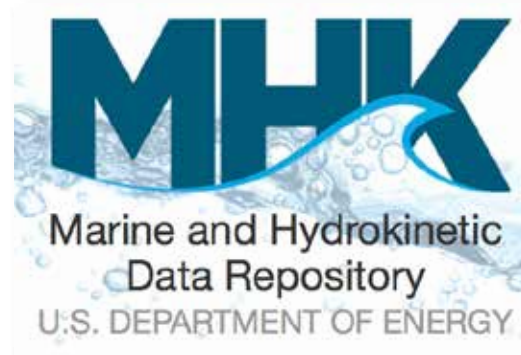
U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

Annual workshop  
& 4 webinars



Most popular public  
dataset on MHK-DR



Broad ranging research  
collaborations



3 patent applications  
(1 granted)



Private developer collaborations

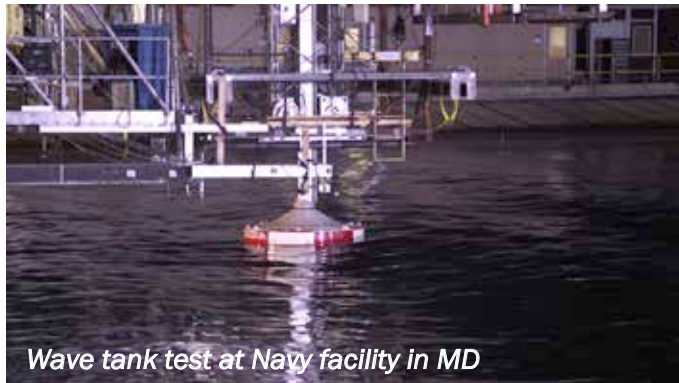


40+ project publications





# Technical Accomplishments

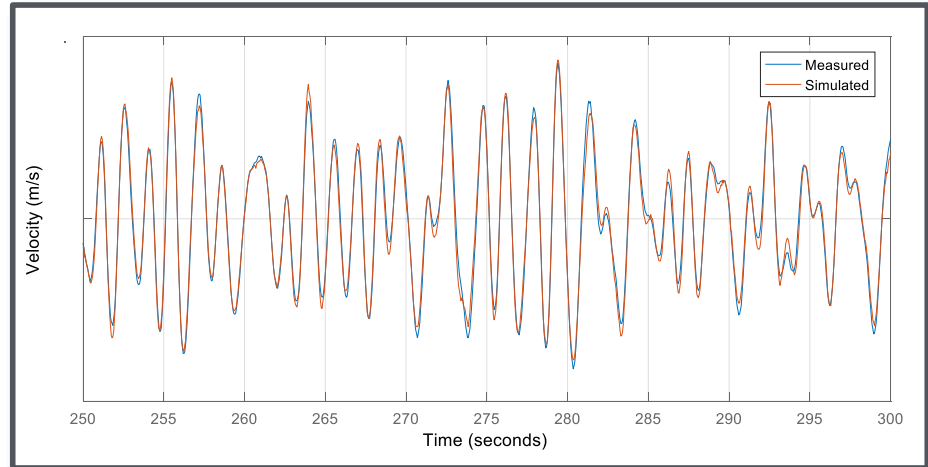


Wave tank test at Navy facility in MD

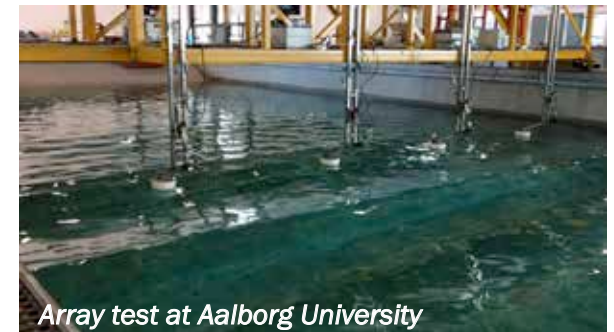
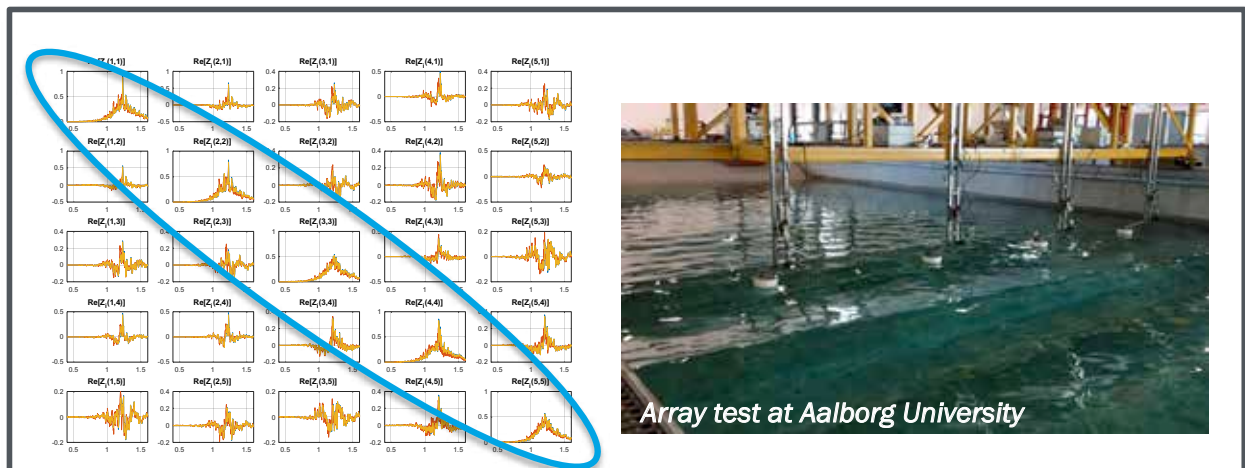


*Testing practices deliver better results in less time*

*Models better than 90% accurate*



*Works just as well on multi-device & multi-DOF systems*



Array test at Aalborg University

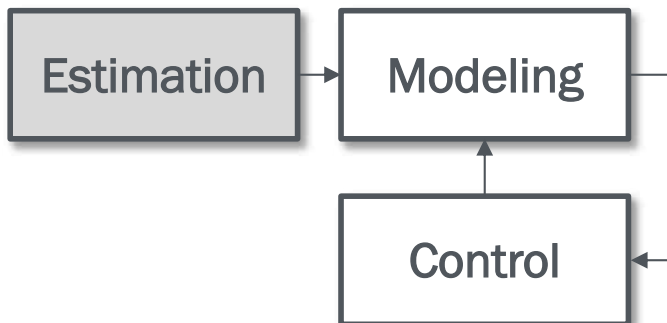
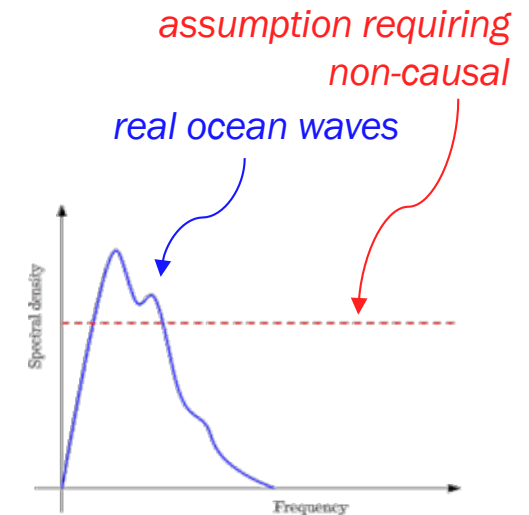
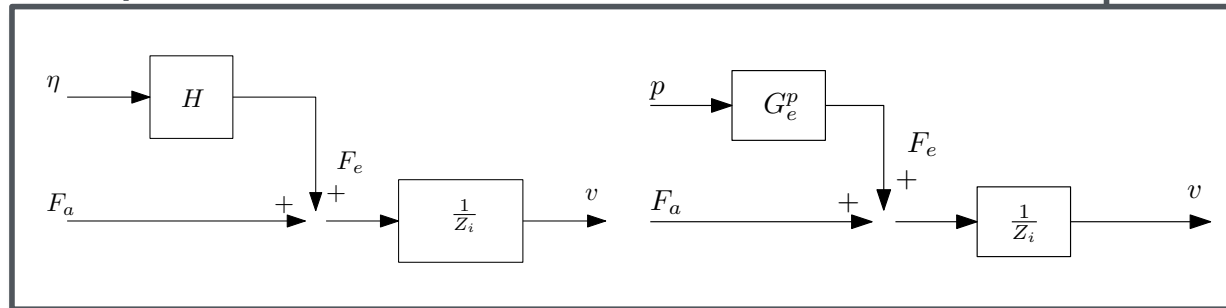
Estimation

Modeling

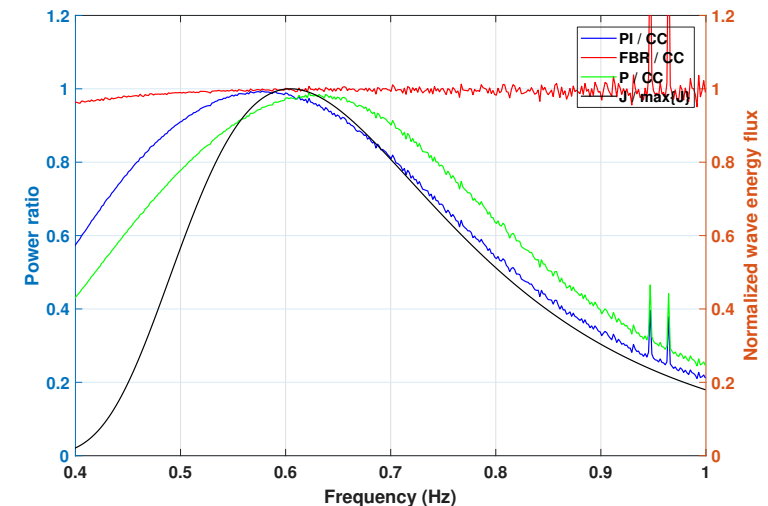
Control

# Technical Accomplishments (Cont.)

*Use pressure to estimate excitation force*

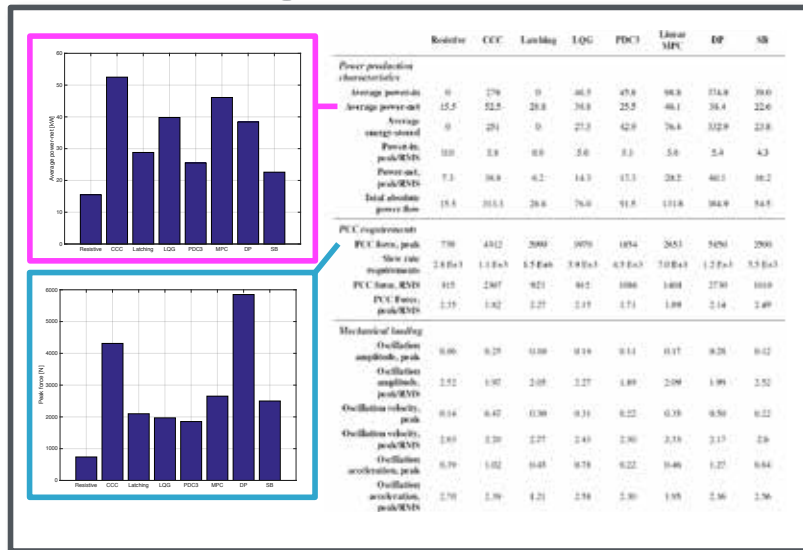


*Engineering approach shows that in real waves, need for prediction disappears*

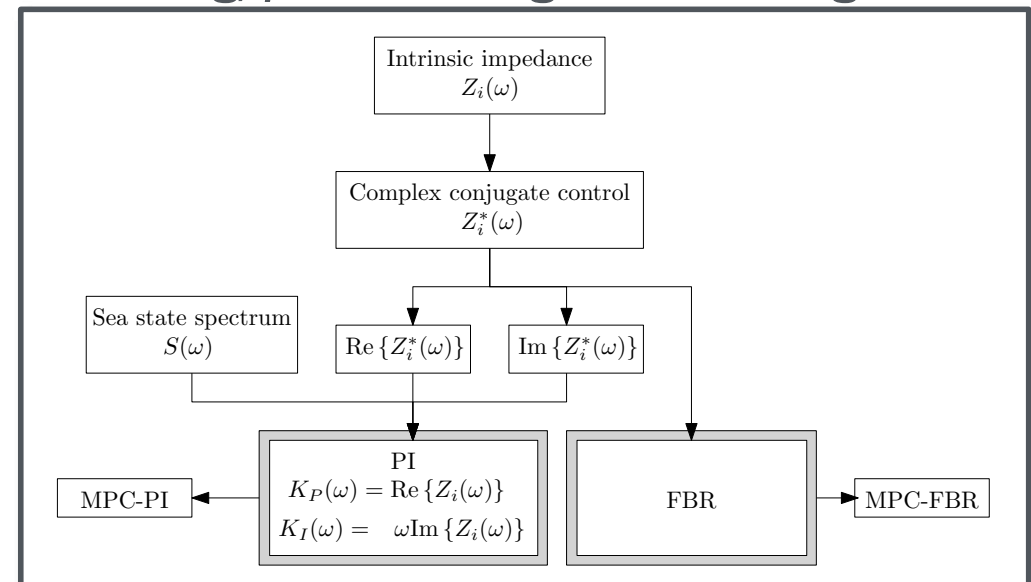


# Technical Accomplishments (Cont.)

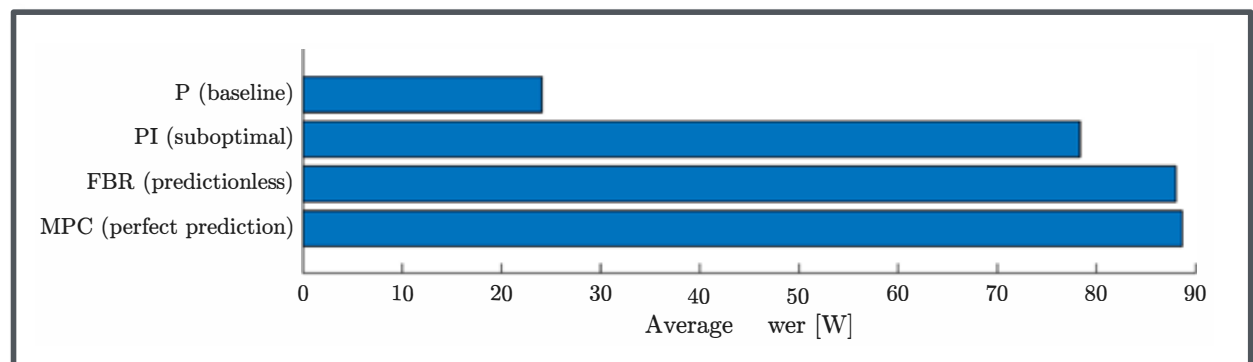
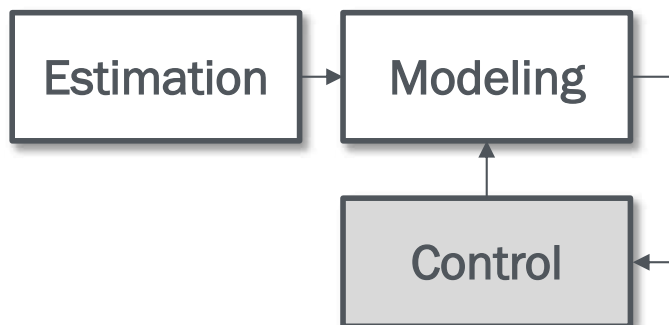
## Control design focused on LCOE



## Feedback approach based on impedance matching, provides insight for co-design

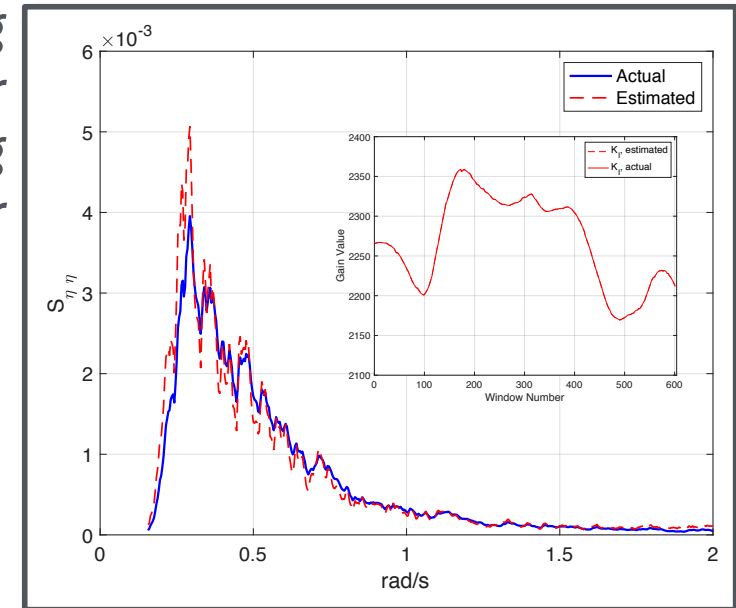


## Nearly optimal performance w/o prediction

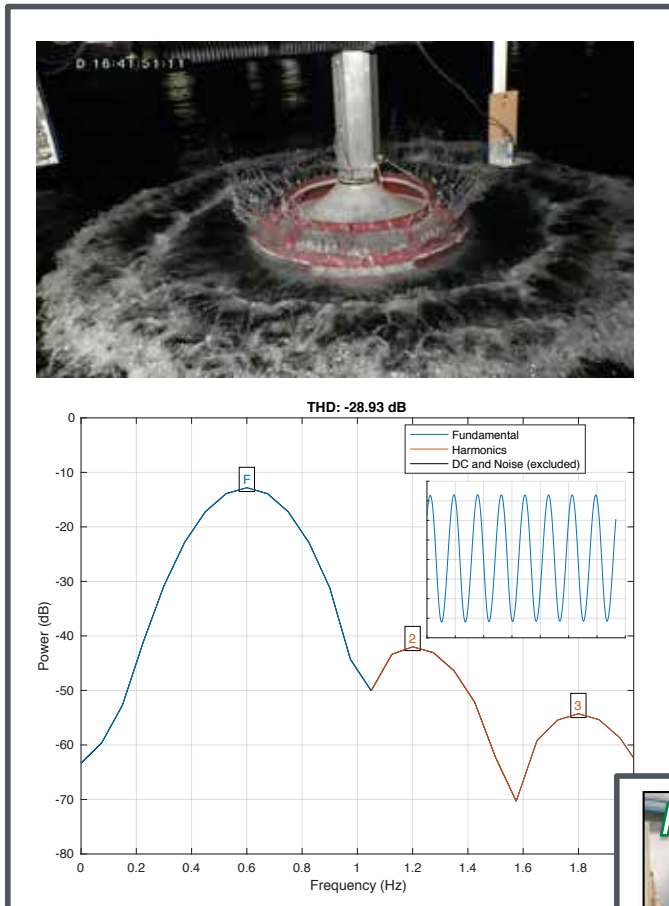


# Progress Since Project Summary Submittal

*Self-tuning  
controller for  
changing  
weather*



*Are these methods really device-agnostic?*

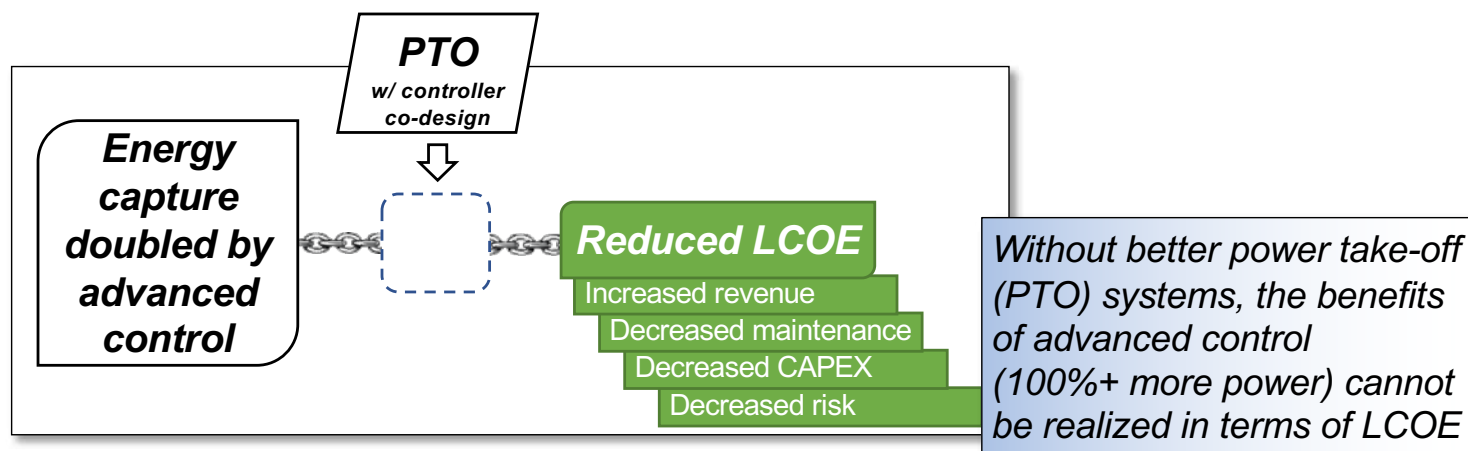


*Just how nonlinear are  
WEC hydrodynamics?*

*FOSWEC bench test*



- **Problem:** WEC PTO design is *linchpin* enabling efficiency gains and load reduction from advanced controls to be realized in terms of LCOE (absorbed power -> generated power)
- **Goal:** Develop method for co-design of WEC PTO and control systems utilizing predictionless control to deliver 100% power increase in full-scale WEC



## Predictionless WEC control

PTO

Hydro-dynamics

Control

Mooring

Sandia's novel predictionless WEC control enables synchronous co-design  
Co-design project would expand and build off predictionless control findings