EE0008951 – CalWave Design for PacWave

Marcus Lehmann, PhD

CalWave Power Technologies Inc.

marcus@calwave.energy

7/20/2022

Disclaimer: this device was not manufactured and deployed under this award.

Project Overview

Project Summary

- The objective of this project is to evolve the *xWave* detailed design to island/remote markets scale.
- Ensure device design is suitable for deploying at the PacWave South test site.
- A smaller scale xWave system was developed with DOE support under FOA- 1663 and has completed 10-months of open ocean testing in San Diego; This project scales up the xWave architecture to a size relevant for remote and island communities.

Intended Outcomes

- Complete xWave design for 2-year operation at PacWave South
- Complete anchor, mooring, and interconnection design for PacWave South
- Integration of relevant design standards (IEC, IEEE)
- Updated device metrics using validated tools and methodologies, including simulations informed by scaled tank tests and Power Take-Off (PTO) bench tests (conducted under CalWave FOA-1837 / EE0008632 efforts)
- Validation of CalWave's *Holistic Control* framework via load management and power generation profile optimization similar to wind turbines.
- Installation, operation, and maintenance (IO&M) processes and risk mitigation strategies required for a deployment at PacWave South for 2 years.
- Confirmation of manufacturing methods and third-party feasibility studies.

Project Information

Principal Investigator(s)

- Marcus Lehmann, PhD
- Thomas Boerner, PhD

Project Partners/Subs

- Sandia National Lab
- NREL
- Czero
- Glosten
- Evergreen Innovations

Project Status

Ongoing

Project Duration

- March 2020
- December 2022

Total Costed (FY19–FY21)

$341k

Project Objectives: Relevance and Approach

MARINE ENERGY PROGRAM MISSION

Conduct research, development, demonstration, and commercial activities that advances the development of reliable, cost-competitive marine energy technologies and reduces barriers to technology deployment.

FOUNDATIONAL R&D	TECHNOLOGY-SPECIFIC SYSTEM DESIGN AND VALIDATION	REDUCING BARRIERS TO TESTING
Drive early-stage R&D on components, controls, manufacturing, and materials; develop and validate numerical modeling tools; improve resource assessments and characterizations; develop quantitative metrics to evaluate devices' potential.	Validate performance and reliability of marine energy systems through prototype testing, including in-water testing, for grid-scale, power at sea, and resilient coastal community markets.	Enable access to open-water, grid-connected, and non-grid connected testing facilities; support environmental monitoring technologies, tools, and data collection to understand potential environmental risks and reduce costs.

DATA ACCESS, ANALYTICS, AND WORKFORCE DEVELOPMENT

Improve access to and use of data, tools, and science, technology, engineering, and (STEM) resources to increase awareness of marine energy technology advances and lessons learned; reduce cost, time, and uncertainty for marine energy permitting; and develop a skilled marine energy workforce.

Direct relevance to Program Goals:

Primarily focuses on Technology-Specific System Design and Validation

Project Objectives: Relevance and Approach

Relevant Standards

Follow

Consider

International Electrotechnical Commission

IEEE Advancing Technology for Humanity

ISO

DNV·GL

IEC 62600	
IEC 62600-2	Design Requirements for Marine Energy Systems
IEC 62600-10	Assessment of Mooring Systems
IEC 62600-30	Electrical Power Quality requirements
IEC 62600-40	Acoustic Characterization
IEC 62600-100	Power Performance Assessment
IEC 62600-103	Best Practices for testing of pre-prototype scale devices
IEC 62600-101	Wave Resource Assessment and Characterization
Other IEC	
IEC 60812	Analysis techniques for system reliability - Procedure for FMEA
IEC 60092-352	Choice and installation of electrical cables
IEC 60228 (2004)	Conductors of Insulated Cables
IEC 60364-5-54	Grounding/Earthing
IEC 61643-1	Lightning Protection
IEC 60204-1	Electric cables environmental resistance
IEC 61882	Hazard and operability studies (HAZOP studies) - application guide
IEEE	
IEEE 1547-2018	Interconnection and Interoperability of Distributed Energy Resources
Other Standards Referenced by IEC 62600	
ISO	
ISO 2394	General principles on reliability for structures
ISO 12473	General principles of cathodic protection in sea water
ISO 19900	Generation requirements for offshore structures
ISO19901-1	Metocean design and operating considerations
ISO19901-4	Geotechnical and foundation design considerations
ISO 19901-6	Marine Operations
ISO 31010	Risk management - Risk assessment techniques
DNVGL	
DNVGL-OS-C301	Stability and watertight integrity
DNVGL-RP-C205	Environmental conditions and environmental loads
DNVGL-OS-D101	Marine and machinery systems and equipment
DNVGL-OS-D201	Electrical installations

Manufacturing Lessons Learned (partially from previous projects)

1. Importance and methods for pressure testing
2. Alignment of steel hull structural welding standards (vessels/offshore structures)
3. Criticality of pre-deployment testing

042.3 Reference Standards

1. *Guide for Steel Hull Welding*, AWS, ANSI/AWS D3.5-93R, 1992.
2. *Structural Welding Code – Steel*, AWS, AWS D1.1/D1.1M:2015, 2015.
3. *Fabrication and testing of offshore structures*, DNV GL, DNVGL-OS-C401, 2018.
4. *Non-destructive testing*, DNV GL, DNVGL-CG-0051, 2015.
5. *Paints and varnishes -- Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 3: Assessment of degree of rusting*, ISO, ISO 4628-3:2016.

Project Objectives: Relevance and Approach

PacWave

IEC

Sandia National Laboratories

WecOptTool
Controls Development

NREL

CFD modeling <-> Controls
Orcaflex modeling

**image from FOA 1663 deployment*

Approach:

1. Design optimization specifically for PacWave & target island commercial sites
2. IEC alignment supporting path towards certification
3. Detailed design/selection of anchoring system
4. Evolve numerical models and tools related to fluid-absorber-PTO interaction, utilizing resource assessments specific to PacWave & target islands; including extreme events
5. Catalog of metrics and improvements leading to long-term cost reductions

Disclaimer: this device was not manufactured and deployed under this award.

Video

Disclaimer: this device was not manufactured and deployed under this award.

Project Objectives: Relevance and Approach

PacWave

IEC

Sandia National Laboratories

NREL

WecOptTool
Controls Development

CFD modeling <-> Controls
Orcaflex modeling

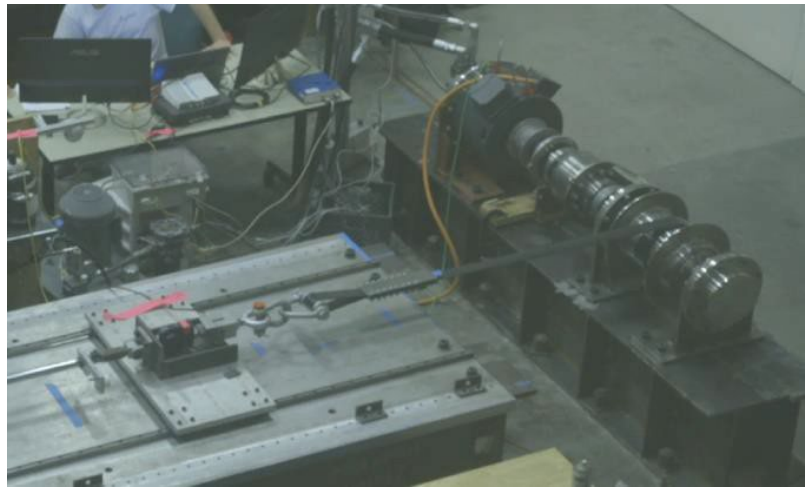
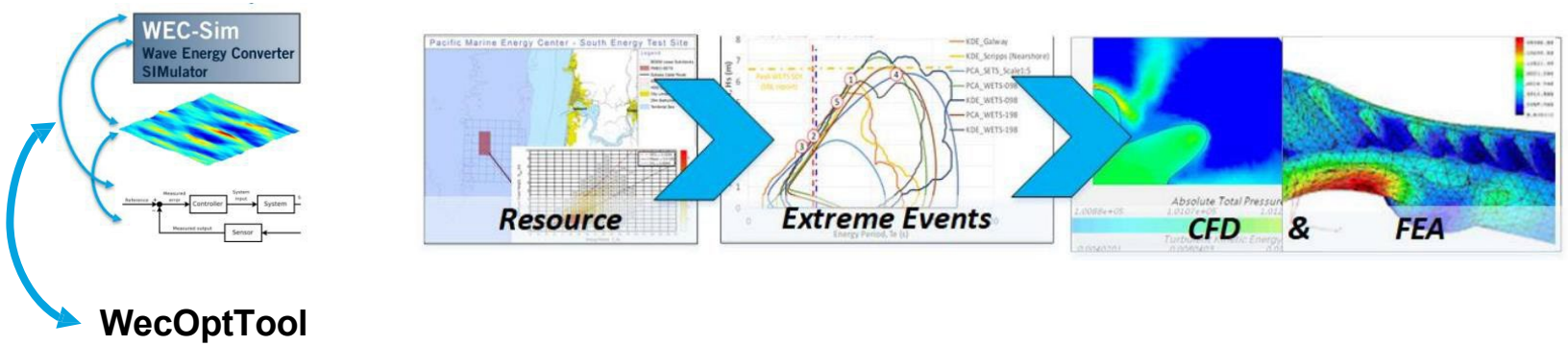


**image from FOA 1663 deployment*



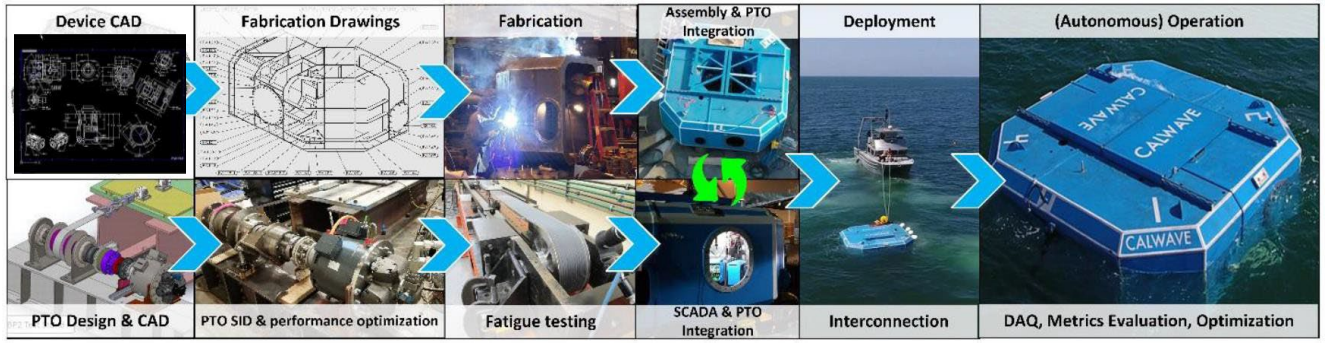
Approach:

1. Design optimization specifically for PacWave & target island commercial sites
2. IEC alignment supporting path towards certification
3. Detailed design/selection of anchoring system
4. Evolve numerical models and tools related to fluid-absorber-PTO interaction, utilizing resource assessments specific to PacWave & target islands; including extreme events
5. Catalog of metrics and improvements leading to long-term cost reductions

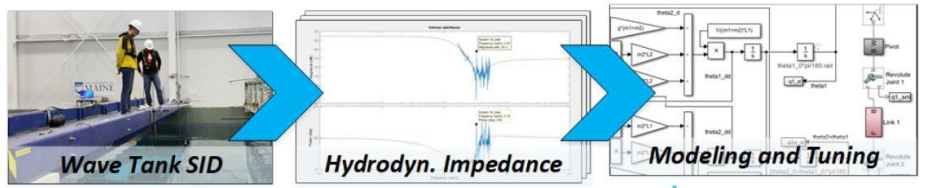
Disclaimer: this device was not manufactured and deployed under this award.

Project Objectives: Relevance and Approach

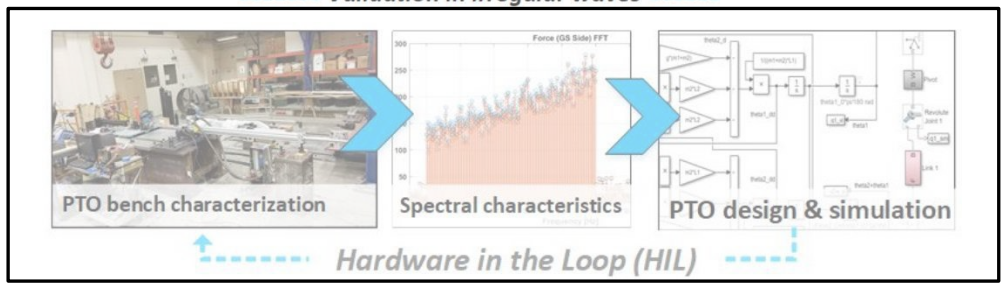
Open water demonstration results and lessons learned



Iteration on updated absorber geometry and controller



Scaled up PTO & test bench to PacWave Scale under FOA-1837

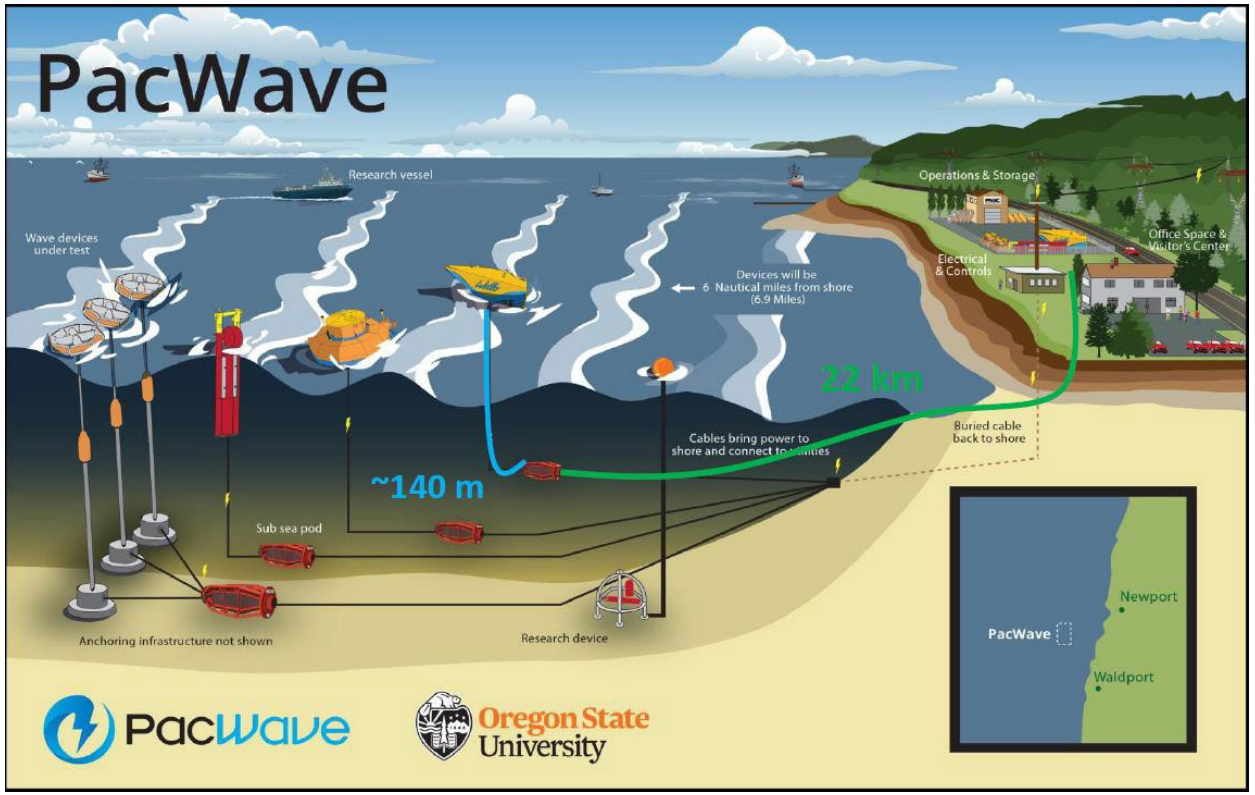


Approach:

1. IOM&D planning for PacWave; Risk evaluation & mitigation;
2. Certification planning and third-party verification of design to appropriate IEC Standards
3. Engagement with commercial & insurance industry to understand requirements for fully insurable and project financeable commercial deployments

Project Objectives: Relevance and Approach

- First cohort deployment at PacWave
- Anchoring and mooring design
- Interconnection example
- Shore side interconnection buildout
- Permitting path

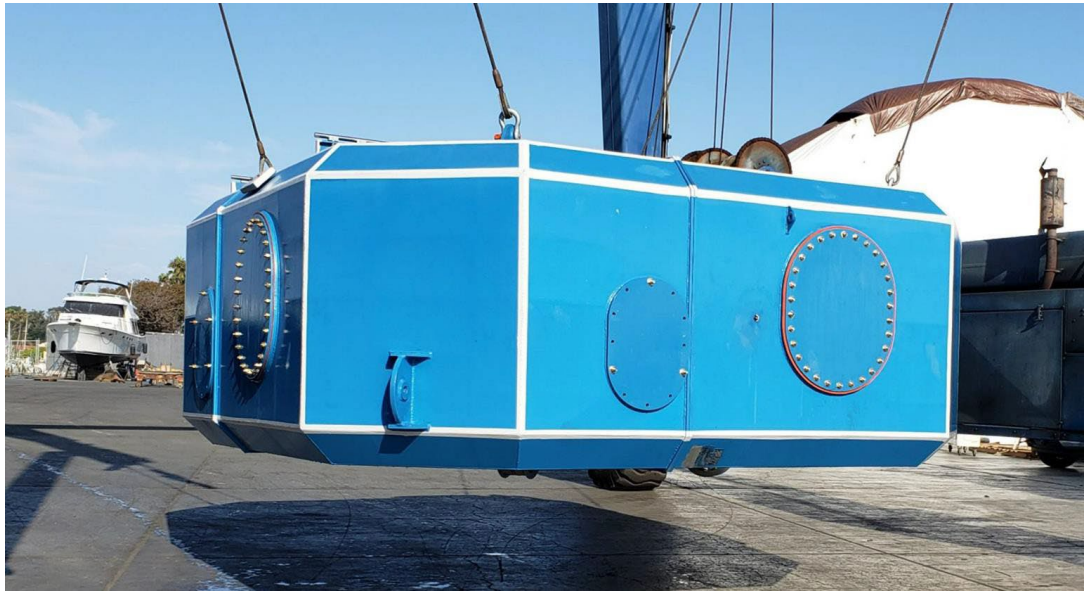


Approach:

1. Develop Installation, Operations, Maintenance & Decommissioning (IOM&D) Plan including specifying vessels, partners and logistical resources local to PacWave test area
2. Grid integration planning
3. Geotechnical analysis to support anchor selection/design
4. Commercial plan

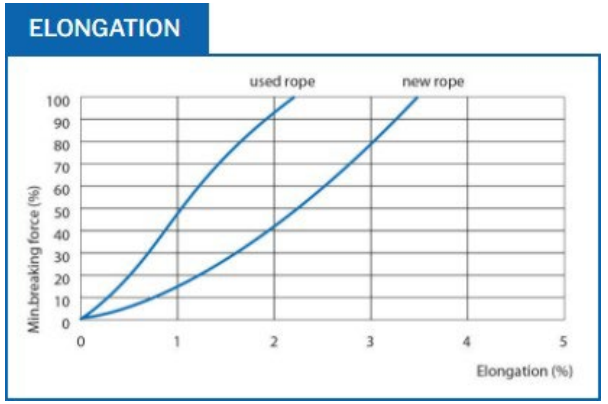
Project Objectives: Expected Outputs and Intended Outcomes

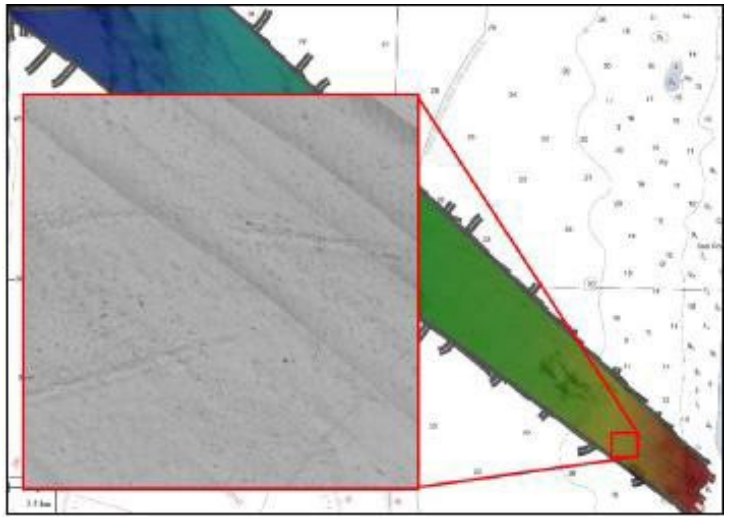
Outputs: xWave Design Basis



- Updated & Optimized Absorber size, geometry, structure
- Robust and proven standard controller
- Robust and proven advanced controller
- Additional advanced controller

Outputs: Anchoring & mooring system for PacWave South





- Updated & Optimized anchoring and mooring layout
- Proper mooring type and size

Disclaimer: this device was not manufactured and deployed under this award.

Project Objectives: Expected Outputs and Intended Outcomes

Outcomes:

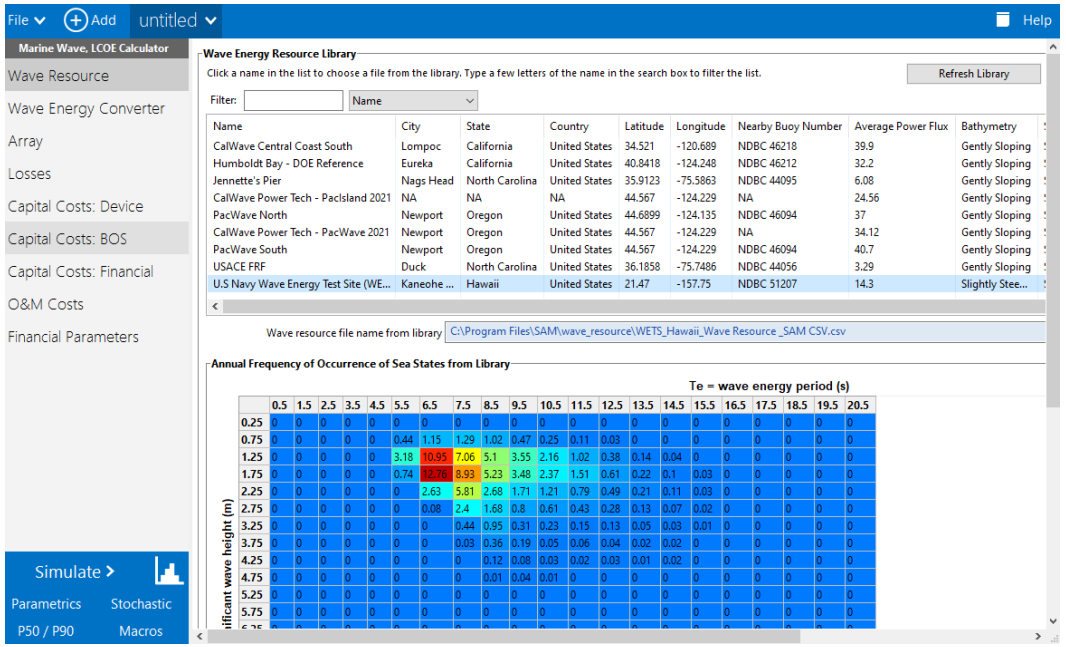
- Detailed risk evaluation and mitigation early on
- Installation considering interconnection, mooring, device
- Operational planning including design load cases (IEC)
- Decommissioning and site remediation fundamental plan

Outputs: Detailed Risk Register; IOM&D plan

Outcomes:

- DOE SAM evaluation
- DOE & OES subsystem metrics

Outputs: Updated metrics (macro level and detailed system level)



Project Timeline

FY 2020

- Derivation of Requirements
- Incorporation of standards
- Preliminary hull design & PTO Integration
- Preliminary electrical/SCADA/ *Holistic Control* design

FY 2021

- IO&M Plan
- Preliminary mooring & anchor design
- Commercialization plan
- Preliminary design report & review meeting

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$1,800K	$450K	$2,250K

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$0K	$31K	$310K	$341K

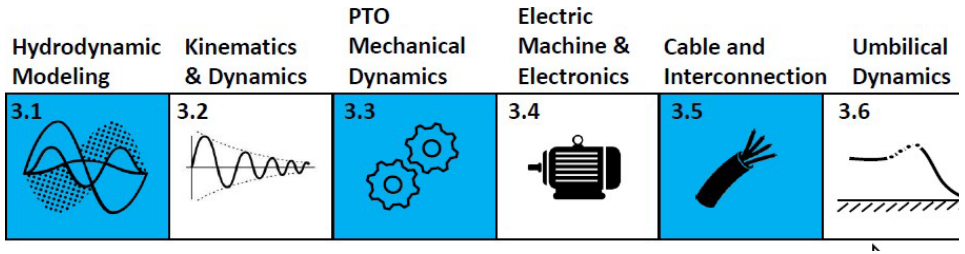
- Expenditures less than expected in FY21 due to delays in engaging external contractors due to pending internal design decisions.
- It is anticipated that these costs will catch up as external contractors are more actively engaged

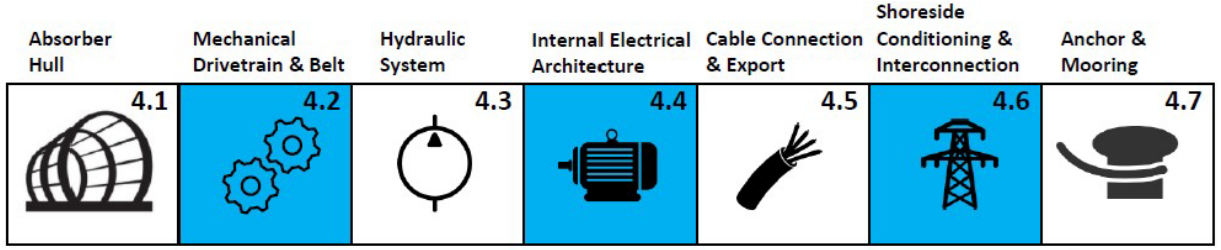
End-User Engagement and Dissemination

- Preliminary and Detailed design reports on MHK-DR
- Commercialization planning as designated task of the award
  - Conversations with end users: Islands, Off-Grid Markets, Navy, other remote locations
  - Conversions with community members
- Engagement with PacWave team
  - Resource assessment
  - Geotechnical data & Analysis
  - Grid integration planning
- MIT Clean Energy Prize Success Stories – Alumni Spotlight
- Highlighted in “Accelerating Energy Innovations for the Blue Economy“ by the Word Ocean Initiative
- Attended 9-hour course on Diversity, Equity, and Inclusion strategies for small companies

Performance: Accomplishments and Progress

- Completed Preliminary Design & Report in 2021





- Completed Preliminary Commercialization Plan
- Successful completion of Preliminary Design Review
- Advancement of Detailed Design with further knowledge about PacWave site specifications

Participation in the following:

- Greentown Labs: ClimateTech Action Summit
- Rice Technology Venture Forum
- EnVest.Earth Presentation
- Solar Impulse Label Awarded

Future Work

- Final hull design & manufacturing plan
  - Hull design approached from manufacturing standpoint / design for manufacturing
  - Coupled with supplier selection and tow plan
- Electrical system alignment with relevant standards / Validation of design according to standards
- Final mooring & anchor detailed design
- Final SCADA design & holistic control integration
- Final design report including estimates for project metrics
- Final design report & design review meeting
- Final commercialization plan

- Target Date of Final Design Review: September 2022

☐ Building the fundamental basis for testing of the xWave at PacWave under FOA-2415 starting 2024

Q&A