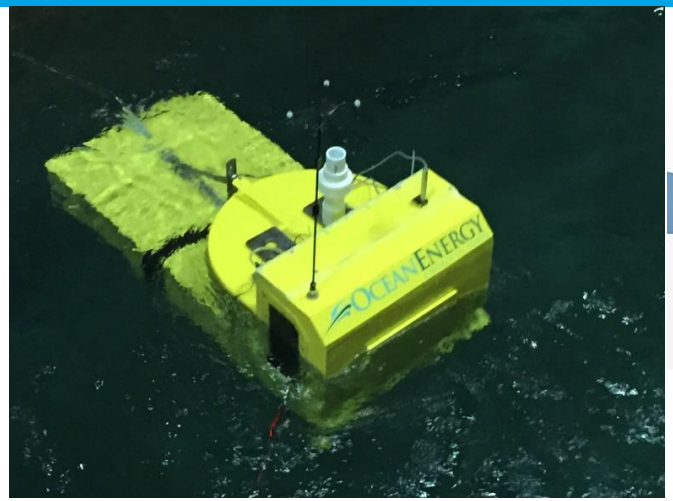

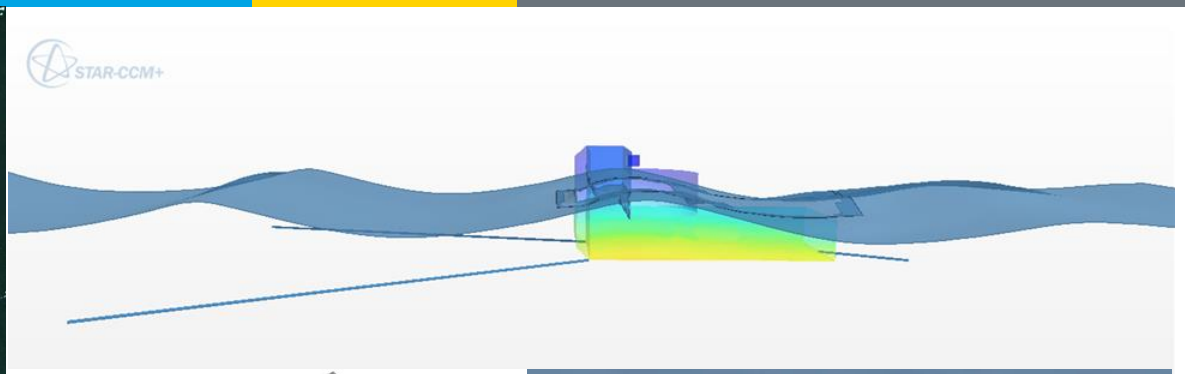

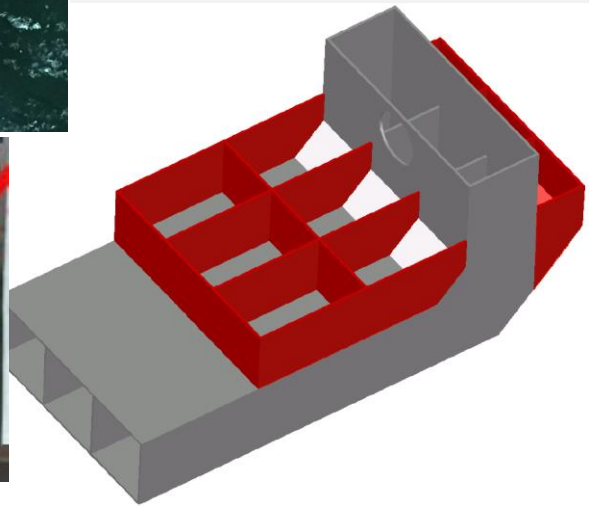

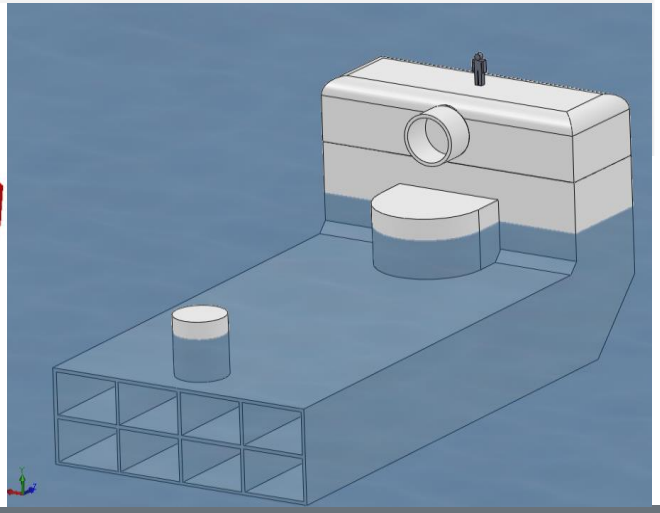

Optimization of Hull Shape and Structural Design for OE Buoy

Mirko Previsic - PI

Re Vision Consulting

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Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Scope:

- Parametric Performance Optimization of Hull Shape
- Assessment of Extreme Structural Loads
- Structural Design of Ocean Energy USA (OE) Buoy to minimize cost

The Challenge:

- Structural cost of OE Buoy is a key driver of levelized cost of energy (LCOE)
- Unclear what the techno-economic optimal dimensions and material choice

Partners:

- **Re Vision Consulting:** PI, Numerical Modeling, Techno-Economic Optimization
- **Ocean Energy USA:** Technical Inputs to Design Process
- **COWI Group:** Structural Design
- **National Renewable Energy Laboratory (NREL):** computational fluid dynamics (CFD) Modeling Support

Program Strategic Priorities

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- **Conduct R&D for innovative MHK components**
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- Support research focused on retiring or mitigating environmental risks and reducing costs
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- Exchange of data information and expertise

Project Strategic Alignment

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- **Conduct R&D for innovative MHK components**
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

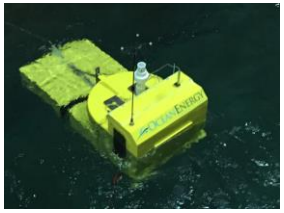
The Impact

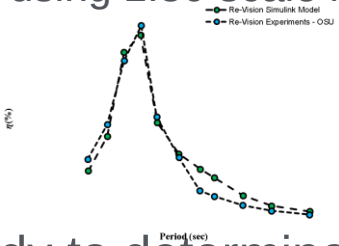
- Target Metric: SPAI Target Metric - Improve power-to-weight Ratio (PWR) by > 50%, resulting in a reduced LCOE
- Result: Improved PWR by > 60%
- Reduced projected LCOE by > 50% at commercial scale
- Evaluated material trade-offs: steel, concrete, fibre-reinforced plastic (FRP)
- Identified clear pathways for cost-reductions on commercial-scale wave energy converter (WEC) devices
- Final Product: A fully optimized FRP design
- Developed modular manufacturing approaches directly applicable to other device types

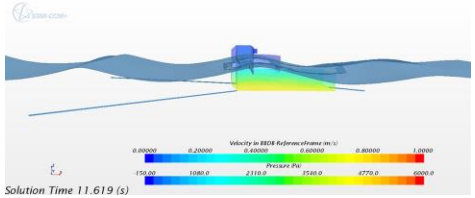
Technical Approach

Computational Model Setup and Validation

- Parametrically driven performance model in time-domain using RE-WEC code
- CFD model in Star CCM+ to identify viscous drag and extreme loads
- Extreme load model using Leidos code
- Model validation using 1:30 scale model tested at Oregon State University

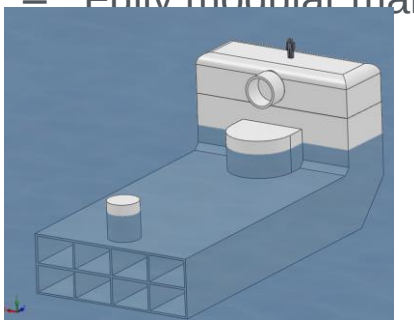


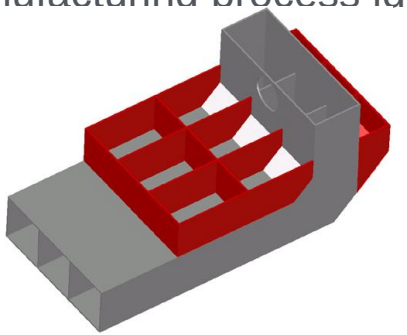


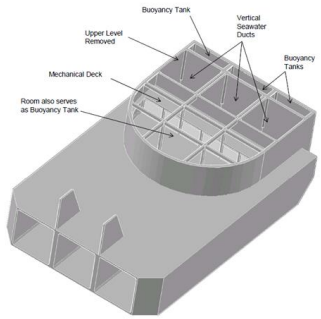


Material trade-off study to determine lowest-cost option

- Concrete, Steel, Concrete/Steel Sandwich, FRP, FRP Sandwich
- Lowest-cost option identified as the FRP Sandwich option
- Fully modular manufacturing process identified







Technical Approach

Establish Parametric Structural design and cost model

- Allowing for parametric variations of key dimensions
- Cost-models validated using manufacturing inputs

Parametric Optimization study using validated tools

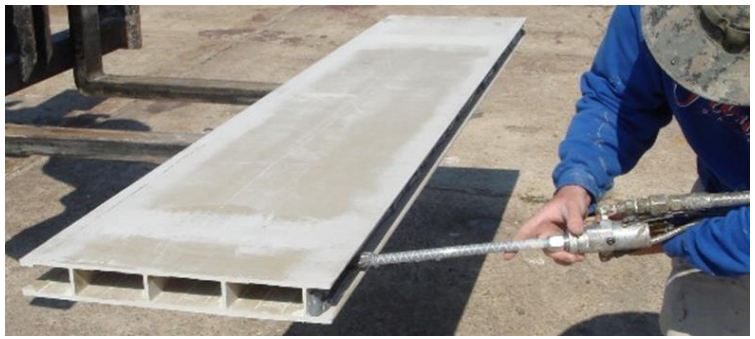
– Over 100 configurations evaluated, leading to techno-economic optimal size

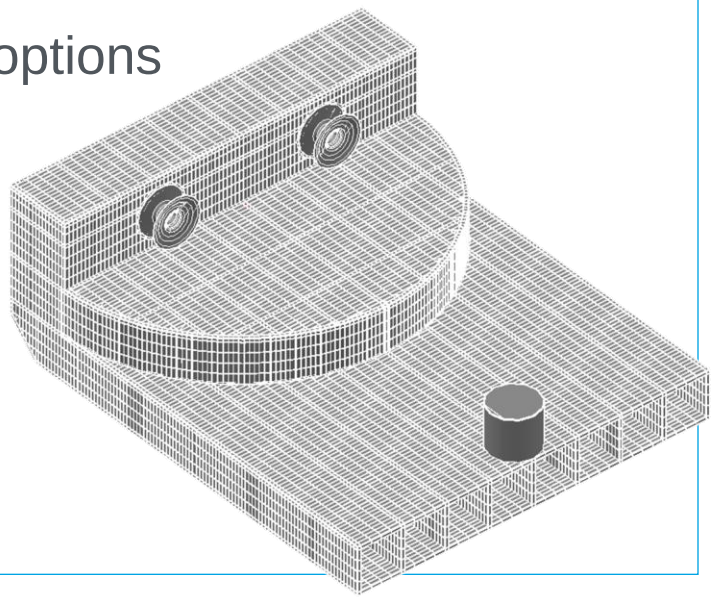
Final design of optimally sized device structure

– Refined design of sandwich-panels and joints
– Final costing of overall device construction

Assessment of novel launch and recovery options

– Identified as critical cost driver





Accomplishments and Progress

- **Funding Opportunity Announcement goals exceeded!**
- Lowered LCOE from OE buoy by > 50% at commercial scale over baseline
- Designed novel modular FRP construction process that scales well from single unit to hundreds of units
- Fully evaluated design options and identified lowest-cost alternative
- Validated performance and extreme load models using wave tank testing campaign
- Identified and validated novel device launch and recovery process

Project Plan & Schedule

- Original contract period: 6-1-14 through 6-1-16
- No-cost extension: 9-30-16
- Additional scope (beyond deliverables under contract)
  - Tank testing of novel launch/recovery process
  - Additional work on FRP manufacturability with FRP companies
- Passed Go/No-Go decision point in FY15

Project Budget

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$96k	$24k	$403k	$101k	$207k	$52k

- The initial project plan was modified to incorporate required changes as the project evolved. These changes related primarily to sub-contractor budgets. The overall budget was unaffected.
- To completion of FY16, over 70% of the budget was invoiced; remaining funds will be invoiced in the coming months

Research Integration & Collaboration

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Partners, Subcontractors, and Collaborators:

Re Vision Consulting: PI, Numerical Modeling, Techno-Economic Optimization

Ocean Energy USA: Technical Inputs to Design Process

COWI Group: Structural Design

NREL: CFD Modeling Support

Communications and Technology Transfer:

- Results will be presented at up-coming conference upon completion of project
- Many generic design-process related items will be transferrable to the wider WEC industry
- Final publicly available project report

Next Steps and Future Research

FY17/Current research: Project Complete.

Proposed future research: Project Complete.