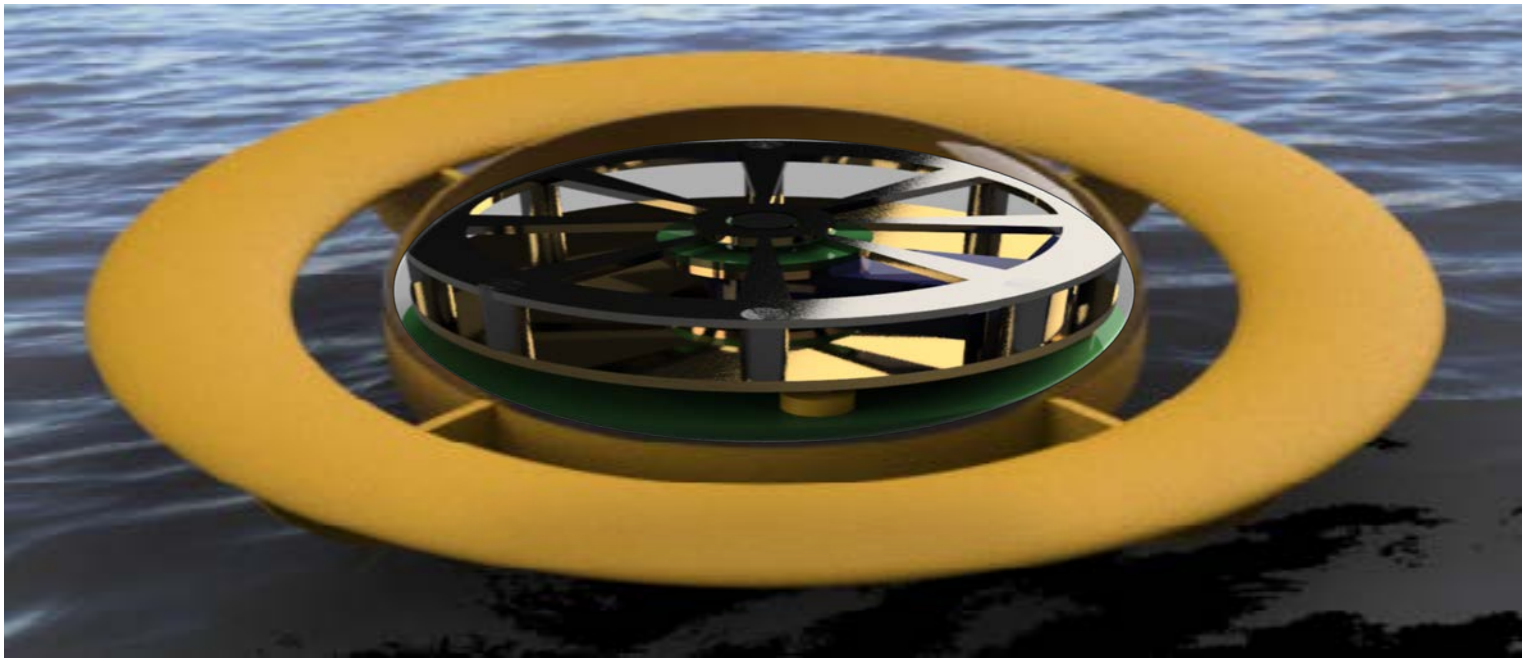
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Water Power Technologies Office 2019 Peer Review

Marine and Hydrokinetics Presentation Template



Robotic Juggler Offshore WEC

EE0008388

Marine and Hydrokinetics Program

10-10-19

Vassos Vamvas

Enorasy LLC

Project Overview

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

Project Summary

The Robotic Juggler (RJ) device is an offshore floating WEC, which utilizes a rotating eccentric mass. This mass rotates about a vertical shaft and provides rotation to a permanent magnet generator. RJ's PTO is entirely enclosed within the WEC's hull. Rolling motion of the PTO occurs within the hull.

Project Objective & Impact

BP1 objective: numerically model the RJ WEC and validate the ACE metric.

BP2 objective: develop, tank test and validate the ACE performance of a 1:20 scale prototype, with active control.

This work is needed to "open the door" to a next project, RJ4 (4 eccentrics), aiming to quadruple the power output utilizing the same hull!

Project Information

Project Principal Investigator

- Vassos Vamvas

WPTO Lead

- Carrie Noonan

Project Partners/Subs

- University of Massachusetts
- National Renewable Energy Laboratory
- Stony Brook University

Project Duration

- Project Start Date: 10/1/2018
- Project End Date: 6/30/2021

Alignment with the Program

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

Alignment with the MHK Program

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

- The project will use the *ACE metric* as an indicator of the power produced in a series of tests and simulations in a variety of wave environments.
- RJ's PTO is entirely enclosed and allows the use of conventional materials and off-the-shelf components, thus lowering CAPEX and maintenance costs, while maximizing the WEC's life-cycle perspectives.
- The project will enable: (i) blue economy applications (ii) defense underwater operations and (iii) the collocation of offshore wind farms with WECs.

Alignment with the MHK Program

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

- The project includes the design and construction of a 1:20 scale RJ prototype, and the evaluation of the prototype's performance and reliability in wave tank tests.
- The RJ system uses conventional components and materials, thus lowering CAPEX and maintenance costs.

Project Budget

Total actual costs < Project budget

Budget is conserved, as the complication of the 6 DOF num. modelling task may require additional resources.

Total Project Budget – Award Information		
DOE	Cost-share	Total
[$808,434]	[$203,464]	[$1,011,898]

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Actual Costs FY17–FY19 Q1 & Q2 (October 2016 – March 2019)
Costed	Costed	Costed	Total
[$0]	[$0]	[$93,052]	[$93,052]

Management and Technical Approach

Management Approach

Enorasy LLC is a young startup and uses complementary expertise from:

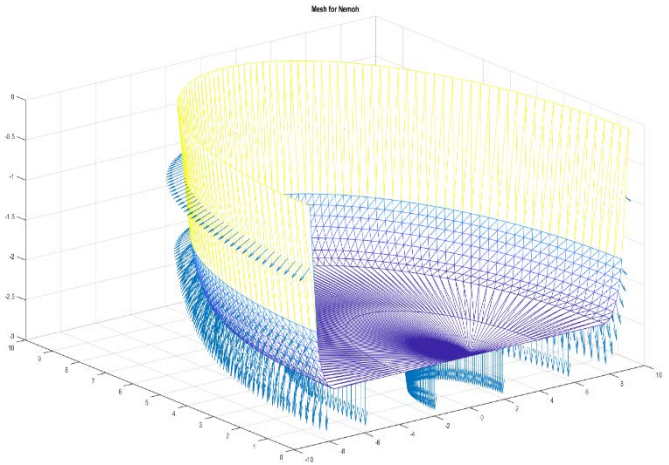
- Key strategic partners, including UMASS and NREL.*
- MIT talent, which is in proximity, i.e. for assistance in RJ's structural analysis study.
- Subcontractors with state-of-the-art skills on motion analysis, numerical modeling, simulation and control systems.

*NREL, is the co-developer of the WEC-Sim software, which is used for RJ's numerical modelling.

Management and Technical Approach

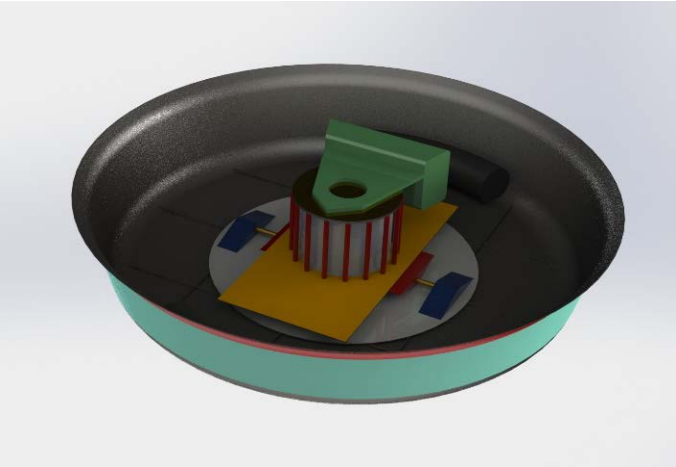
Technical Approach

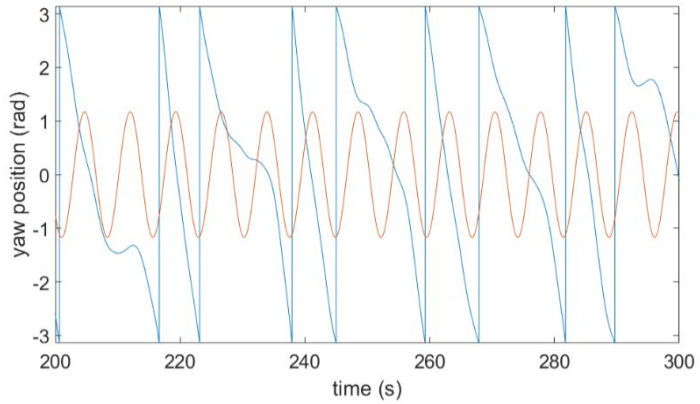
- Numerical modelling and simulation with feedback from pre-existing small scale prototype tank tests.
- Construction of a representative 1:20 scale prototype to demonstrate RJ features, power output and robustness.
- Key project milestones:
  - RJ materials and generator selection: completed
  - RJ's 3D CAD design: completed
  - RJ's hydrodynamic analysis: completed
  - Num. modelling: under development
  - Active control: under development
  - ACE calculations: under development
  - BP1 report expected: June 2020

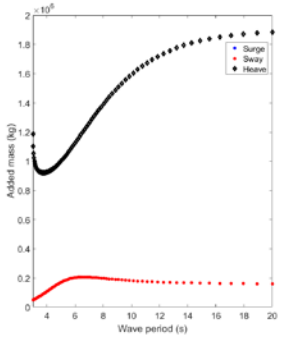


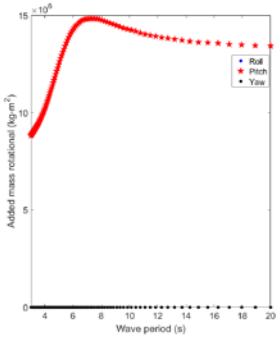
Management and Technical Approach

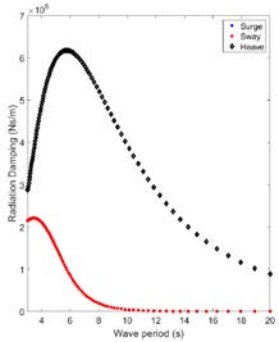
- RJ's wave power capture is maximized when the rotating mass completes a 360º rotation per wave period.

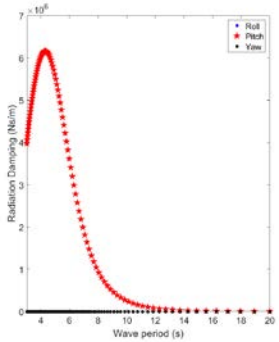






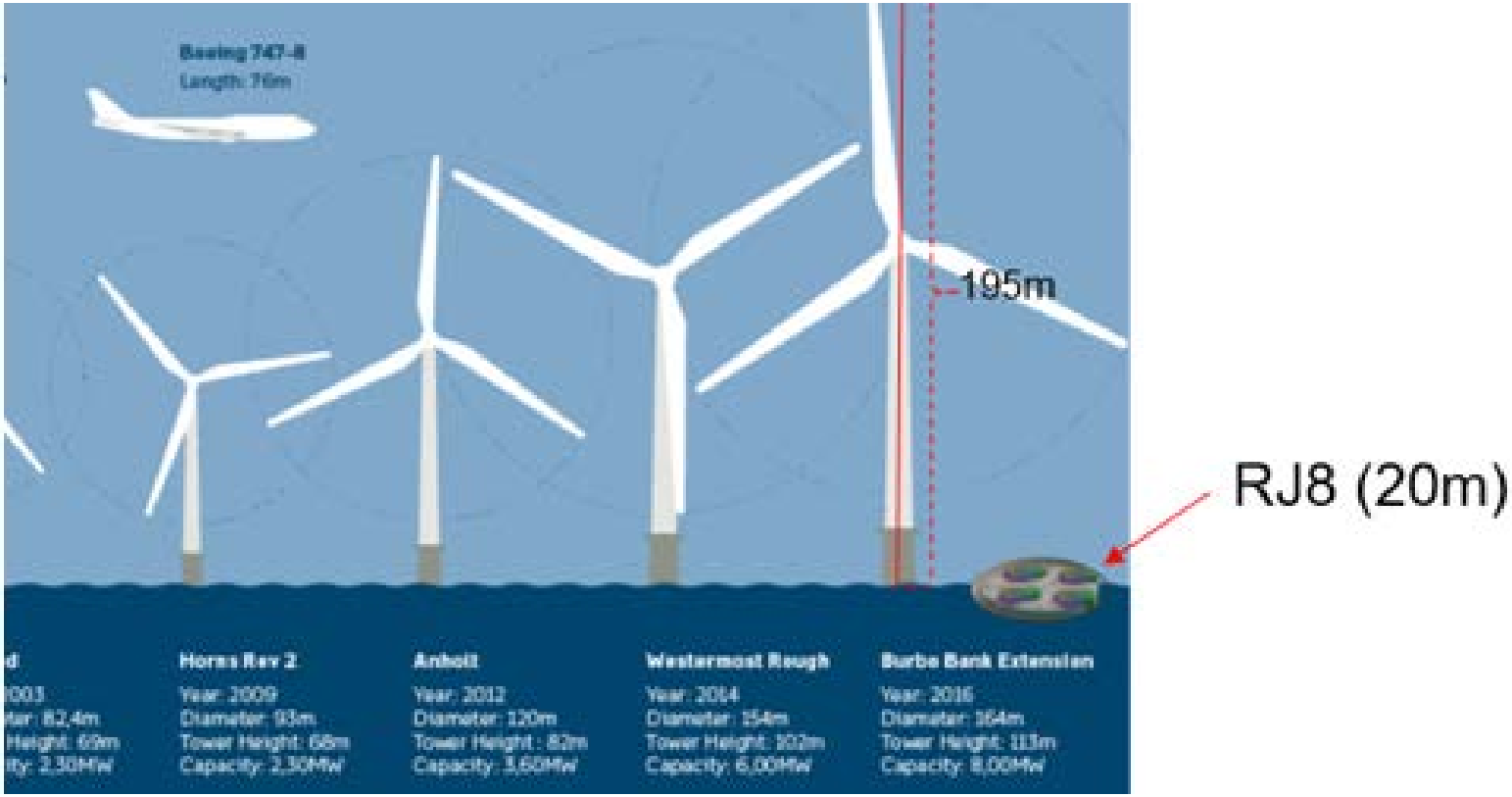






Management and Technical Approach

- **Critical success factors for commercial viability:**
  - substantial electrical power production
  - survivability in harsh wave climates



End-User Engagement and Dissemination Strategy

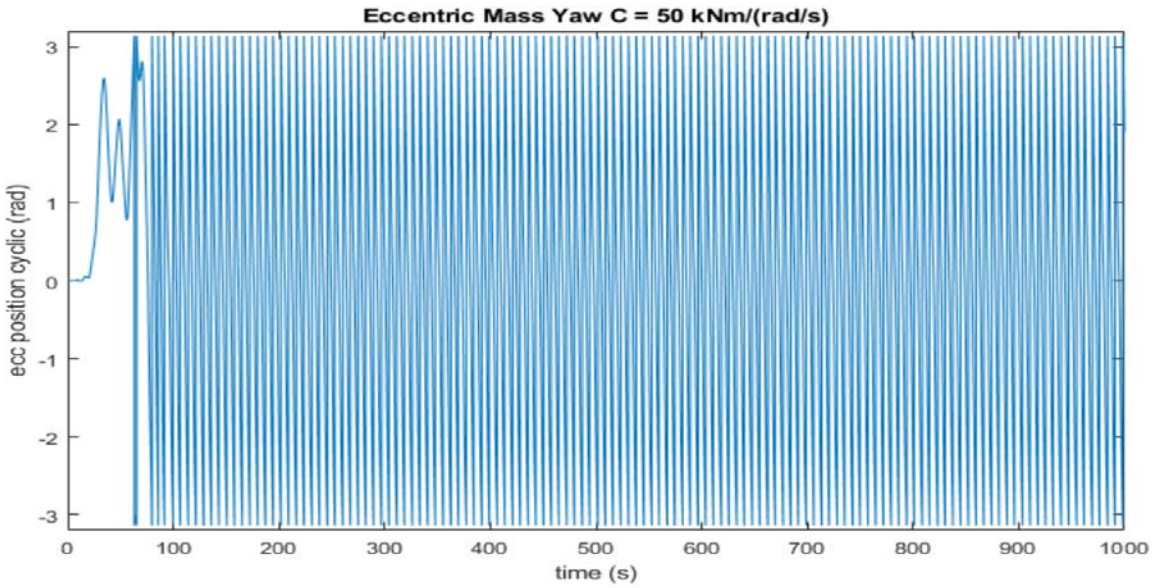
- RJ is a scalable WEC. A variety of blue economy stakeholders and end-users of aquaculture, desalination, UUV recharging and eventually the electrical grid will benefit from RJ's renewable electrical power output.
- A report on RJ's hydrodynamic analysis was presented in Water Power Week 2019.
- A DARPA presentation was delivered at DARPA's headquarters in May 2019.
- Defense industry stakeholders are interested in the magnitude of the electrical power that can be produced from the project's wave tank tests in BP2.
- Stakeholders will be informed on R&D improvements through presentations, posters and prototype demos aiming at a strategic partnership and commercialization.

Technical Accomplishments

- RJ's 3D CAD completed, (1st qtr., as planned). It provided the basis for the hydrodynamic analysis.
- RJ's hydrodynamic analysis and validation completed (2nd qtr., as-planned). It provided the systems' hydrodynamic "id" to be used in the development of the numerical model.
- Currently we are improving RJ's numerical model and developing a control system.

Progress Since Project Summary Submittal

- Improved RJ num. model without active control matches the wave period.



Future Work

- The project's challenge is to improve RJ's numerical model to reflect, at least, the preliminary results achieved by RJ's 1:58 physical prototype.
- BP1's future work will be dedicated to the improvement of the num. model, and validation of the ACE metric.
- BP2 will build a 1:20 representative prototype and calculate an ACE.