Advanced Laboratory and Field Arrays (ALFA)

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Project Overview

Advanced Laboratory and Field Arrays (ALFA): Accelerating the development of next-generation arrays of wave and current energy converters (WECs and CECs) by reducing the levelized cost of energy (LCOE) through a suite of field-focused research and development activities.

The Challenge: Array LCOE is driven by multiple technical, economic, and environmental factors. Expertise across a spectrum from extreme resource characterization to array optimization to environmental monitoring is difficult to assemble outside of multi-university consortiums.

Partners: Oregon State University (OSU), University of Washington (UW), University of Alaska Fairbanks (UAF)

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 systems & 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

Technology Maturity

- Test and demonstrate prototypes
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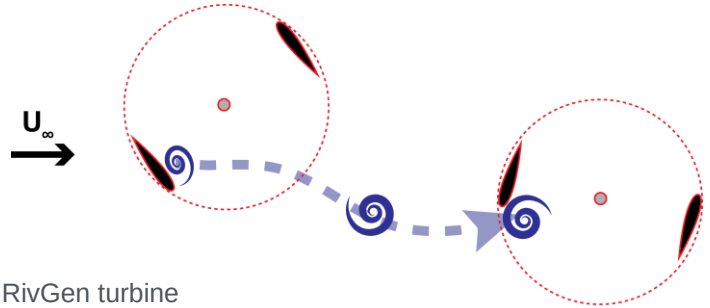
The Impact

- The ALFA project provides a suite of innovative tools and knowledge about aspects of array design and operations.
- Industry can leverage these tools and knowledge for their own novel approaches to reduce LCOE and increase private investment.
- *Tools*: Autonomous debris detection, low-cost remotely operated underwater vehicle (ROV) for operations and maintenance (O&M), anchoring and mooring system models, coordinated control of WECs and CECs

Ocean Renewable Power Company RivGen turbine



Program Strategic Priorities

Deployment Barriers

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The Impact

- Provide recommendations for standardized biological monitoring plans that streamline monitoring requirements and permitting processes

Northwest National Marine Renewable Energy CenterSea Spider equipped with autonomous fisheries echosounder

Program Strategic Priorities

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Crosscutting Approaches

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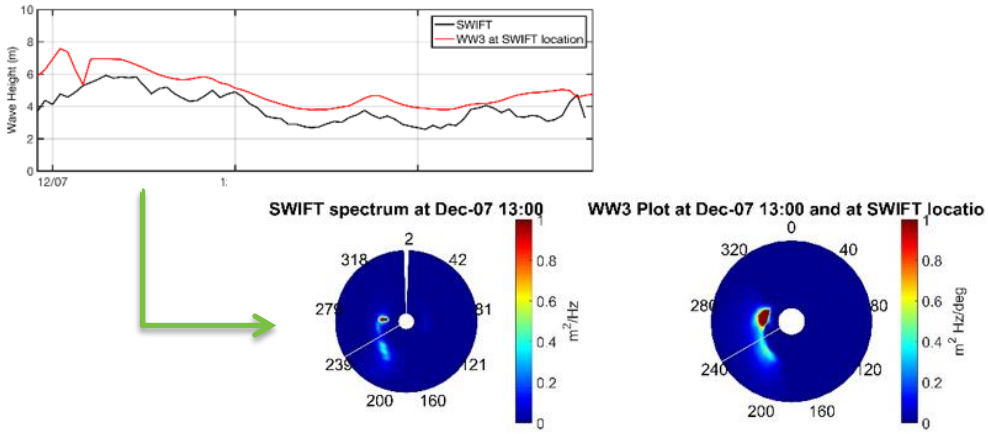
The Impact

- Improve understanding and prediction of wave extreme conditions in resource characterization to inform design for survivability through first-of-a-kind in-situ measurements and comparison to models during extreme wave events



Comparison between in-situ measurements and WaveWatch III during event with H_S = 8 m

Debris Modeling, Detection, and Mitigation (Task 1)

Objective: Develop tools to assess and mitigate damage to WEC/CEC from debris

- Collect in-situ data using active acoustics
- Develop "Hydrokinetic Debris Impact Simulator" (discrete element model) coupled to computational fluid dynamics (OpenFOAM)

- *Demonstrated active sonar to detect debris in water column*
- *Hydrokinetic Debris Impact Simulator able to simulate debris impact*

Representative debris accumulation on a river current turbine in Alaska

Autonomous Monitoring and Intervention (Task 2)

Objective: Develop control software to transform an inexpensive commercial off-the-shelf underwater vehicle into autonomous O&M platform.

- Low-cost (~$150k) semi-autonomous underwater vehicle with: INS, DVL, Sonar, Visual cameras
- Develop and demonstrate control algorithm for automatic station-keeping (< 1 m error in sea state 3)

Demonstrated Autonomous Underwater Vehicle station keeping exceeds proposed technical targets

Base platform: Seabotix vLBV300

Field deployment of prototype at PMEC-SETS

Characterization of Extreme Wave Conditions (Task 3)

Objective: Improve representation of extreme conditions in wave resource characterization

- Current method for extreme wave characterization is a purely statistical representation of buoy data
- Develop and implement a new method using three inter-related approaches:
  - In-situ wave buoy measurements targeting extreme events
  - Spectral wave forecasts
  - Wave metrics

Discovery of coastal jet affecting extreme wave prediction accuracy

Helicopter-deployed SWIFT

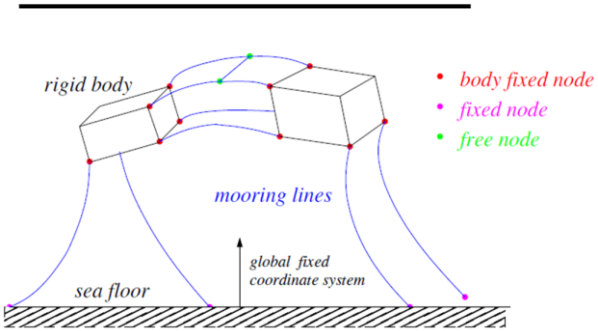
SWIFT measuring extreme waves

Improved Models for Design of Offshore Anchoring and Mooring Systems (Task 4)

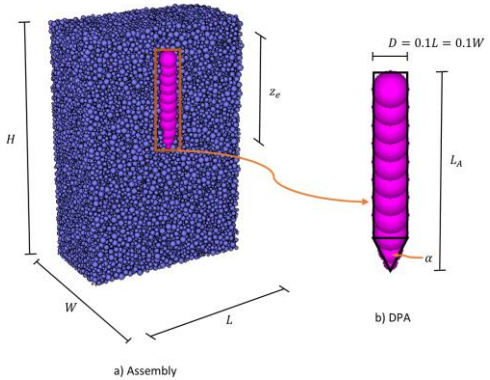
Objective: Develop improved approach to analyzing anchoring and mooring systems performance for cost-effective marine energy converter (MEC) deployments

- Simulation couples anchoring and mooring models with capacity for active and passive control of MECs

New capability to predict anchor holding power under cyclic loading



Schematic of mooring simulation framework



Discrete element model of torpedo anchor penetration

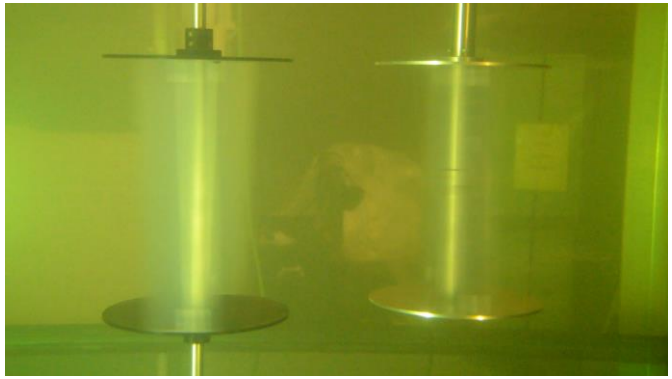
Technical Approach and Outcomes

Performance Enhancement for Marine Energy Converter Arrays (Task 5)

Objective: Develop MEC array control schemes that improve performance over baseline, non-coordinated control approaches

- *WEC*: Develop coordinated array control with optimal array layouts that takes into account interplay between WEC placement within an array and array control with real-time estimation
- *CEC*: Increase turbine density through coordinated control

Oscillating water column WEC



Cross-flow turbine array

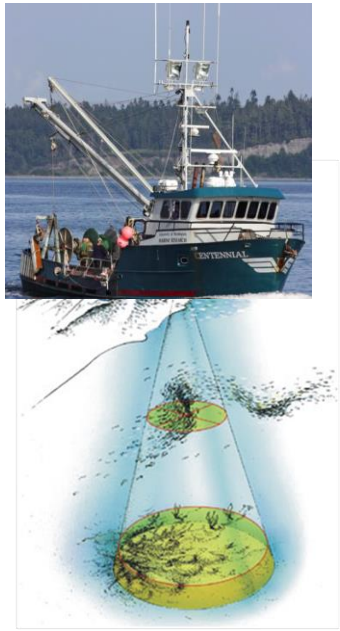
15% performance increase for coordinated control of closely spaced turbines

Evaluating Sampling Techniques for Hydrokinetic Biological Monitoring (Task 6)

Objective: To advance novel, cost-effective, environmental monitoring techniques

- No current standard requirements for biological monitoring in MHK licenses
- Survey fish species to evaluate current monitoring techniques and potential changes
- Compare distribution variability of pelagic organisms at test sites

Passive acoustic array survey results eliminated requests for post-installation green sturgeon monitoring



Active acoustic survey

Passive acoustic receivers

Project Plan & Schedule

- January 1, 2015 – December 31, 2017 (now Jan. 31, 2018)
- Delays in regulatory approvals (National Environmental Policy Act, IACUC) have led to delays in field work milestones (approximately a quarter or two)
- Delay in mooring simulation code due to personnel changes at UW; task redirected to OSU; task will require a no-cost extension
- Delay in wave array control task due to prototype selection issues; task is on track for timely completion

- Go/No-Go decisions at the ends of Budget Periods 1 and 2

Project Budget

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
N/A	N/A	$633K	$274K	$957K	$372K

- Budget reallocated from project management toward array control and testing (Task 5)
- 90% of current allocated funding has been spent (nearing end of BP 2)
- Cost match provided by OSU, UW, UAF, and Washington Commerce exceeding mandatory levels

Research Integration & Collaboration

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Partners, Subcontractors, and Collaborators: OSU: Belinda Batten, Bret, Bosma, Ted Brekken, Bryony DuPont, Matt Evans, Merrick Haller, Sarah Henkel, Geoff Hollinger, Tuba Ozkan-Haller, Merrick Haller, Bob Paasch, Solomon Yim; UAF: Jeremy Kasper, Jerry Johnson, Anton Kulchitsky; UW: Brian Polagye, Alberto Aliseda, Steve Brunton, Craig Hill, John Horne, Jim Thomson

Communications and Technology Transfer: 17 presentations delivered at Northwest National Marine Renewable Energy Center Annual Meetings; Marine Energy Technology Symposia; 8 additional publications. Data products uploaded to MHK Data Repository. Industry partner network of 20 companies.

Next Steps and Future Research

Goals for FY17:

- Complete tools to estimate the probability of debris impact, and resulting forces, on MHK infrastructure
- Demonstrate a decrease in the time for maintenance and intervention in MHK arrays by up to 30% versus using tele-operated ROVs
- Produce a comprehensive methodology and demonstration dataset for the high-fidelity representation of extreme wave conditions
- Complete a coupled anchoring-mooring model to serve as a decision making tool for a broad range of WEC-anchor-cable combinations under multiple loading scenarios

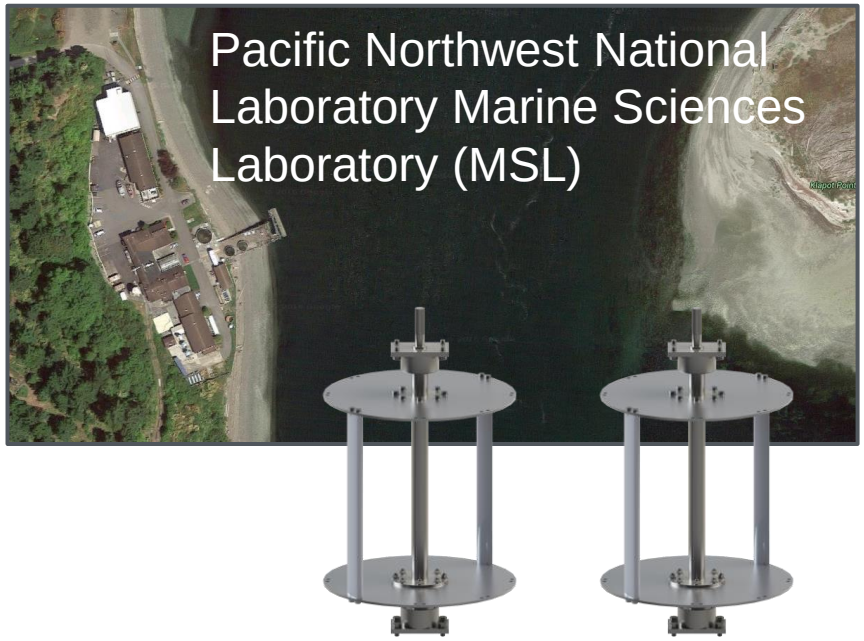
Next Steps and Future Research

Goals for FY17:

- WEC arrays: Demonstrate coordinated control of WEC arrays with optimized layout and optimal state estimation schemes
- CEC arrays: In the field, demonstrate the ability of coordinated control to increase the average power output of a dense array of cross-flow turbines as compared to a case individually controlled turbines in the same geometric arrangement
- Produce recommendations for sampling procedures for standardized monitoring fish species at MHK sites

Next Steps and Future Research

Proposed future research: Application, demonstration, and further development of ALFA products on full-scale WECs/CECs deployed in the field



Naval Facilities Engineering Command-funded 12+ month deployment of “field-scale” cross-flow turbines at MSL