



Wave Energy Prize—Carderock Test Design and Rigging to Accommodate Diversity of Device Types

Rick Driscoll

National Renewable Energy Lab

Frederick.driscoll@nrel.gov, 303 .384.7153

February 2017

Wave Energy Prize: Testing and Data Analysis

The Challenge: Drive technical innovation and through testing, evaluate energy capture in a resource relevant to large U.S. markets. The challenge was to determine testing conditions, develop processing algorithms, and execute tests for equitable and consistent evaluation of different wave energy converter (WEC) technologies.

Partners: National Renewable Energy Laboratory (NREL)
Sandia National Laboratory (SNL)
Naval Surface Warfare Center (NSWC) Carderock Division
Ricardo

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**

Legend:

- **Key Priorities for Prize Administration**
- **Key Priorities for Testing**
- **Key Priorities for Prize overall**
- **Additional Priorities covered by Prize**

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**

The Impact

- Verified equitable testing methods that can be used to evaluate technologies for the U.S. Wave Resource
- Robust public data sets for a range of technologies that can be used for cross-platform evaluation and technology metrics development
- Identification of potentially high-performing disruptive technologies
- Public templates for test plans, test methodologies, and data analysis
- Identification of areas of scaling and testing where further research and development is needed
- Increased U.S. national wave energy technology testing experience and knowledge

Increase MHK deployment in opportune markets

Market Development

- Support project demonstrations to reduce risk and build investor confidence

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Exchange of data information and expertise

The Impact

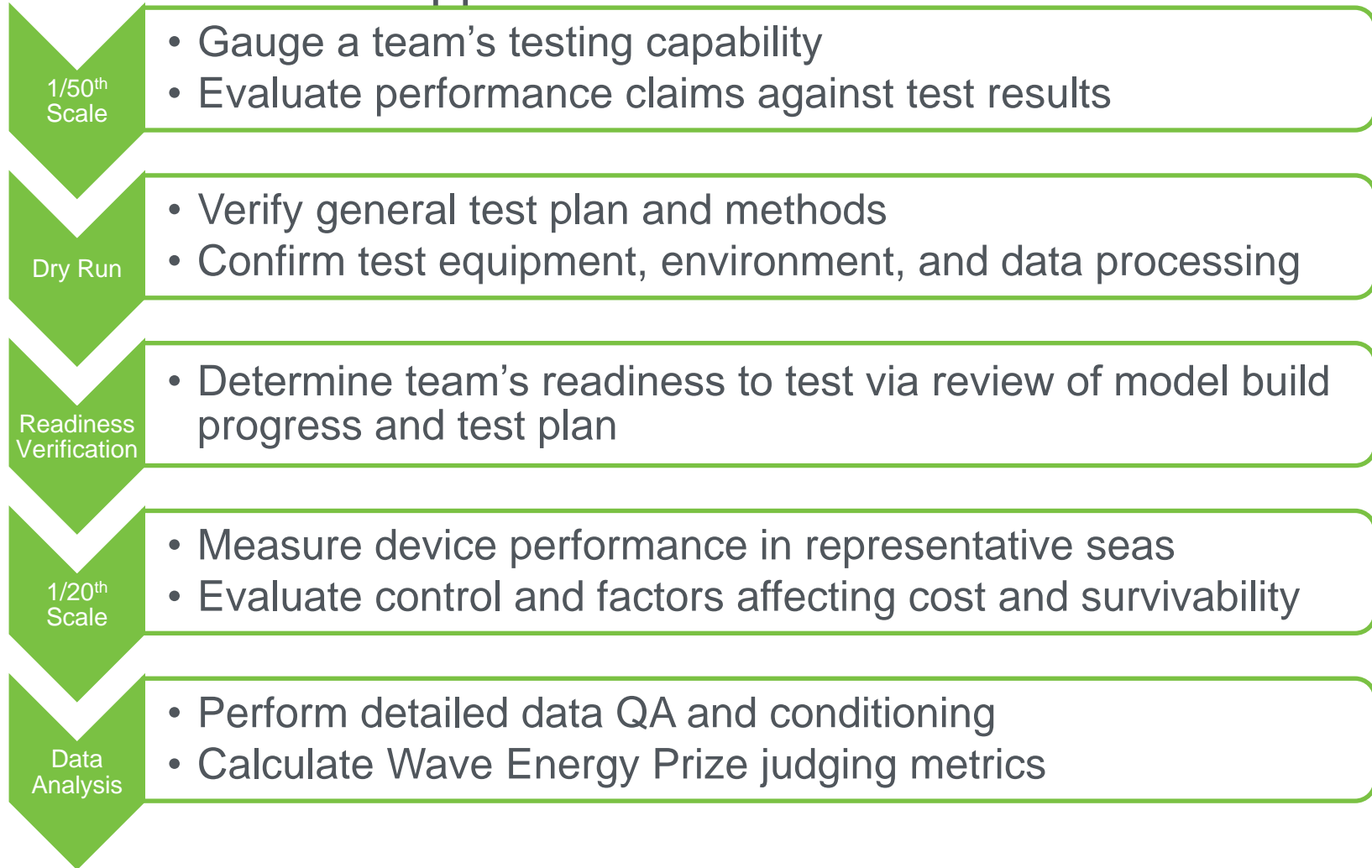
- Tested and quantitatively evaluated a range of innovative WEC technologies using Average Climate Capture Width per Characteristic Capital Expenditure (ACE) and Hydrodynamic Performance Quality (HPQ) metrics, all results will be made public
- Demonstrated that sub-scale tank testing yields valuable performance and design information at the earliest stages of design
- Established that the United States has multiple test facilities that are capable of test WEC devices at different scales
- Engaged and familiarized several test facilities with testing wave energy devices, thereby increasing the U.S. testing capability

Technical Approach

Develop test methods to uniformly test WEC technologies and produce high-quality data by:

- Determining a set of test waves that represent the range of wave conditions on the U.S. West Coast (both typical and storm)
- Developing data processing and QA algorithms that can be applied across different technologies in near real-time
- Implementing robust, high-performance, and proven data acquisition technologies
- Developing testing procedures that maximize test success and generation of high-quality data
- Test team devices and calculate Wave Energy Prize metrics

Incremental Test Approach



The semi-finalist and finalist teams were able to successfully evolve, test, and demonstrate their technologies at 1/50th and 1/20th scales.

“We wouldn’t have achieved what we did without the structure and focus that the wave energy prize provided us. In addition to providing rational metrics and checkpoints for our development, we were also introduced to extremely helpful, encouraging, and inspirational people along the way” – Aqua Harmonics

“Our team was impressed with the Carderock facility and the knowledge and experience of the staff and Prize committee, we had the privilege of working with. It was exciting to observe our prototype in the various Prize specified wave conditions, especially the realistic wave cases” - CalWave

“Of equal value to our technology’s development has been the wave tank testing and engineering support that the DOE has made available to participants of the competition” – Harvest Wave Energy

“the prize program has delivered full validation of our numerical simulations and the possibility of a 40% uplift in performance through improved geometry” - Waveswing

The testing team with support from the Project Administration Team (PAT) and DOE

- Met aggressive schedules and ensured readiness for testing at the small scale facilities and at Carderock
- Created processing and QA scripts that allowed near real-time and equitable evaluation of data during testing by the teams and the testing staff
- Delivered test results to the PAT within two weeks of the final testing
- Applied ACE (ACCW) and HPQ and verified their effectiveness at evaluating early-stage technologies
- Performed WEC testing and established/demonstrated capabilities at five small-scale (U Maine, Oregon State U, Stevens IT, U. Iowa, and U. Michigan) and one larger-scale (NSWC-Carderock MASK) sites.
- Demonstrated the testing at small scales is valuable for evaluation of early-stage technologies. It provides valuable design feedback and input into metrics such as Technology Performance Levels, which help steer development and investment.

2015

2016

TIMELINE

1:50 test planning

1:50 Scale
Testing

Data
Analysis

TECHNOLOGY
GATE 1

TECHNOLOGY
GATE 2

April

Jun

July

August

January

1st

Wave Energy Prize registration opens on waveenergyprize.org



30th

Wave Energy Prize Registration closes.



Announcement of Official Registered Teams!



15th

Technical Submission deadline for Teams.



16th through Aug. 13th

Technical Submissions are reviewed by an Expert Judging Panel and Qualified Teams are determined.



14th

Announcement of Qualified Teams!



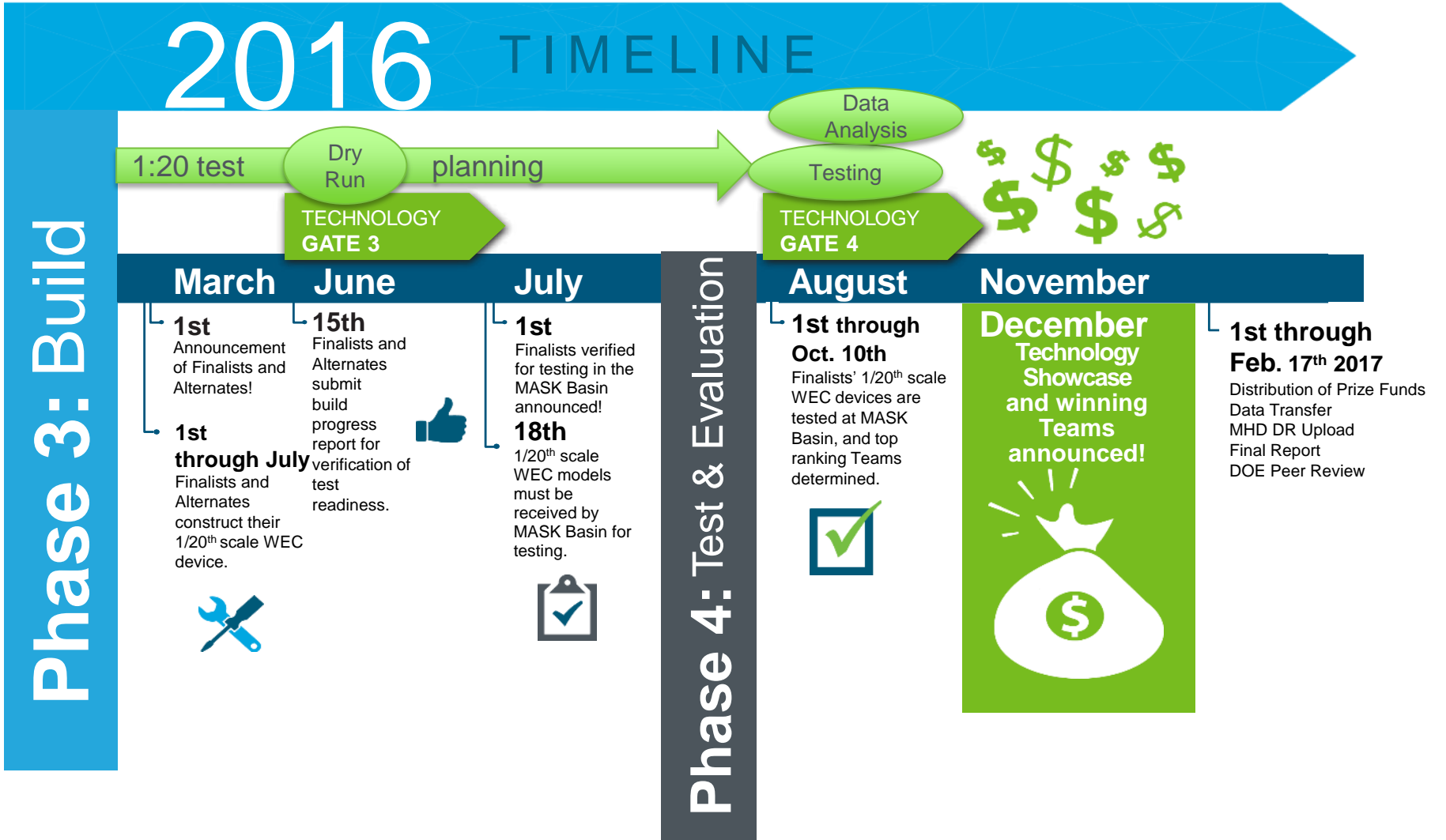
29th

Results of small scale testing and 1/20th Scale Model Design and Construction Plan due from Teams.



Phase 2: Design

2016 TIMELINE



Budget History					
NREL Budget					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$150k		\$545k**		\$380.33k	
Sandia Budget					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$150k		\$663.975k		\$350k	
Carderock Budget					
FY2014		FY2015		FY2016	
	Cost-share	DOE	Cost-share	DOE	Cost-share
\$25k	---	\$1,175k	\$40k***	\$500k	\$600k**

* \$545k carryover transferred in FY15 from other Water Power projects which is included here as new funding to the project

** \$600k contributed by Naval Facilities Command. Assigned by Assistant Secretary of the Navy - Energy, Installations & Environment Dennis McGinn

*** \$40k contributed by Carderock's Technical Director to support judging duties

- 83% of all NREL funding was costed by the end of FY16

Partners, Subcontractors, and Collaborators:

Prize Administration Team:



DOE and Program Identified Partners:



Other Entities:



Small Scale Test Facilities



Partners, Subcontractors, and Collaborators:



Wave Energy Prize photo taken at NREL during TG4 – back row, Scott Jenne (NREL), Wesley Scharmen (Ricardo), Rick Driscoll (NREL), Julie Zona (JZ Consulting), Scott Beatty (Cascadia Coast), Alison LaBonte (DOE), Darshan Karwat (DOE), Budi Gunawan (SNL); front row, Stephanie Hodge (DOE), Bob Thresher (NREL), Vince Neary (SNL), Phil Michael (Ricardo), Jochem Weber (NREL), Annie Dallman (SNL), David Newborn (NSWC), Lee Jay Fingersh (NREL)

Communications and Technology Transfer:

- Contributed to blogs, presentations, webinars and presentations
- Bi-weekly meetings with all nine teams
- Maneuvering and Seakeeping Basin tour and testing webinar with teams
- Provided tours of 1/20th scale testing to >30 non-Navy staff from the Hill, DOE, Office of Management and Budget, etc.
- Data analyst training webinar
- Test plans, test data, and processing codes will be made public in one year via the MHK Data Repository

FY17/Current research:

- Finishing processing all data and submit results to judges (completed 10/2016)
- SNL/NREL to extend performance evaluation with additional performance metrics and comparison with other WEC technology performance benchmarking studies

Sea Potential



**Waveswing
America**

