Project Title

Open Wave-Energy Control System Development Platform

Federal Agency and Award Number

DOE – EERE

DE-EE0009444

Principal Investigator Contact Info

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Recipient Organization

Monterey Bay Aquarium Research Institute

Submission Date

7/30/2022

DUNS Number

178341772

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Project Period of Performance

10/1/2021 - 9/30/2025

Reporting Period End Date

6/30/2022

Accomplishments

a) Major Goals and Objectives

The primary goal of this project is to create a software infrastructure for the MBARI Wave Energy Conversion buoy that will allow outside collaborators to develop control algorithms that take advantage of all features of the MBARI buoy, and execute these algorithms during the regularly scheduled deployments. The intent of this is to provide an at-sea test-bed for controls researchers that they would not ordinarily have access to, and promote real-world control system research and testing in this manner. The project contains three main activities;

i) Buoy Software Infrastructure: This is the development of an application programming interface (API) on the buoy system that provides developers consistent access to all sensor data on the buoy and a means by which to programmatically specify control inputs to the wave-energy converter. With this API, developers will be able to concentrate almost entirely on the control algorithm portion of the task, without needing to develop specific expertise in the lower level software and hardware infrastructure of the wave-energy converter. The architecture of the MBARI wave-energy converter buoy is well suited to this abstraction and allows new control code to be uploaded and executed in this model, while the buoy is at sea. It is intended to be routine to perform design iterations in which code is uploaded and run, results analyzed, modifications made and new code uploaded and run, without the need to recover the system.

ii) Simulation Environment: In order for developments using the API to proceed efficiently, a simulator is also required that allows newly developed code to be tested before deployment on the hardware. A key requirement of this simulator is that it provides an API that is identical to the buoy API. Meeting this requirement means that code that runs in the simulation environment can also run entirely unchanged on the buoy while it is at sea. This simulation environment also will provide some safety checks on code before it is run on the buoy, and allow researchers to do some algorithm performance testing before at-sea testing. The simulator is being developed to run faster than real-time, and will have a range of settings that balance code execution speed and simulation fidelity.

iii) Marketing and Outreach: The most critical and challenging component of this project is developing engagement with our target users. There are a wide range of potential users and we are targeting academic and non-profit institute researchers as per the funding opportunity announcement. We also envision teaching opportunities for this platform and can imagine a university course in marine hydrokinetic energy harvesting being developed that uses the materials resulting from this project. We are planning a number of activities such as webinars, seminars, and conference events to support this. Additionally, we have included requirements in our software development and documentation specification for ease of use for individuals new to ROS and this type of programming.

To facilitate these activities, this project includes Open Robotics Software Foundation (ORSF) as a significant subaward. ORSF develops and promotes the popular "Robot Operating System" (ROS, https://www.ros.org) which is a middleware that allows robotics and other real-time software to be divided into a number of processes that share data over a common publish/subscribe message architecture. By developing the required API using this framework, we expect to provide an API that uses a well-documented form and that is approachable for academic researchers. ROS provides language bindings in C++ and Python, which provides some built-in flexibility to meet researchers in their own areas of computing expertise.

Budget Period 1 of this project concentrates on building the necessary software tools, and incorporating a few beta users into the system, using the simulation tools in the near term and for on-buoy operations in the second year of the project. Budget Period 2 is focused on marketing the result and helping users make use of the system.

Table 1: Budget Period 1 Milestone Progress

			Completion Month	
	Milestone	Percent Completed	Scheduled	Actual
1.7.1	ROS Running on MBARI WEC Computer	100%	6	5
2.2.1	Simulator selected	100%	5	5
2.8.1	Simulator integrated	60%	8	
3.4.1	All software packages are published publicly	60%	9	
4.3.1	MBARI control running in ROS system	100%	9	5
5.3.1	Portal ready to launch	40%	9	
6.2.1	Webinar completed	0%	11	
7.2.1	Buoy Deployed	0%	16	
8.2.1	Successful on-buoy use of user code	0%	21	
9.1.1	Workshop or online training completed	0%	16	

b) Accomplishments in this Reporting Period

The bulk of the work performed in this reporting period has been related to the simulator development portion of the project. At the very end of the previous reporting period (March 31, 2022) we had an in-person kick-off meeting at MBARI with Open Robotics to discuss how to proceed and have made significant progress since. A key action at that meeting and subsequently was to evaluate the suitability of the Gazebo software for the simulation task. As reported earlier, we made this selection after identifying two limitations in the software and a path to address them. Progress since has validated that decision, we have completed the basic physical simulation of all components of the buoy and system in Gazebo, and are working now to refine the accuracy of some components and balance model fidelity with run-time speed. There has been progress in three areas (described further below); physical simulation of the MBARI wave-energy converter in Gazebo, refinement of the Gazebo physics simulation capabilities to included added-mass effects and make it suitable for use in marine hydrodynamics, and the development of the ROS interface to the simulator that matches the MBARI buoy system.

Gazebo Simulation

In this reporting period, the MBARI and Open Robotics teams have been working together quite productively and have made good progress on establishing the basic architecture of the simulator in the Gazebo environment as was as completing many details. To illustrate the progress that has been made, a computer rendering of the buoy in the simulation is shown Figure 1, the link in the caption is to an animation of this simulation and shows realistic behavior of the system in waves.

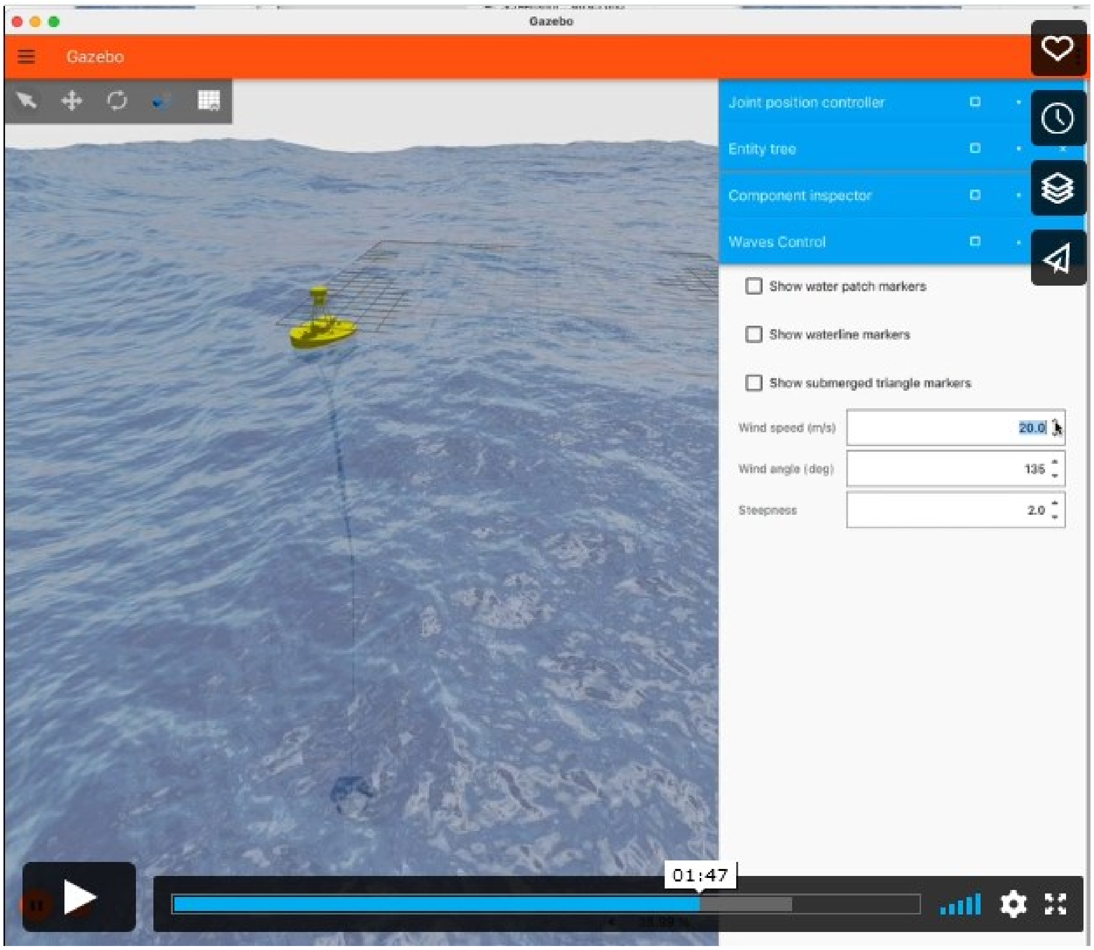

Figure 1: Screen capture of the MBARI/DOE buoy simulation inserted into Rhys Mainwaring's wave-body interaction environment. Video here: https://vimeo.com/714469817

This software development is proceeding in the same open-source development style as the ROS and Gazebo projects, with developments and most discussion about the developments taking place in public on GitHub. In particular, the project now consists of four related GitHub repositories as follows (clicking on these links or pasting into web-browser will bring you to the work):

- https://github.com/osrf/buoy_entrypoint
- https://github.com/osrf/buoy_examples
- https://github.com/osrf/buoy_msgs
- https://github.com/osrf/buoy_sim

Currently, the "buoy_entrypoint" repository is intended as the place users will start, and lead them to whatever resources they need to work with the project. Currently, instructions are included in this repository to allow new participants to build and use the system. The documentation included in these repositories has proven adequate for the developers that have become involved (MBARI, Open Robotics, and some outsiders), but isn't yet enough for the envisioned outside users of the system. In the Plans for the Next Reporting Period section below, more details about expanding the documentation for this project are provided.

The "buoy_examples" repository contains a number of already developed examples of using the simulator, ultimately this repository will form the basis of the tutorials planned to help users become familiar with using this software.

The "buoy_msgs" repository contains the specific ROS message definitions that allow user code to communicate with the MBARI WEC and/or the simulated buoy. These definitions are required for subsequent code development, but will only be changed by MBARI personnel in response to changes in the physical buoy hardware or software.

The "buoy_sim" repository contains the software developed by this project to simulate the MBARI WEC in the Gazebo environment. Although the Gazebo infrastructure provides much of what is needed, a handful of specific components needed to be developed to model the MBARI WEC. The architecture of Gazebo specifically accommodates this type of addition through the use of software plug-ins, and in most cases the work done by this project has been to create plug-ins that implement the functionality needed to simulate the MBARI WEC. Specifically, Gazebo plug-ins now exist that simulate the specific behavior of the Power-Take-Off unit of the MBARI WEC, including details about the electro-hydraulic power take-off, battery systems, and pneumatic spring components that are specific to this device.

A capability that is required for this project but not yet implemented in Gazebo is a physic-based representation of the forces on the buoy due to the ocean waves. This is an important component to be physically realistic. Most work in Gazebo to date in this area has been centered more around a visually-realistic interaction behavior, with techniques drawn from the video game industry. Therefore, there is a requirement for this project to implement a physically accurate wave-body interaction plugin, utilizing linear wave-body interaction theory (at a minimum), similar to how this is handled in WEC-Sim. This has always been within the scope of this project and much of the underlying code has been completed to implement this capability. In June however, we became aware of Rhys Mainwaring's independent work in a similar direction. Rhys is an independent software developer based in England and has been exploring applying his computer science expertise to this problem, building on some previous Gazebo related work. The animation in Figure 1 above highlights Rhys' work. In that work he had found this projects' work on Github and independently incorporated our WEC simulation into his wave-body interaction code to produce the impressive result shown. We have since met with Rhys to investigate the specifics of what he's done and opportunities to utilize his work which he has also released under an open-source license. We have learned that Rhys has indeed used some video-game heuristics and tuning in his result, but has architected his software such that it should be possible to swap in a more physics-based representation of the buoy forcing due to waves, while maintaining the excellent wave-characterization and rendering work he has done. This is a remarkable highlighting of the power of open-source development and we hope to leverage Rhys' interest further.

Finally, as identified in the evaluation of Gazebo for this project, Gazebo does not currently have the ability to include effects of added-mass in the physics simulation. Added mass is the inertial effects of the fluid surrounding a body that is accelerated when the body is accelerated. Because Gazebo has largely been used for terrestrial robots, this has always been a negligible effect because the robots are typically much denser than the surrounding air. This effect can not be neglected in marine hydrodynamics and requires changes to several of the internal software libraries that Gazebo uses to incorporate. Louise Poubel at Open Robotics has been working to implement the required changes. At this point the required changes have been ratified by the Gazebo community via comment on this proposal: http://sdformat.org/tutorials?tut=added_mass_proposal&branch=chapulina/added_mass. Additionally, implementation and test work has been proceeding and these features will be included in the next release of Gazebo (code-name Garden). We will be the first primary users of these features and will be testing them thoroughly in our upcoming work.

Open Source Development

This software development is utilizing the open-source development processes common to Gazebo and ROS. The project has leveraged these practices to good effect and benefited from Open Robotics' expertise in these matters. In particular, a Continuous Integration process is being followed in which each time a developer commits changes to the code the entirety of the project is automatically re-built and automatic tests are run to ensure the new changes don't compromise the existing capabilities of the code. This does require some additional work to develop specific tests for each code component, but ideally leads to more robust and maintainable software. Because we aim to draw in external researchers to use this software, reliability and predictability are of paramount importance so we believe the addition work we are doing at this development stage is worthwhile.

The open-source code being developed under this project is being released under the same software license as ROS/Gazebo, and the following copyright and license statement are included in every file:

```
// Copyright 2022 Open Source Robotics Foundation, Inc. and Monterey Bay Aquarium Research Institute
//
// Licensed under the Apache License, Version 2.0 (the "License");
// you may not use this file except in compliance with the License.
// You may obtain a copy of the License at
//
// http://www.apache.org/licenses/LICENSE-2.0
//
// Unless required by applicable law or agreed to in writing, software
// distributed under the License is distributed on an "AS IS" BASIS,
// WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
// See the License for the specific language governing permissions and
// limitations under the License.
```

ROS/Gazebo Usage

ROS and Gazebo are sophisticated pieces of software that require a moderate amount of computer set-up and software dependency management, sometimes causing a barrier to use. Docker technology (https://www.docker.com/) provides some relief to this barrier and appropriate containers are provided by our project such that users have that option to use this software without re-configuring their machines to adapt to the particular dependencies our project has. Instructions for this path are also included in the "buoy_entrypoint" repository.

c) Training and Professional Development Opportunities

Post-doctoral fellow Chris Dizon at Oregon State University (under Professor Ted Brekken) has begun working with the MBARI and Sandia Engineering teams and is gaining familiarity with our previous Wec-Sim model of this system. We continue to work with him to identify research areas that can benefit from access to the MBARI WEC and the hardware/software access this project will provide.

d) Results Dissemination

The open-source software development in this reporting period represents bulk of the results dissemination as the public at large has had access to what we are doing. Although this is a limited audience, we have seen outside software developers express interest and utilize our results.

e) Plans for the Next Reporting Period

Work in the next reporting period will concentrate on completion of the Gazebo simulator of the MBARI-WEC, development of user documentation and tutorials for the system, and the beginning of outreach to identify and entrain users. Work is needed to identify the best platform for the systems user documentation, there are a range of options from utilizing the Github "pages" features through to a custom-created website for the project. We do not currently believe a full custom website will be necessary or cost effective, and are looking at a range of services such as https://readthedocs.org/ in addition to Github pages. Whichever path is chosen, we believe that an accurate and concise web-presence will be important to drive use, and that this is a pre-curser to extended efforts to entrain users.

We also expect to become more involved in the Gazebo simulation community. That group has a marine-robotics working group that has occasional meetings. Although we have been attending these meetings, we intend to make a presentation on this project at some point, probably in the next reporting period.

We are also still planning to give a presentation at the ***16th International Conference on Motion and Vibration Control (MoViC 2022)*** in Los Angeles September 7-9. The abstract itself is in Appendix B of this report and is oriented to introducing this project and opportunities to collaborate to the traditional wave-energy research community that will be represented at that meeting.

Products

a) Publications, conference papers, and presentations:

- An abstract has been accepted at the *9th IFAC Symposium on Mechatronic Systems (Mechatronics 2022)* and the ***16th International Conference on Motion and Vibration Control (MoViC 2022)***. This is a Ryan Coe organized sub-meeting with an emphasis on wave-energy. These meetings are to take place September 7-9 at UCLA in Los Angeles. (See Appendix B for the presentation abstract). The project PI will attend this conference and make a presentation on this project as an outreach and marketing activity.

b) Websites:

The following web-sites contain software developed by this project:

- https://github.com/osrf/buoy_entrypoint
- https://github.com/osrf/buoy_examples
- https://github.com/osrf/buoy_msgs
- https://github.com/osrf/buoy_sim

c) Technologies or Techniques

This project has spurred changes to the Gazebo simulation framework to properly include added-mass effects in the physics simulation. This is a necessary capability for Gazebo to be used for marine robotics.

d) Inventions, patent applications, and/or licenses

None.

e) Other products

None.

Participants & Other Collaborating Organizations

a) Individuals

1. Name: Andrew Hamilton
2. Total Number of Months: 2
3. Project Role: PD/PI
4. Researcher Identifier: None
5. Contribution to Project: Principal Investigator and Project Manager, directs all activities.
6. State, U.S. territory, and/or country of residence: California, U.S.A.
7. Collaborated with individual in foreign country: No
8. Country(ies) of foreign collaborator: Not Applicable
9. Travelled to foreign country: No
10. If traveled to foreign country(ies), duration of stay: Not Applicable

1. Name: Michael Anderson
2. Total Number of Months: 3
3. Project Role: Other Professional – MBARI Software Engineer
4. Researcher Identifier: None
5. Contribution to Project: Performs Software Engineering, Programming, and Documentation Tasks. Participates in all meetings.
6. State, U.S. territory, and/or country of residence: California, U.S.A.
7. Collaborated with individual in foreign country: No
8. Country(ies) of foreign collaborator: Not Applicable
9. Travelled to foreign country: No
10. If traveled to foreign country(ies), duration of stay: Not Applicable

1. Name: Rich Henthorn
2. Total Number of Months: 1
3. Project Role: Other Professional – MBARI Software Engineer
4. Researcher Identifier: None
5. Contribution to Project: Performs Software Engineering, Programming, and Documentation Tasks. Participates in all meetings.
6. State, U.S. territory, and/or country of residence: California, U.S.A.
7. Collaborated with individual in foreign country: No
8. Country(ies) of foreign collaborator: Not Applicable
9. Travelled to foreign country: No
10. If traveled to foreign country(ies), duration of stay: Not Applicable

1. Name: Louise Poubel
2. Total Number of Months: 2
3. Project Role: Other Professional – ORSF PD/Software Engineer
4. Researcher Identifier: None
5. Contribution to Project: Leads Open Robotics activities

6. State, U.S. territory, and/or country of residence: California, U.S.A.
7. Collaborated with individual in foreign country: No
8. Country(ies) of foreign collaborator: Not Applicable
9. Travelled to foreign country: No
10. If traveled to foreign country(ies), duration of stay: Not Applicable

1. Name: Dharini Dutia
2. Total Number of Months: 2
3. Project Role: Other Professional – ORSF Software Engineer
4. Researcher Identifier: None
5. Contribution to Project: Software engineering and programming
6. State, U.S. territory, and/or country of residence: California, U.S.A.
7. Collaborated with individual in foreign country: No
8. Country(ies) of foreign collaborator: Not Applicable
9. Travelled to foreign country: No
10. If traveled to foreign country(ies), duration of stay: Not Applicable

1. Name: Tully Foote
2. Total Number of Months: .25
3. Project Role: Other Professional – Co PD/PI
4. Researcher Identifier: None
5. Contribution to Project: CO-PI and project oversight
6. State, U.S. territory, and/or country of residence: California, U.S.A.
7. Collaborated with individual in foreign country: No
8. Country(ies) of foreign collaborator: Not Applicable
9. Travelled to foreign country: No
10. If traveled to foreign country(ies), duration of stay: Not Applicable

b) Change in PI/Senior Personnel

None.

c) Partner organizations

1. Open Robotics Software Foundation.
2. Mountain View, CA USA.
3. Partner's contribution to the project is Collaborative research and In-kind support.
4. Open Robotics Software Foundation is a domestic organization that that supports all administrative and technical development of ROS, ROS2 and the associated Gazebo simulator. These open-source projects form the software basis for most of this project. Having this organization as an official subaward on this project provides access to expertise and best-practices for these software products. This is allowing this project to produce a professionally developed product that will be maintainable and suitable for inclusion in the larger ecosystem of ROS and Gazebo software.

d) Other collaborators

- We have a long-standing collaboration with the Ryan Coe group at Sandia with funding independent of this project. We anticipate this project will benefit that effort and facilitate some of the goals of that partnership. Therefore, we continue to keep the Sandia group apprised of our work here and this project is benefiting from previous modelling work done by Sandia, and their expertise in general.

- We continue to develop a relationship with Ted Brekken and Chris Dizon at Oregon State University as possible users of this project's products.

- Rhys Mainwaring has expressed and interest in collaborating with project as an outlet for his wave-body interaction developments for Gazebo and we are exploring how formal this arrangement needs to be.

Impact

a) Impact on the principal disciplines
None yet. In the future we hope to facilitate research results in the area of wave-energy conversion device control.

b) Impact on other disciplines
This project has spurred changes to the Gazebo simulation framework to properly include added-mass effects in the physics simulation. This is a necessary capability for Gazebo to be used for marine robotics.

c) Impact on development of human resources
None

d) Impact on teaching and education
None yet.

e) Impact on infrastructure
None expected.

f) Impact on technology transfer
None yet.

g) Impact on society
None.

h) Budget percentage spent in foreign countries
0%

Changes/Problems

a) Changes in approach.
None.

b) Actual or anticipated problems or delays and actors or plans to resolve.
This project was a bit slow getting started after the award was made, mostly due to staffing constraints and the time it took to get the Open Robotics Subaward in place. However, the project is making up time and is now only slightly behind schedule. In particular, the simulator development was originally scheduled to be completed in Month 9 of the project, and while the bulk of that development will be done, developments may bleed some into the testing and use phases.

c) Changes that have an impact on expenditures
None.

d) Changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents.
None and not expected to be applicable.

e) Change in primary performance site location.
None.

Appendix A: WBS for Budget Period 1.

Green indicates completed in previous reporting periods.

Red indicates completed in this reporting period.

Black indicates still to be done.

PROJECT TITLE					**Open Wave-Energy Control System Development Platform**		
Recipient Name					MBARI		
Project Start Date					11/1/2021		
Project End Date					10/30/2025		
Budget Period #	**Task Type**	**Task #**	**Subtask #**	**M or D #**	**Milestone/Deliverable Description**	**Planned Project Month START**	**Planned Project Month END/DUE**
1…10	*Select*	*0…50*		*0…n 0.0…n*	*Title text from SOPO*	*1…120*	*1…120*
1	T	1	0	0	ROS integration into buoy controller	1	6
1	ST	1	1	0	System architecture planning	1	2
1	ST	1	2	0	Create ROS Package defining message data structures	3	5
1	ST	1	3	0	Create ROS package that publishes CANbus data	3	5
1	ST	1	4	0	Create ROS package that publishes AHRS/GPS data	3	5
1	ST	1	5	0	Create ROS package that logs data on the buoy	3	5
1	ST	1	6	0	Create ROS package that provides streaming telemetry	3	5
1	ST	1	7	0	Test on Buoy Computer	6	6
1	M	1	7	1	ROS Running on MBARI WEC Computer	6	6
1	T	2	0	0	Integrate wave-energy simulator into ROS environment	3	8
1	ST	2	1	0	Planning	3	4
1	ST	2	2	0	Evaluate simulation tools	4	4
1	M	2	2	1	Simulator selected	5	5
1	ST	2	3	0	Integrate selected simulation into ROS package	4	5
1	ST	2	4	0	PTO and power system simulation	4	5

1	ST	2	5	0	Implement Heave Cone simulation	4	4
1	ST	2	6	0	Develop Simulation Inputs	5	7
1	ST	2	7	0	Develop visualization tools	4	7
1	ST	2	8	0	Test code interoperability with buoy hardware	7	8
1	M	2	8	1	Simulator integrated	8	8
1	T	3	0	0	**Publish Simulated Environment**	8	9
1	ST	3	1	0	Publicly release software from task 1 and 2	8	9
1	ST	3	2	0	Create example tutorial	8	9
1	ST	3	3	0	Test example tutorial	8	9
1	ST	3	4	0	Export example tutorial to website/portal	8	9
1	M	3	4	1	All packages are published publicly	9	9
1	T	4	0	0	**Port existing MBARI control to ROS system**	6	9
1	ST	4	1	0	Transfer current logging and control features to ROS system	6	8
1	ST	4	2	0	Transfer current system control features to ROS system	6	8
1	ST	4	3	0	Run standard performance/logging tests with ROS system	8	9
1	M	4	3	1	MBARI control running in ROS system	9	9
1	T	5	0	0	**Develop website/portal for user access/outreach**	7	9
1	ST	5	1	0	Planning and toolchain selection	7	7
1	ST	5	2	0	Establish communication channel for online community	7	8
1	ST	5	3	0	Create website entry-point	8	9
1	M	5	3	1	Portal ready to launch	9	9
1	T	6	0	0	**Launch of simulation capabilities to beta group**	9	15
1	ST	6	1	0	Planning and identification of beta users	9	9
1	ST	6	2	0	Prepare and hold webinar	9	10
1	M	6	2	1	Webinar completed	11	11
1	ST	6	3	0	User Support	10	15
1	ST	6	4	0	Website and data management	10	15
1	ST	6	5	0	Results review	12	15
1	T	7	0	0	**Buoy deployment, recovery and maintenance #1**	15	21
1	ST	7	1	0	Pre-deployment assembly and test	15	16

1	ST	7	2	0	Deployment	15	16
1	M	7	2	1	Buoy deployed	16	16
1	ST	7	3	0	At-sea monitoring	16	21
1	ST	7	4	0	Recovery, cleaning and refurbishment	21	21
1	T	8	0	0	**Support of on-buoy operations for beta group**	17	21
1	ST	8	1	0	Safety review of controller behaviors in simulation	17	17
1	ST	8	2	0	User support during on-buoy operations	17	21
1	M	8	2	1	Successful on-buoy use of user code	21	21
1	ST	8	3	0	Data management	17	21
1	ST	8	4	0	Assistance with results analysis and publication	20	21
1	T	9	0	0	**Marketing and outreach**	13	24
1	ST	9	1	0	Documentation and workshop or online training preparation	13	15
1	M	9	1	1	Workshop or online training completed	16	16
1	ST	9	2	0	Advertising	13	24
1	ST	9	3	0	Website/portal maintenance	13	24
1	ST	9	4	0	Workshop or online training	18	18
1	ST	9	5	0	Conference attendance	13	24
1	ST	9	6	0	Coordination with MERC	13	24
1	T	10	0	0	**Support of simulation capabilities for all interested parties**	15	24
1	ST	10	1	0	User support	15	24
1	ST	10	2	0	Code maintenance	15	24
1	ST	10	3	0	Results review	15	24
1	T	11	0	0	**Go/No-Go Review**	20	24

Appendix B: Abstract for presentation at MoVic 2022, Sept 7-9, UCLA.

Open Wave-Energy Control System Development Platform

Andrew Hamilton, MBARI

The Monterey Bay Aquarium Research Institute (MBARI), the Open Source Robotics Foundation (OSRF), and the US Department of Energy have recently teamed up to make the small-scale wave-energy converter developed by MBARI available to the external community of wave-energy control systems researchers. The MBARI WEC is a small point absorber design that is routinely deployed in Monterey Bay and generates average powers of 250W in its current configuration. This WEC is heavily instrumented and includes a four-quadrant electro-hydraulic power take-off device, on-board battery storage, on-board computing infrastructure, and an always-on link to the internet. To date, advanced controls have not been developed or implemented for this system, and the 250W average power values that are realized result from a simple linear-damping control law. This project is implementing an Application Programming Interface (API) based on the popular open source Robotics Operating System (ROS2). This software infrastructure provides a means for third-party software running on the buoy to have real-time access to all data telemetry from the system, and take control of the target PTO forces and other items in the system that are under software control. The aim of this project is to develop and document this API to the point where wave-energy control researchers from organizations outside of MBARI can develop algorithms and run code on the MBARI WEC during at-sea deployments. The architecture of the MBARI WEC has fail-safe features that provide the necessary device security to allow this. To facilitate code development and test, a dedicated software simulator is also under development that candidate software can be tested against. The aim is that the simulator is a software facsimile of the WEC such that candidate software can run unchanged on the real buoy after running against the simulator. This talk will highlight the technical implementation of the MBARI WEC and control system API developed for this effort. The numerical model and resulting simulation environment will be described and details about how external groups can implement algorithms for this system, and then exercise them during our test deployments will be described.