

Project Number: 902008

Project Start: Jan. 1, 2020

Project Duration (in years): Year 1 of 1

Please indicate if proposal includes requests for any of the following (mark all that apply).

☐

Ship Time

☐

ROV

☐

AUV

☐

Wave Glider

☐

Mini ROV

Please indicate what type of project is being proposed (mark only one).

☒

Feasibility/Scoping
[Less than 100 days
effort]

☐

Development¹

☐

Research

☐

Infrastructure²

☐

Education

☐

Time Series

☐

Institute
Initiative

Project Manager²: Ben Raanan

Principal Investigator: Yanwu Zhang

Lead Scientist: John Ryan

Lead Engineer: Ben Raanan

**Project Title: Multi-vehicle simulation
environment**

Please indicate which category best describes the project theme (mark only one).

☐

Ocean
biogeochemistry

☐

Ecosystem
dynamics

☐

Ocean
visualization

☒

Exploration &
discovery

¹ Development and infrastructure projects must complete the risk matrix (see end of the proposal form).

² Not all projects will require all four titles to be filled in. Please indicate individuals only for those titles that are appropriate for your project.

2020 Proposal Process – Internal-Only Projects
Submission Deadlines: Phase I – July 17th at 8:00 a.m., Phase II – September 5th

Please indicate percentage of effort on this project anticipated for 2020 toward these three highest institutional goals (percentage total should equal 100%).

Goal	Developing/adapting innovative technologies	Utilizing developments to explore and understand ocean systems	Technology/knowledge transfer³
Percentage	90%	0	10%

³ This category includes transfer of hardware, know-how, publications, presentations, etc.

1) ABSTRACT (new projects only)

Multi-vehicle operations are essential to the future of autonomous vehicles in ocean science. MBARI is already a leader in the application of multi-vehicle operations in ocean science, and we are uniquely poised to advance these operations and the scientific research they enable. Alongside MBARI's growing fleet of autonomous platforms, the ability to simulate a multi-vehicle scenario under realistic and reproducible settings could increase the scalability of ongoing development efforts, enable rapid prototyping and testing of new algorithms, and improve the overall reliability, extensibility, and exportability of MBARI's autonomous platform technology.

To this end, we propose a 6-month effort to assess the feasibility of integrating existing open-source software for multi-vehicle underwater simulation, including the ability to simulate sensor data and environmental forcings, with LRAUV's software ecosystem. As part of this effort we will formulate requirements for the simulation framework and survey existing open-source tools and architectures to identify potential candidates for adoption. If a candidate framework is recognized, we will scope the required development and integration efforts to interface with LRAUV's software stack, conduct a concept design review, and develop a proof-of-concept demonstration that will form the basis for a multi-year project proposal.

2) PROPOSAL

a) All Projects

Statement of the challenge, why it is important

Multi-vehicle collaborative sampling methods have become a key component in field programs such as CANON (Chavez), ESP (Birch and Scholin), Acoustical Ocean Ecology (Benoit-Bird), and Biodiversity & Biooptics (Haddock). To date, the development of new autonomous multi-platform capabilities at MBARI is led by a small group of engineering staff and relies primarily on validation and testing in the field. As the demand for autonomous multi-vehicle operations increases, MBARI PIs seeking advanced methods of ocean observation will require an effective and scalable development path for new multi-vehicle applications and tools to help guide planning and decision making during multi-vehicle field campaigns. Our goals are to adapt and develop software validation tools to enable rapid prototyping and testing of multi-platform applications in reproducible virtual environments and formalize a design workflow to make development more accessible to MBARI researchers.

Relevance

How does it relate/contribute to MBARI's mission and strategic plan?

The overall objective of the Multi-vehicle Simulation Environment project is to develop or adapt innovative technology that will enhance autonomous multi-platform capabilities at MBARI. These capabilities are relevant to the "Exploration and discovery" research theme of MBARI's strategic plan.

In addition, we are exploring the use of open-source software that is developed and used by the underwater robotics community. While reuse of existing tools stands to offer much value to MBARI researchers, it also presents an opportunity to network and collaborate with external researchers and opens a viable path for technology export.

Finally, the ability to simulate a multi-vehicle scenario under realistic and reproducible settings is a prerequisite for iterative machine learning approaches such as reinforcement learning, policy learning, and automated planning and command and control algorithms, all of which have been outlined in the 2020 External Review document.

Does it relate to the Technology Roadmap? If so, please describe how. (See <http://mwww.mbari.org/oed/TechnologyRoadmap.pdf>.)

Targeted sampling within a Lagrangian reference frame is inherently a multi-vehicle problem. A canonical use case is tracking and sampling by two vehicles, where one vehicle tracks a feature of interest (and acquires samples), while a second vehicle vertically surveys neighboring waters to provide contextual data and search for new features. The goals of this project to improve autonomous multi-vehicle capabilities align with multiple components of MBARIs Technology Roadmap, specifically, enabling targeted sampling, taking the laboratory into the ocean, and advancing a persistent presence.

How does it relate/contribute to the Packard Foundation's Ocean Grantmaking Program? (See <https://www.packard.org/what-we-fund/ocean/> and documents therein.)

Developing a framework to improve autonomous multi-platform capabilities supports the Packard Foundation's vision of solving basic technology problems to better understand marine ecosystems.

Overall approach to the challenge: Over the complete term of the project, what is needed to address the challenge (e.g., sensors, platforms, marine operations, de novo R & D, etc.)

Research

Not applicable.

Engineering/Technology Development

The goal of this feasibility study is to scope the required effort for creating effective software tools for development and validation of multi-vehicle applications for LRAUV. The core challenge is creating a reproducible virtual environment for development of new mission strategies and high-level algorithms for cooperative behavior: the simulation needs to realistically model not only hydrodynamic forces acting on each vehicle, but also acoustic communication between vehicles and the complex environments in which the operations take place.

Due to the complexity involved in developing these capabilities, our objective will be to identify existing open-source software for simulating marine autonomous robots in multi-vehicle settings. A successful framework must address the following high-level criteria:

- Physical fidelity for the simulation of rigid-body dynamics and collisions.
- Capability for multi-robot simulation.
- Low complexity for setup of new scenarios and vehicle models.
- Extendibility for integration of sensor, environment, and control modules.
- Graphical user interface and scene visualization/rendering capabilities.
- Adequate documentation.
- Open-source application with permissive license (e.g., MIT, Berkeley Software Distribution BSD, Apache).

If a candidate framework is recognized, we will scope the required development and integration efforts to interface with LRAUV's software stack, conduct a concept design review, and develop a proof-of-concept demonstration that will form the basis for a multi-year project proposal.

Marine Operations/Field Programs

Not applicable.

Data

What data products will be generated?

We will generate and store only modest amounts of engineering data.

How will the data products be managed?

Data and documentation generated during development and testing will be stored in project library directories on Atlas.

Describe data availability outside of the project team.

Not applicable.

Describe data storage requirements.

1 GB of data stored on Atlas server.

Anticipated Impact

Who are the consumers of the instruments, methods, systems, and data that will be generated?

A well-designed simulator will make software development for LRAUV more accessible and provide an effective development avenue for engineers and MBARI researchers requiring advanced methods of ocean observation (e.g., PI labs developing back-seat applications for LRAUV).

b) Continuing Projects

If the proposed project includes multiple individual projects, please list each of these projects as a subheading in the proposal. For each subheading, please address the following:

Current status of project and results to date

[Click here to enter text]

What percentage of labor and budget have been used through the 1st half of year?

[Click here to enter text]

Will you complete the current year's scheduled work?

[Click here to enter text]

If you are at less than 50% resource usage, what is the plan to complete, or what work won't be done this year?

[Click here to enter text]

Significant changes from previous project proposal

[Click here to enter text]

Over the past two years, what peer-reviewed publications, education and/or outreach activities have resulted directly from this project? Please be brief.

[Click here to enter text]

c) All Projects: Specific Plans for 2020

Research Activities

None.

Engineering/technology development

Task: Assess the feasibility of integrating existing open-source software for multi-vehicle underwater simulation, including the ability to simulate sensor data and environmental forcings, with LRAUV's

2020 Proposal Process – Internal-Only Projects
Submission Deadlines: Phase I – July 17th at 8:00 a.m., Phase II – September 5th

software ecosystem.

1. Assemble use cases and formulate a requirements document for the multi-vehicle simulation framework.
2. Survey and evaluate candidate open-source tools and architectures for underwater multi-vehicle simulation.
3. Scope integration effort with LRAUV's software, assemble design documents, and conduct a concept design review.
4. Pending concept design review recommendations:
 - a. Submit 2021 proposal abstract.
 - b. Develop a proof-of-concept multi-vehicle simulation environment for LRAUV.

Field programs (detail ship requirements/deployments/diver requirements)

In addition to describing anticipated field programs, please be sure to include requirements for specific platforms and equipment (Dorado AUVs, LRAUVs, Wave Glider, mini ROV, etc.) for each proposed field program so that expectations are clear. Requests must also be entered in the budget entry system.

Not applicable.

Isotope Usage

Project teams must provide details regarding any planned isotope use on shore, on ships, in the Sanctuary, etc. Please review the guidance on isotope usage at <http://www.mbari.org/at-sea/cruise-planning/hazardous-materials/> and policy at http://www.mbari.org/safety/SafetyManual/Isotope_Use_Policy.pdf, and then provide details on plans below.

Not applicable.

Safety Disposal Needs

So the Safety office can plan and budget accordingly, please respond to the questions below regarding any anticipated safety disposal needs for the coming year. Budget for cost of such removal will be captured by the safety office based on responses received.

Will this project generate more than 1 gallon (4 liters) of battery waste per year?

No.

If yes, please indicate the type of batteries (alkaline, NiCad, NiMH, lithium ion or lithium metal) and the approximate amount of each to be generated.

Not applicable.

Will this project generate more than 15 gallons (60 liters) of hazardous liquid waste per year?

No.

2020 Proposal Process – Internal-Only Projects
Submission Deadlines: Phase I – July 17th at 8:00 a.m., Phase II – September 5th

If yes, please indicate the composition of the waste(s) and the quantity of each to be generated.

Not applicable.

Specific deliverables

The specific deliverables for 2020 are:

- Requirements document for multi-vehicle simulation framework.
- Labor scope and hour estimate for integrating an open-source simulation framework (e.g., ROS-Gazebo) with LRAUV's existing software ecosystem.
- Multi-vehicle simulation framework interface document and software architecture block diagram.
- Prototype multi-vehicle simulator for LRAUV (proof-of-concept).

Milestones and required personnel (see [personnel classification list](#) for staff classifications):

2020 Project Start Date: 01/01/2020	Milestone 1	Milestone 2	Milestone 3	Milestone 4	Total Resources⁴ (in hours) for each resource category for all milestones listed here
Milestone Date	Feb, 10	March, 20	April, 20	July, 20	
Milestone Description	Requirements doc. formulated	Candidate open-source framework(s) identified	Concept design review completed	Proof-of-concept prototype completed	
Research Engineer					
Zhang	10	10	20		40
Research Specialist					
Ryan	10	10	20		40
Electrical Engineer					
Software Eng-Embedded					
Kieft	5	10	25	20	60
McEwen	5	10	5	80	100

⁴ This number should be the same number you entered on the resource requests for this particular resource.

2020 Proposal Process – Internal-Only Projects
Submission Deadlines: Phase I – July 17th at 8:00 a.m., Phase II – September 5th

Software Eng-Info Eng					
Mechanical Engineer					
Hobson	5	--	15	--	20
Mechanical Eng-Division					
Mechanical Eng-Mfg					
Associate Engineer					
Raanan	40	80	80	120	320
Electrical Tech					
Software Tech					
Mechanical Tech					
Machinist					
Divers					

Budget justification

Personnel:

Ben Raanan: 320 hours

- 40 hours for project management, assembling use cases, and formulating a requirements document.
- 80 hours for conducting survey and evaluating candidate open-source SW for underwater multi-vehicle simulation.
- 80 hours for scoping integration effort with LRAUV's software, concept development, and preparing materials for a concept design review.
- 120 hours for developing a proof-of-concept multi-vehicle simulation environment for LRAUV.

Rob McEwen: 100 hours

2020 Proposal Process – Internal-Only Projects
Submission Deadlines: Phase I – July 17th at 8:00 a.m., Phase II – September 5th

- 20 hours for open-source software evaluation and concept development.
- 80 hours for development of proof-of-concept simulation environment for LRAUV.

Brian Kieft: 60 hours

- 10 hours for open-source software evaluation.
- 30 hours for scoping integration effort with LRAUV's software and concept development.
- 20 hours for development of proof-of-concept simulation environment for LRAUV.

Yanwu Zhang: 40 hours

- 10 hours for open-source software evaluation.
- 30 hours for scoping integration effort with LRAUV's software and concept development.

John Ryan: 40 hours

- 40 hours for open-source software evaluation and concept development.

Brett Hobson: 20 hours

- 20 hours for scoping integration effort with LRAUV's software and concept development.

Equipment: Total=\$4,000

- \$4,000: High performance desktop PC with graphics accelerator for running the simulation physics engine and rendering of the simulated environment.

Project team

Yanwu Zhang will be the PI and John Ryan will serve as the project's lead scientist. Together, they will provide guidance to ensure that relevant science use cases are represented and that MBARI can benefit from the concepts developed under the project. Ben Raanan will be project manager and lead engineer for all activities. Rob McEwen will lead development as it pertains to physical fidelity of the simulation, rigid-body dynamics, and vehicle control. Brian Kieft and Brett Hobson will support the evaluation process and concept development.

Our project is related to work conducted under the User-centered design and development of interfaces for scientists to more efficiently and effectively deploy AUVs project. Consequently, we will work with Brian Kieft and Leila Takayama to coordinate our development efforts.

Project lab and office space requirements

In addition to any changes to current space usage, please also include anticipated office and lab needs for students, postdocs, collaborators, etc.

None.

R/V Paragon Requests

If the project team will be requesting time for the R/V Paragon, please specify the operators in the group and provide estimates of their availability to operate the vessel. DMO staff have extremely limited availability to be operators and only with advanced budgeting and planning.

None.

Risk matrix (development and infrastructure projects only)

	Technical Risk	Organizational Risk	Tech Transfer Risk	Labor Estimate Risk
High				
Medium				
Low	X	X	X	X

d) Compliance Considerations

Export Regulation

Does the project team anticipate any foreign collaborations or international travel? If so, please identify collaborators by name, institution, and country.

Not applicable.

Does the project team plan or anticipate export-controlled purchases, shipments, or transfers of items (e.g., research instruments, proprietary data, hand-carried tools or samples) outside the U.S. temporarily or permanently? If yes, please identify country or countries and indicate whether these items will remain under MBARI control while abroad or controlled by others. Will the items be exported to more than one country? Please include foreign collaborator information as described above.

Not applicable.

Monterey Bay National Marine Sanctuary (MBNMS)

General Permit

Projects teams need to indicate if any work will be performed that is either: (1) currently authorized under our general permit; or (2) will require that we obtain authorization. The current permit can be

2020 Proposal Process – Internal-Only Projects
Submission Deadlines: Phase I – July 17th at 8:00 a.m., Phase II – September 5th

viewed at http://mwww.mbari.org/pco/permits/mbnms-2015-002_feb2015.pdf. Please see Mandy Allen for questions.

Is a permit with MBNMS required for your work?

No.

SESAs ([General map](#))

Projects will need to indicate whether or not work will be conducted within one of the Monterey Bay National Marine Sanctuary's Ecologically Significant Areas (SESAs). An interactive map can be found on the Sanctuary's SIMoN webpages at https://sanctuarysimon.org/regional_sections/maps/mpaviewer/. If your work will be conducted in one of these areas, please indicate which area by number or name (zoom in to see names of MPAs).

None.

California Department of Fish & Wildlife

A Scientific Collecting Permit will be required for biological and geological sample collections offshore California (even in Federal waters and beyond), and for many activities in State Marine Protected Areas. Please see Mandy Allen for questions.

Will you be collecting samples that require a permit?

No.

Will you be working in a [State Marine Protected Area](#)?

No.

United States Coast Guard

If your project will deploy or maintain moorings, the project team must ensure proper compliance and notification of these activities to the US Coast Guard. DMO does not automatically do these notifications on behalf of projects. Two common types of permits and notifications that may apply to your project are [Private Aid to Navigation \(PATON\)](#) authorizations (required for buoys deployed for six (6) months or longer) and Notice to Mariners, which must be submitted for temporary PATONs (less than 6-month deployments). Other science operations may submit a request for a [Local Notice to Mariners](#) and are useful for missions or deployments with risk of 3rd Party Liability such as the Wave Glider.

Will your project require a PATON?

No.

If yes, have you obtained a PATON? (Please provide a copy to Mandy Allen.)

2020 Proposal Process – Internal-Only Projects
Submission Deadlines: Phase I – July 17th at 8:00 a.m., Phase II – September 5th

No.

Will your project require submission of a Local Notice to Mariners?

No.

If yes, please indicate who will be submitting request and provide a copy of the submission to Mandy Allen.

Not applicable.

Authorizations/Permits from other Agencies or Organizations

Is the project team aware of any other permits or authorizations that will be necessary to perform the proposed work? If so, please list below along with status of authorizations (obtained, pending, need to apply, etc.). Please see Mandy Allen if you have questions.

None.

Active Acoustics

We are keeping an inventory of acoustic instrumentation. The current list is posted here: https://mww.mbari.org/resources/2019_Proposal_Process/documents/mbari_acoustic_instruments_updated_july_2018_ver_12.xlsx. If you have or plan to use equipment that is not already on this list, please be sure to include that information here.

Not applicable.