Project Number: 901800

Project Start: Jan. 1, 2018[1] **Project Duration (in years): 3**

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

[X]	[ ]	[X]	[X]	[ ]
Ship Time	**ROV**	**AUV**	**Wave Glider**	**Mini ROV**

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

[ ]	[X]	[ ]	[ ]	[ ]	[ ]	[ ]
Feasibility/Scoping [Less than 100 days effort]	**Development[2]**	**Research**	**Infrastructure[2]**	**Education**	**Time Series**	**Institute Initiative**

Project Manager[3]: Brett Hobson

Principal Investigator: Brett Hobson

Lead Scientist: Francisco Chavez, Yanwu Zhang, Kelley Benoit-Bird, Chris Scholin, Steve Haddock

Lead Engineer: Brian Kieft

Project Title: LRAUV Payloads

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

[ ]	[X]	[ ]	[ ]
Ocean biogeochemistry	**Ecosystem dynamics**	**Ocean visualization**	**Exploration & discovery**

Please indicate percentage of effort on this project anticipated for 2019 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 transfer[4]
Percentage	70	30	

[1] This date and number should remain the same for the duration of the project. If your project start date for 2019 is not January 1, please indicate the start date in the first cell of the milestone chart. Format for duration example: "Year 2 of 5".
[2] Development and infrastructure projects must complete the risk matrix (see end of the proposal form).
[3] 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.
[4] This category includes transfer of hardware, know-how, publications, presentations, etc.

1) ABSTRACT (new projects only)

[Paste abstract here]

2) PROPOSAL

a) All Projects

Statement of the challenge, why it is important

One of the greatest challenges to understanding ecosystem dynamics in the open ocean is predicting where and when important features exist and then observing and sampling those features for days to weeks. Building on the capabilities of the Long Range AUV, MBARI is finally able to begin addressing this challenge with an array of LRAUVs configured with complementary sensors that work together as an O**pen Ocean, AUV-based Lagrangian Observatory.** Using careful mission planning based on remote sensing and the historical patterns together with on-board target sampling techniques we have shown we can find important hot-spot edge effects like fronts and layers. Once these features are located, the Lagrangian drift mode of the LRAUVs are used to mark, follow, and sample features for over one week and marker vehicles can be replaced as batteries or sampler are exhausted. Through inter-vehicle communication and location other LRAUVs can monitor the relevant water parameters around the feature and soon be able to use stand-off acoustics to identify backscatter targets within and around the feature. Other LRAUVs equipped with a bathyphotometer, and soon cameras, microscopes and nutrient and other sensors will be able probe the feature, collecting data that can be placed in the reference frame of the feature over time. And this observatory can be deployed and used without a ship and work far from land.

This is a proposal for the second year of a three year project. We seek to make improvements in the bredth and duration of the observations and improve the usability of the system by making the LRAUVs more reliable and easier to use.

Collaborator	Project	Project #	Description
Chavez	CANON	901009	Application dev. and Ops. support
Scholin	ESP	901205	Application dev. and Ops. support
Benoit-Bird	Bio-Acoustics	901700/901800.98	Instrument Intg. and Ops. Support
Haddock	Bioluminescence	901103	Instrument Intg. and Ops. Support
Zhang	Targeted Sampling	901513	Application dev. and Ops. support
Hamilton	AUV Docking	901405	Application dev., Instr Integ. and Ops. support
Rock	PC/TRN	600034	On-board processor Integ. and Ops. Support
Chaffey	Camera	901804	Instrument Intg. and Ops. Support
Messie/Haddock	Plankton Proxies	703001	On-board processor Integ. and Ops. Support
Kemp	Fault Prognostication	901706	Application dev. and Ops. support
Katija	Mesobot	701136	Technology export
Hobson	DHS/WHOI	708135/708156	Technology export

Figure 1: LRAUV Collaborators

Relevance

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

This project is focused on the Ecosystem Dynamics theme of MBARI's Strategic Plan by developing an ability to possibly follow and document the trophic evolution of entire ecosystem as it evolves from raw nutrients in freshly upwelled water, to the phytoplankton blooms through to zooplankton grazing, fish and whale predation.

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

If this effort is supported, MBARI scientists will be able to program the LRAUVs to find transient areas of high productivity though bio-acoustics for **Targeted Sampling** and use the on-board sensors to distinguish different plankton species, which is taking the **Lab into the Ocean** and then park offshore until a second or third sampling session is initiated, which is **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.)

This proposed effort aims to illuminate a holistic view of the ecosystem dynamics in the open ocean, the largest biome on the planet. This expanded understanding of the ocean can be used to improve the models of open ocean CO_2 uptake and predict the effects of proposed open ocean aquaculture.

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.)

Engineering/Technology Development

The LRAUV Payloads project forms the nucleus of a growing body of MBARI researchers and external collaborators that are working together to make sustained observations at scales from microbes to whales. This project is reaching out to recruit new users of autonomous vehicles, the drones of the sea, and to be successful the LRAUV needs to be useable by the science teams, not just specialist operators. It needs to be relatively easy to get these instruments in the ocean, keep them at sea for weeks at a time, and coordinate multiple platforms to work together. This requires platforms that are reliable and are paired with software tools to make them easy to use. There is still a lot of room for improvement and this proposal is the next step in the development process.

This proposal is broken into four sections:

1. Support for Science Operations: This is where we detail the support the engineering team offers to the science users.
2. Vehicle Payloads: This is where we propose to increase the breadth, range or accuracy of measurements
3. Vehicle Improvements: Incremental tasks to extend vehicle capabilities or make the vehicles more reliable or accurate.
4. End-User Enhancements: This section is how we are trying to make the LRAUVs easier to use.

5. Project Management: This is the glue section that holds us all together and keeps the project resilient to challenges.

Marine Operations/Field Programs

Most of the LRAUV field operations are detailed in the individual science proposals. Field operations to support the development tasks in this proposal area outlined in section 1 below.

Data

What data products will be generated?

The LRAUV data is generated in netcdf and matlab files that contain both science and engineering data while the vehicles are at sea.

How will the data products be managed?

The basic data flow is currently automated. Binary files are downloaded from the vehicle and copied to the Atlas server. From there they are ingested into STOQs.

Describe data availability outside of the project team.

All data are available via the STOQS interface shortly after a vehicle returns to shore.

Describe data storage requirements.

10-50 Gb per year per vehicle.

Anticipated Impact

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

MBARI PIs and collaborators are the primary consumers.

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

The LRAUV program made significant contributions to the scientific community over the past year. The fleet of vehicles spent over 2,500 hours at sea with a fleet lifetime of over 16,000 hours at sea. Reliability is increasing and more operators are participating in running vehicles. MBARI's first LRAUV *Tethys* set a new record of 12 days without an unplanned operator intervention. As operating overhead decreases, opportunities for

groundbreaking science increase. Most notably was the official export of 3 ESP enabled LRAUVs to the University of Hawaii. This transition took place during a month long cruise aboard the *R/V Falkor* in the spring and showcased the impact that the combination of both platforms provide studying microbes in open ocean eddies. While providing support for ongoing science operations, development and vehicle enhancements continued. A "back seat driver" interface and lightweight communications and marshaling (LCM) data middleware infrastructure were added allowing for future use of other computers and instruments to interact more efficiently and effectively with the LRAUV's main computer. These additions also offer extensibility of the system and have allowed re-use of the core architecture in future vehicle designs such as the Mesobot collaboration with WHOI. The past year also saw the first time a suite of autonomous vehicles have been solely responsible for collecting time series data. The LRAUVs, along with a Waveglider, and Dorado have been running the Monterey Bay Time Series (MBTS) line and collecting water samples for analysis in the BOG lab. The MBTS deployments are run monthly by lab staff and rarely require intervention from the LRAUV team.

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

This project has used about 56% of our overall labor during the first half of the year and 53% of our expense budget.

Will you complete the current year's scheduled work?

We expect to complete all but a few small software tasks during 2018.

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

Significant changes from previous project proposal

There are no significant changes from the previous proposal.

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

Raanan, Ben & Bellingham, James & Zhang, Yanwu & Kemp, Mathieu & Kieft, Brian & Singh, Hanumant & Girdhar, Yogesh. (2017). Detection of unanticipated faults for autonomous underwater vehicles using online topic models. Journal of Field Robotics. 10.1002/rob.21771.

Yanwu Zhang, Brian Kieft, M. Jordan Stanway, Brett W. Hobson, James G. Bellingham, Robert S. McEwen, John P. Ryan, Thomas C. O'Reilly, Ben Y. Raanan, Monique Messi´e, and Jason M. Smith, and Francisco P. Chavez. "Isothermal Tracking by an Autonomous Underwater Vehicle in drifting Mode." *Journal of Oceanic Engineering*, n.d.

Y. Zhang, J. G. Bellingham, J. P. Ryan, B. Kieft, and M. J. Stanway. "Autonomous 4-D Mapping and Tracking of a Coastal Upwelling Front by an Autonomous Underwater Vehicle."*Journal of Field Robotics* 33, no. 1 (January 2016): 67–81.

Chavez, F., Pennington, J.T., Michisaki, R., Blum, M., Chavez, G., Friederich, J., Jones, B., Herlien, R., Kieft, B., Hobson, B., Ren, A., Ryan, J., Sevadjian, J., Wahl, C., Walz, K., Yamahara, K., Friederich, G., Messié, M., 2017. Climate Variability and Change: Response of a Coastal Ocean Ecosystem. Oceanography 30, 128–145. https://doi.org/10.5670/oceanog.2017.429

Supported LRAUV technology and science applications at Open Houses at MBARI and Falkor

Participated in a Google Hangout with school classrooms to talk about the LRAUVs on the Falkor

c) Specific Plans for 2019

Engineering/technology development

1. **Support for science operations**

   1.1. **CANON:** Support for mission and behavior alterations within the LRAUV application to support two CANON field programs.
   1.2. **Bioluminescence Deployments:** This task supports vehicle operations support for the offshore testing of a prototype version of the vehicle propeller excited biloluminescense sensor.
   1.3. **Line Capture Development Testing:** Sea-testing of the basic functionality of the DUSBL and then a series of un-manned homing tests.
   1.4. **Tow-Out / Anchor Event Response**: Sea-testing of Waveglider tow-out and a variant of the technique where the LRAUV releases from an seafloor anchor instead of the Waveglider. The Waveglider tow-out

2. **Vehicle Payloads**

   2.1. **Bioluminescence sensor for open propeller, Klimov Biolum**
   Plans for the 2018 integration of a WetLABS UBAT bathyphotometer offers an excellent opportunity of validation and calibration of a method of measuring bioluminescence on an open propeller potentially allowing continuous dusk-to-dawn measurement using vehicle propulsion energy to excite bioluminescence. The UBAT instrument consumes as much energy as the vehicle thruster, most of which is used to excite bioluminescence with an internal thruster. In addition, the UBAT is large and consumes the entire payload bay. We believe The Klimov Biolum instrument can be made small and low power enough to be a core sensor on all LRAUVs. Two optical detectors are going to be combined into one compact pressure housing just forward of propeller on the bottom of rear fairing, in order to pick up bioluminescence from the tips of the propeller blades in one channel, and background light from outside of the propeller in another channel, as a reference. The differential signal is going to be amplified and sent to appropriate LCB in LRAUV dry bay. To reduce material cost, the electrical interface of the bioluminescence sensor is going to be unified with existing PAR sensor as much as possible, so they could be used interchangeably.
   To check the feasibility of the method and geometry of the bioluminescence trail induces by the open propeller, the bench test setup was built and tested in 2017. The setup consists of glass jar 7”

diameter and 18" tall, a 2" diameter dual-blade plastic propeller; attached to 2 mm stainless steel shaft, and driven by shaded pole electric motor with the speed controller (fig2). This setup represents a 1:5 scale-down model of LRAUV propulsion drive. The bioluminescence had being observed with a mixture of concentrated culture *Pyrocystis fusiformis* mixed with 6.5 liters of filtered seawater, using color industrial Imaging Source camera placed in front of the vessel, and set to 1 sec image accumulation (fig 1); at propeller RPM set at about 700-800 RPM to achieve adequate linear speed of propeller blades. Setup had being covered by light-tight enclosure in order to achieve low-light environment. The geometry of observed bioluminescence trail in reference to propeller dimensions allows preliminary selecting of the placement of detectors on the LRAUV fairing and optical envelopes of detectors.

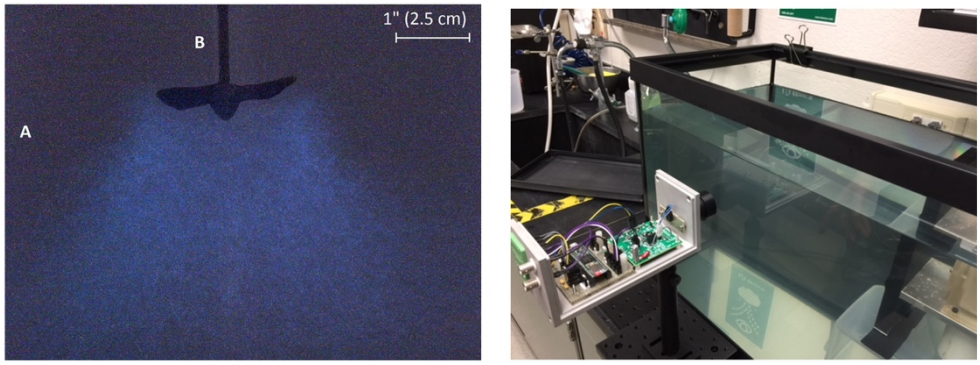

Figure 2. Bioluminescence profile induced by the rotating propeller; superposition of 2 photos: (A) photo of trail with rotating propeller; (B) photo of stationary propeller for scale and position reference. The prototype detector/amplifier/acquisition unit looking into a test aquarium on the right.

2.2. Line Capture

Collaborators at WHOI have developed, refined and exported to Hydroid an electro/mechanical system that includes deployable tines and a cable latch in an oil-filled and compensated housing (below), along with an integral acoustic homing sensor (below right). This unit is being integrated onto the WHOI/DHS's LRAUV under support from DHS. There is an opportunity to extend the planned basic functionality testing in Monterey Bay to include more rigorous homing line capture testing. The line capture capability will be required when WHOI/DHS begin operating their vehicle under ice in the arctic, which isn't scheduled until 2020. Therefore, WHOI DHS wasn't planning to develop the line capture capability until 2019. We propose MBARI capitalize on the availability of the WHOI/DHS vehicle and support this extended testing. If this testing demonstrates a reliable solution, MBARI can purchase the critical components (~$60k) under the 2020 proposal.

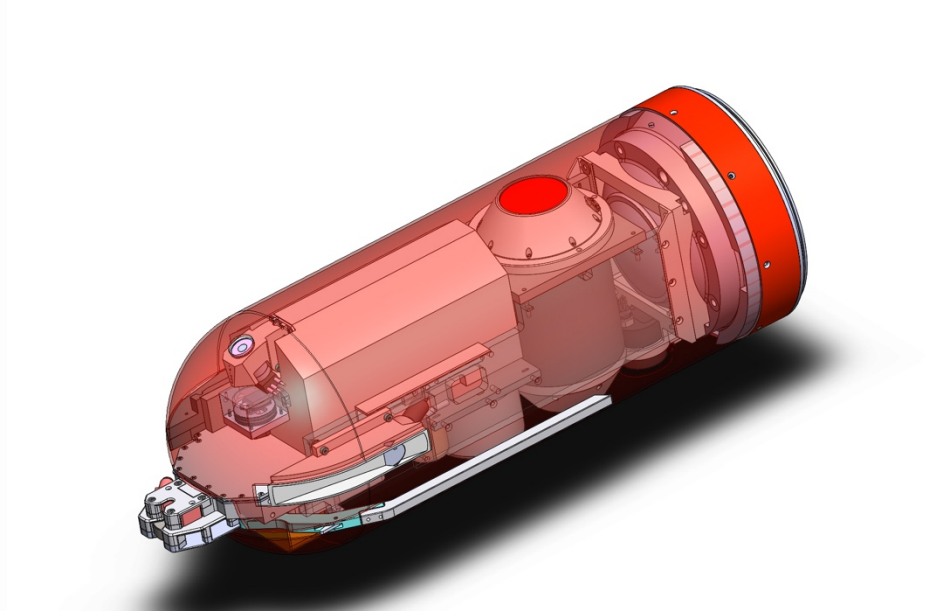

Figure4: WHOI LRAUV Line Capture System and DUSBL

2.2.1. Electro-Mechanical Integration: This task is mostly supported under existing DHS funding though we anticipate some minor modifications will be required for the MBARI tests.

2.2.2. Software Integration: An instrument driver will be developed to work a new line capture mission to arm the device, operate the USBL homing sensor, detect a cable and latch the cable. We have demonstrated acoustic homing on the LRAUV with the 360 degree DAT and we believe the 2D, narrow field-of-view WHOI homing USBL will work even better, if the vehicle is able to point towards the target.

2.2.3. Homing Algorithm, USBL integration and Simulator mods: These are tasks for Rob McEwen to reacquaint himself with the LRAUV code base and simulator, and make changes to those systems to facilitate him using them efficiently. The old homing mission will be cleaned up and the new WHOI DUSBL sensor will be modeled and added to the simulator.

2.2.4. Tow-out and Loiter Anchor Improvements: A prototype release mechanism to attach an LRAUV to the Wave Glider towbody will be built and tested in the Fall of 2018 but we expect there to be improvements needed so engineering time and technician time is requested here. We will also use this release mechanism to all the LRAUV to release from a seafloor mooring. An expendable (steel or rock) anchor and degradable riser (manila rope) will hold a buoyant LRAUV in place for up to two weeks. A Wave Glider can transmit an acoustic "release" command, just as it will for the Tow-out technique.

3. **Vehicle improvements**

3.1. **Outside Services. Underwater Acoustic Communications and support**.

In 2018 the Goby Underwater Autonomy Project was integrated into the LRAUV Software system, providing the LRAUV with a robust solution for reliable underwater

modem communications. Initial testing was performed in the lab and initial sea trials are planned before 2019. Further tasks for outside services include:

3.1.1. Encapsulate specific types of data (such as a lat/lon/time fix) as structures that can be transmitted as single data element

3.1.2. Modify the command line to accommodate setting and getting such structures

3.1.3. Extend Tethys simulator to handle simulation of multiple vehicles working in coordination.

3.1.4. Provide example Tethys mission scripts for multi-vehicle patch tracking missions and simulations of such missions.

3.1.5. Provide debugging assistance and code-writing advice on LRAUV and TethysDash software systems, as challenges are identified in Jira and BitBucket tickets.

3.2. **Deep Variable Buoyancy Integration:** Integrate a new pump motor allowing the LRAUVs to operate in "drift" mode across their entire operating depth. This greatly increases vehicle endurance especially for longer sampling missions when a lagrangian sampling technique is desired. The prototype pump/motor was developed and tested in 2018 and will be ready for integration onto all vehicles in 2019.

3.3. **Battery Pack and DAT upgrade for *Makai:*** *Makai* has the prototype battery pack that was assembled with 2.8 A-hr cells (3.4 A-hr cells are standard – 20% more capacity) and doesn't have a Directional Acoustic Transducer (DAT). Our fleet management plan relies on all vehicles being interchangeable so this task and expense are required to bring *Makai* up to the standard configuration. This provides the ability to run the longer duration missions necessary for the 60 sample ESP component. A DAT will allow Makai to circle or home to an acoustic target such as a Waveglider, an LRAUV, or a dock/wire capture device.

3.4. **Battery charger replacement investigation:** Due to deprecation of the existing hardware, a new battery charge controller is needed. This task is to investigate solutions to be proposed for 2020.

3.5. **Battery and Load Control Subsystem Support and Troubleshooting:** This task provides general support for the battery and load control subsystems. It includes troubleshooting, configuration management, and inventory management.

3.6. **Data Analysis:** Analysis of science and engineering data following missions to investigate anomalies and confirm data quality. Specific plots as needed.

3.7. **Intervention Reduction:** Reduce the number of false positive critical failures such that human user interventions are reduced generally across the fleet of vehicles.

3.8. **SBIT / Configuration Automation:** Currently Startup Built In Test (SBIT) does not fully test all instruments that are in the vehicle configuration. Add this feature to provide a go/no go status to the user. Some sensor inventory management onboard the vehicle will also be added as part of this task.

3.9. **Thruster motor controller power reduction**: The existing propulsion motor is efficient and well suited to its task, but is being driven by a general purpose servo drive with much higher bandwidth than needed, and corresponding overhead power consumption of 1-2 watts. This wastes as much as several percent of vehicle battery capacity during long duration deployments. Higher efficiency motor drive chips are available, which should be adaptable to the LRAUV propulsion application resulting in a roughly 10X reduction in overhead power and several percent increase in endurance on low-power missions. A suitable chip will be paired

with an inverter (power stage) and placed on a D-shaped card, replacing one Load Control Board and freeing space currently occupied by the servo drive.

3.10. **Backseat Computer hardware**: integrate a secondary computer or System on Module (SOM) unit on the LRAUV to support on-board science applications and relieve CPU load from the main SOM unit. The infrastructure for a secondary SOM is already supported by the existing LRAUV motherboard 3.x hardware; this task covers adaptations to the motherboard, linux kernel, and other relevant existing components, as well as configuration, installation, testing, and troubleshooting of the secondary unit.

3.11. **Backseat Computer Interface**: define and implement a generic software Application Programming Interface (API) for talking to the main vehicle program from secondary or backseat computer.

3.12. **App and Kernel Tuning:** Various modifications to the kernel (computer operating system) and the LRAUV program to reduce system lockups, increase SD card performance, and tune operations to reliably run on the low power computer necessary for long-range or persistent platforms.

4. **End User Enhancements** This section encompasses work on the command and control aspects of the LRAUV as well as situational awareness of the fleet.

4.1. **Intuitive vehicle status reporting**

4.1.1. Graphical definition of waypoints for select missions using as much available open source code as possible (e.g. Neptus)

4.1.2. Vehicle configuration and command queue display including which instruments are currently active and a clear representation of the status of the scheduler.

4.1.3. Data telemetry configuration tools

4.2. **Documentation**

4.2.1. Define workflow for documentation development, revision, and protocol for integration in official space.

4.2.2. Coordinate with users that will be providing input for documentation (e.g. UH)

4.2.3. Write documentation

4.3. **Merging FleetStatus and TethysDash**

4.3.1. Continue integration of FleetStatus and TethysDash GUIs as part of the TethysDash3 frontend.

4.4. **TethysL Mission Authoring Tool**

4.4.1. Continue evaluation/refinement based on user feedback (syntax/semantics, ease-of-use) toward stability/usability improvements of the language and documentation enhancements.

4.4.2. Make TethysL editor stable and fully integrated with LRAUV/TethysDash system and replace all existing missions with TethysL missions.

4.4.3. Expose TethysDash/LRAUV mission definitions and execution via Planning Execution Service as developed in CANON

4.5. **Metadata enrichment** –

4.5.1. Add more descriptive meta data to netcdf file outputs for things like instrument serial numbers, calibration coefficients, etc. This task may require updates to unserialize and/or updates to the LRAUV application software.

4.5.2. Science users data resolution - 2 to 4 second averaged science data (averaged to reduce noise prior to linear approximation) to shore via SBD or cell. Ideally this resolution could be changed by end users via the dash interface.

4.5.3. Engineering data quick plots - End users often need access to full resolution engineering data to review vehicle performance during a given mission. We propose a web app that allows users to display time/value plots and zoom in to full resolution.

4.5.4. STOQS Animation - LRAUV animations have proven very useful for analysis of vehicle dynamics. However performance at this time is fairly slow and needs to be updated to increase performance.

5. **Project Management**

5.1. **Overhead for meetings, etc**

This task allocates time for weekly meetings, scheduling, brainstorming for the team.

5.2. **Contingency to respond to issues**

In addition to the many successes of 2018 the team also spent time responding to failures and newly discovered bugs. While no specific issues can be listed here, the core team anticipates responding to similar issues in 2019. (e.g. ground faults, control surface overloads, environmental alarms, communications failures, incident reports, etc).

5.3. **Project Management**

This task covers general overhead related to project management and includes tasks like reporting, board updates, budget reviews, scheduling, etc.

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

Sixteen days of Paragon vessel support is requested. However, we normally only use the vessel for a few hours each day.

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://mww.mbari.org/safety/SafetyManual/Isotope_Use_Policy.pdf, and then provide details on plans below.

N/A

Specific deliverables

[Click here to enter text]

Milestones and required personnel (see personnel classification list for staff classifications)

[Click here to enter text]

2019 Project Start Date: MM/DD/2019	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Total Resources[5] (in hours)** for each resource category for all milestones listed here
Milestone Date						
Milestone Description	**Science Opps**	**Vehicle Payloads**	**Vehicle Improvements**	**End user Enhancements**	**Project Mgt**	
Electrical Engineer		**185**	**730**		**110**	**1025**
Software Eng-Embedded	**80**	**425**	**955**		**175**	**1635**
Software Eng-Info Eng				**730**	**50**	**780**
Mechanical Engineer	**105**	**535**	**110**			**1015**
Mechanical Eng-Division						
Mechanical Eng-Mfg						
Associate Engineer	**100**	**145**	**570**			**835**
Electrical Tech		**70**	**40**			**135**
Software Tech				**100**		**100**
Mechanical Tech		**25**	**100**			**125**
Machinist		**30**	**40**			**70**
Divers						

Budget justification

Item	Description	price	Notes
1	Makai Batteries (62@$122+)	$8,325	+25% capacity, match fleet
2	Makai DAT	$28,127	Match fleet
3	Compass for Makai and Daphne	$4,100	Match fleet
4	Outside Services (Intuaware)	$8,000	Task 3.1 Required for a-comms

[5] This number should be the same number you entered on the resource requests for this particular resource.

5	Instrument calibration	$5,300	
6	Iridium, Argos, Cellular airtime (6 vehicles)	$20,000	Estimate – without knowing total fleet request
7	Misc. spare parts for 6 vehicles	$10,000	Estimate
8	Lab supplies	$2,500	
9	Backseat computer	$1,500	
10	External boat rental	$1,000	~ six MLML RHIB rentals
11	Argos/VHF emergency relocation (3)	$3,500	Replace non-serviceable, sealed batteries
	Total =	$92,352	

Project team

Hobson, Kieft, Mellinger, Erickson, Klimov, O'Reilly, Rueda, Raanan, McEwen, Martin, Cline, McCann, Roman, Salamy

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.

Maintain current presence in shared Engineering lab upstairs Bldg. B

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.

Brett Hobson and Brian Kieft are Paragon captains.

Risk matrix (development and infrastructure projects only)

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

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.

No foreign travel or collaborators.

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.

No plans.

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

Is a permit with MBNMS required for your work?

Yes, we operate a WaveGlider and LRAUV in the Sanctuary

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

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_2018-05-29_ver_11.pdf. If you have or plan to use equipment that is not already on this list, please be sure to include that information here.

All active acoustics are on the list.

Appendix A: Labor

				575	515	745	500	250	125	135	70	635	680	815	275	30	100	200	100	150
			Totals	Kieft	Hobson	Mellinger	Erickson	Klimov	MT	ET	Machine	O'Reilly	Rueda	Raanan	McEwen	Martin	McCann	Cline	Karen	Roman
Support for Science Operations																				
	Description	Task ID																		
	CANON	1.1	45		5									40						
	Bioluminescence	1.2	20		20															
	Development -Line Capture Eng Test	1.3	90	40	20									30						
	Development - Tow-out and loiter/anchor	1.4	130	40	60									30						
	Total		**285**	80	105	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
Vehicle Payloads			**Totals**																	
	Description	Task ID																		
	Bioluminescence sensor for open propeller	2.1																		
	Lab testing	2.1.1	55	10				45												
	Electrical packaging for Test deployment	2.1.2	85					85												
	Integration	2.1.3	170	15			20	25	25	30	30			25						
	Testing	2.1.4	130	40				30				30		30						
	Line Capture	2.2																		
	Electro-Mechanical Integration	2.2.1	340		150		165			25										
	Software Integration	2.2.2	90	40										50						
	Homing Algorithim, USBL, Sim mods	2.2.3	250												250					
	Tow-out and Loiter Anchor Improvements	2.2.4	295	40	50		150			15				40						
	Total		**1415**	145	200	0	335	185	25	70	30	30	0	145	250	0	0	0	0	0
Vehicle Improvements			**Totals**																	
	Description	Task ID																		
	Underwater Acoustic Communications (outside services)	3.1	0																	
	Deep VB upgrade	3.2	260				80		100	20	40			20						
	~~GPS fast fix~~	3.3	0																	
	Makai update battery and DAT	3.4	50	10	20					20										
	Battery charger replacement investigation	3.5	40				10	20						10						
	Battery and LCS support and troubleshooting	3.6	40			20		20												
	Data Analysis	3.7	60											60						
	Intervention Reduction	3.8	115	55										60						
	SBIT / Config Automation	3.9	220	80								40		80		20				
	Thruster motor controller power reduction	3.10	690			640						40				10				
	Backseat Computer hardware	3.11	120	20										100						
	Backseat Computer Interface	3.12	740	40								500		200						
	App and Kernel Tuning	3.13	210	20										40						150
	Total		**2545**	225	20	660	90	40	100	40	40	580	0	570	0	30	0	0	0	150
End-User Enhancements			**Totals**																	
	Description	Task ID																		
	Integrated TethysDash/FleetStatus fully in place, with various outstanding	4.1.1	170										170							
	Make TethysL editor stable and fully integrated with LRAUV/TethysDash	4.1.2	200										200							
	Expose TethysDash/LRAUV mission definitions and execution via Planning	4.2.1	180										180							
	TethysDash/FleetStatus/TethysL documentation	4.2.2	80										80							
	Meta data enrichment	4.5.4	200															200		
	Science users data resolution	4.5.5	100														100			
	Engineering data quick plots	4.5.6	100																100	
	~~STOQS Animation~~	4.5.7	0																	
	~~Navigation correction~~	4.5.8	0																	
	Total		**1030**	0	0	0	0	0	0	0	0	0	630	0	0	0	100	200	100	0
Project Management			**Totals**																	
	Description	Task ID																		
		5.1	325	75	50	25	25	25		25		25	50		25					
	Contingency to respond to issues	5.2	190	50	30	60	50													
	Project Management	5.3	110		110															
	Total		**625**	125	190	85	75	25	0	25	0	25	50	0	25	0	0	0	0	0

	Task Name	Start	Duration	Work	Resource Names
1	**Support for Science Operations**	**1/1/19 8:00 AM**	**1 day**	**1,485 hrs**	
2	CANON	5/2/19 8:00 AM	108 days	45 hrs	Brett,Ben
3	Bioluminescence	8/1/19 8:00 AM	150 days	1,200 hrs	Brett
4	Development -Line Capture Eng Test	1/1/19 8:00 AM	110 days	100 hrs	Brett,Brian,Ben
5	Development - Tow-out and loiter/anchor	6/3/19 8:00 AM	152 days	140 hrs	Brett,Brian,Ben
6	**Vehicle Payloads**	**1/1/19 8:00 AM**	**261 days**	**5,061.68 hrs**	
7	**Bioluminescence sensor for open propeller**	**1/1/19 8:00 AM**	**261 days**	**120.68 hrs**	
8	Lab testing	1/1/19 8:00 AM	60 days	12.65 hrs	Denis
9	Electrical packaging for Test deployment	3/24/19 8:00 AM	60 days	19.53 hrs	Denis
10	Integration	6/1/19 8:00 AM	90 days	58.62 hrs	Denis
11	Testing	10/1/19 8:00 AM	60 days	29.88 hrs	Denis
12	**Line Capture**	**1/1/19 8:00 AM**	**110 days**	**4,941 hrs**	**Brett,Jon,Brian,Be**
13	Electro-Mechanical Integration	1/1/19 8:00 AM	72 days	340 hrs	
14	Software Integration	1/1/19 8:00 AM	45 days	90 hrs	
15	Homing Algorithim, USBL, Sim mods	1/1/19 8:00 AM	87 days	696 hrs	Rob
16	Tow-out and Loiter Anchor Improvements	7/5/19 8:00 AM	128 days	295 hrs	Brett,Jon,Ben,Briar
17	**Vehicle Improvements**	**1/1/19 8:00 AM**	**1 day**	**2,583 hrs**	
18	Underwater Acoustic Communications (outside services)	1/1/19 8:00 AM	130 days	53 hrs	Intuaware
19	Deep VB upgrade	1/1/19 8:00 AM	261 days	260 hrs	Jon
20	Makai update battery and DAT	1/1/19 8:00 AM	44 days	50 hrs	ET,Brett,Brian
21	Battery charger replacement investigation	1/1/19 8:00 AM	44 days	40 hrs	Denis
22	Battery and LCS support and troubleshooting	1/1/19 8:00 AM	261 days	40 hrs	Denis
23	Data Analysis			60 hrs	Ben
24	Intervention Reduction			100 hrs	Ben,Brian
25	SBIT / Config Automation			220 hrs	Ben,Brian
26	Thruster motor controller power reduction	1/1/19 8:00 AM	261 days	690 hrs	Ed
27	Backseat Computer hardware	7/1/19 8:00 AM	132 days	120 hrs	Brian,Ben
28	Backseat Computer Interface	7/1/19 8:00 AM	132 days	740 hrs	Tom
29	App and Kernel Tuning	5/1/19 8:00 AM	109 days	210 hrs	Brent
30	**End-User Enhancements**	**1/1/19 8:00 AM**		**1,110 hrs**	
31	Integrated TethysDash/FleetStatus	1/1/19 8:00 AM	30 days	270 hrs	Carlos
32	Make TethysL editor stable and fully integrated with LRAUV/Tethy	2/12/19 8:00 AM	30 days	200 hrs	Carlos
33	Expose TethysDash/LRAUV mission definitions and execution via P	3/26/19 8:00 AM	30 days	240 hrs	Carlos
34	TethysDash/FleetStatus/TethysL documentation	5/7/19 8:00 AM	30 days	180 hrs	Carlos
35	Meta data enrichment	1/7/19 8:00 AM	1 day	80 hrs	Danielle
36	Science users data resolution			40 hrs	McCann
37	Engineering data quick plots			100 hrs	Karen
38	**Project Management**	**1/1/19 8:00 AM**	**261 days**	**625 hrs**	
39	Overhead for meetings, etc.			325 hrs	Group
40	Contingency to respond to issues			190 hrs	Brett,Brian,Ben,Ed,
41	Project Management			110 hrs	Brett