Project Number: 902101

Project Start: Jan. 1, **2021**[1] **Project Duration (in years):** **3**[1]

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

[ ] Ship Time	[ ] ROV	[x] AUV	[ ] Wave Glider	[ ] Mini ROV

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

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

Project Manager[3]: Brett Hobson

Principal Investigator: Brett Hobson

Lead Scientists: Francisco Chavez, Yanwu Zhang, Kelly Benoit-Bird, Chris Scholin, Steve Haddock

Lead Engineers: Brian Kieft and Ben Raanan

Project Title: LRAUV Technology Development and Fleet Operations

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

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

[1] This date and number should remain the same for the duration of the project. If your project start date for 2021 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.

Please indicate percentage of effort on this project anticipated for 2021 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	50	25	25

[4] This category includes transfer of hardware, know-how, publications, presentations, etc.

1) ABSTRACT (if submitted during abstract phase)

This umbrella project seeks to tie all of the various LRAUV related efforts together, and bridge gaps with new development. Our shared vision is that in the near future LRAUVs will be working together with complementary sensors for months at a time in remote corners of the ocean, being recharged from energy harvested from the waves and sun to find, follow and sample hot spots of interest to ocean scientists at MBARI and beyond. This vision builds on a robust foundation. During the past ten years, we have built a fleet of vehicles and assembled a capable team of engineers, operations support and most importantly, a group of MBARI scientists who are finding new and novel ways to address their science questions using LRAUVs. To help identify the next steps in vehicle research, development and operations, we are looking to address the following:

1. How can we keep vehicles operational for months at a time to match the time scales of change for the ocean systems they are observing? How do we get vehicles out to remote work sites, and recover and return vehicles, even if they suffer a failure, without a ship?
2. How can users create their own missions, run sophisticated target sampling algorithms on the vehicles and then troubleshoot, and simulate their work before heading out to sea? How can we export this technology for use by other ocean scientists and use-cases?
3. Can we use the LRAUVs near the seafloor to image and map in places like Sur Ridge or other more remote locations at depths down to 1500 meters?
4. What does it take to maintain a fleet of LRAUVs and what minor upgrades are required to keep the fleet responsive to the user's needs?

During 2021 we propose the following work:

1. **Persistence:** (a) Improve Wave Glider Tow-out and (b) develop AUV docking in collaboration with Hamilton's Niobicon power transfer project, and (c) Investigate Surface vehicle-based launch and recovery options.
2. **Autonomy and Export:** (a) Refine TethysL mission authoring to allow non experts to write missions, (b) continue to develop the LCM vehicle interface and backseat computer environment so users can interact with the AUV and develop their own programs for path planning, targeted sampling, swarm behaviors or anything else, and (c) more aggressively market the LRUV platform outside MBARI with ITD at trade shows and with the MiVEGAS vehicles to pursue collaborations with groups like NOAA, USGS, US Coast Guard, ONR and others.
3. **Capabilities and payloads**: Continue implementing and testing TRN and the low-altitude bottom following system developed under Rock's Precision Control project, (b) with external funding from DHS and collaboration with WHOI complete a high resolution seafloor mapping payload and (c) develop the 1500 meter depth rating upgrade for LRAUV Tethys under project 902010.
4. **Infrastructure**: This is ongoing support for the platform and includes (a) refinements and support for the Dash, and (b) the vehicle software, as well as range extension through (c) thruster motor controller loss reduction, and (d) the replacement of the COTs battery chargers that are no longer available. Maintain support and minimal improvements of key technical systems with the engineers who developed them.

2) PROPOSAL

a) All Projects

Statement of the challenge, why it is important

The ocean is our most precious resource yet we still do not fully understand how the nutrient, microbial and biological systems work, not to mention that they're all changing under the stress of global climate change and other anthropogenic impacts. In the face of this, we are losing our traditional access to the ocean through reductions in the oceanographic research fleet. Fortunately, robotic ocean exploration vehicles are available and are finally smart, reliable and capable of conducting continuous observations of the nutrient, microbial and biological systems at time and spatial scales that can reveal new discoveries that were not possible from platforms limited by the humans within. MBARI's LRAUV and the breadth of payloads now available are at the forefront of this new robotic exploration revolution. Over the previous 11 years, MBARI developed from scratch the LRAUV system and along the way entrained many of the researchers. The next phase of development should be focused on autonomy, persistence and export of the technology to external collaborators and licensees.

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, one of the outcomes will be that MBARI scientists will be able to program the LRAUVs to find transient areas of high productivity for **Targeted Sampling** and use the on-board sensors to distinguish different plankton species, which is taking the **Lab into the Ocean** and then follow the feature, with the initial vehicle being replaced with a second or third sampling vehicle at that precise location, 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

Our plan is to develop a fleet of un-crewed vehicles that can autonomously work together, without human or ship support, to find, follow and sample the patchiness of the ocean and map and image important seafloor features. To achieve that plan we need the sustained support of a team of engineers, technicians, marine operations experts and expense funding working in concert with scientists to keep the develop focused on the most important questions facing ocean science today.

Data

What data products will be generated?

The LRAUV data is generated in binary, netcdf, and MATLAB files that contain both science and engineering data while the vehicles are at sea. Some video files will be collected, though most will be handed off to the science champions.

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 and TethysDash web interfaces shortly after a vehicle returns to shore.

Describe data storage requirements.

Approximately 10-50 Gb per year.

Anticipated Impact

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

MBARI Science PIs are the primary consumers of the technology developed under this project.

Anticipated Outreach

What outreach assets might you need to better reach the audience/consumers you are targeting? Specify how you might like to reach your audience (published paper, seminar, conference, social media, etc.) and what type of assets (graphic, animation, video, etc.) you might need ITD to help generate.

To help us "sell" the technology developed under this project we request ITD support to generate illustrations showing how the technology developed here could be used to solve ocean science problems.

Intellectual Property (IP) Considerations

Do you anticipate a need for a cooperative research and development agreement or licensing arrangement with an external entity?

Yes, we hope to expand our existing licensing agreement beyond WHOI during 2021.

Will novel IP be created, and how might it be disseminated (e.g., open-source, royalty-free license, commercial license agreement)?

Yes, we expect novel IP to be created under this project and that we will choose to license that technology.

Will the work potentially result in a patentable product or service?

Yes, it is possible patentable devices or procedures will be developed.

For additional guidance please review MBARI's intellectual property internal web page: https://mww.mbari.org/itd/ip/.

[Click here to provide any additional details]

b) All Projects: Specific Plans for 2021

Engineering/technology development

1.) Persistence

Note: Refer to Fig. 1 below for task labor allocation.

1.1 Waveglider Tow-out and Tow-in

Tow-out testing in moderate weather late in 2019 exhibited unacceptable shock loading during slack-line surge events. During fall 2020 we will try several methods to avoid the shock loading by changing the shape of the tow cable catenary and possibly adding a shock dampener. A delay in the delivery of the Whisker Box docking module from WHOI, due in part to COVID, had delayed the Tow-in capability development part of this program. We expect delivery in October or November and will then install it on LRAUV Tethys along with a docking fixture for the Wave Glider tow-body and begin experiments to dock on the tow-body early next year.

1.1.1 Electro-Mechanical Integration of whisker box – Physically integrate the Whisker-box onto Tethys.
1.1.2 Whisker box software Integration – Migrate homing software from the WHOI Micromodem to the Benthos DAT modem MBARI uses. Write a release/tow behavior for the whisker-box interface.
1.1.3 Tow-out surge dampening – Mitigate the shock loading.
1.1.4 Testing / Mission iteration – Run Monterey Bay tests with towing and line capture

1.2 AUV Docking

Our team will work with Dr. Hamilton's Niobicon project to integrate a new line capture system with integrated power/data transfer. This may be a nose-mounted assembly similar to the WHOI whisker-box, or integrated behind the standard LRAUV sensor nose assembly with a single side mounted capture whisker. We will then perform a series of tank and ocean tests to demonstrate accurate homing and capture to the vertical wire containing the Niobicon power transfer section. The vehicle homing, capture, and latching software leverages successful work on the WHOI/DHS under-ice program. One of the important lessons learned with WHOI is that even though the AUV can capture the cable from any direction, it is much more accurate if the approach is aligned with the current. We plan to develop a passive weathervane mount for the homing acoustic beacon so it passively aligns with the current and employ a feature of the Benthos modem that allows the acoustic transmission of the modem's compass heading to the AUV during the homing approach. A new whisker box software interface and revised docking missions will be written. We plan to use either LRAUV Tethys or Galene, neither of which are used for routine science operations.

1.2.1 Modify an existing nose shell and fabricate new brackets to hold the new docking components along with a DVL, and sufficient floatation to render the nose neutrally buoyant.
1.2.2 Add a new charging port to the front endcap and wiring inside the hull.
1.2.3 Refine the AUV docking behavior – We'll leverage the DHS/WHOI line capture work by refining the docking behaviors to integrate the current estimation, approach heading, and reverse thrust for robust un-docking.
1.2.4 Design and build weather-vaning modem on cable - When homing to an acoustic modem, take advantage of the additional serial output to indicate current direction by applying a physical weathervane to the modem and broadcast the compass data out of the serial port.

1.2.5 Develop a new "In Dock" mission - While docked for extended periods, the AUV needs to monitor critical systems, save energy, and be available to respond to acoustic commands.
1.2.6 System integration and testing – The actual work of integrating the various hardware components to write data to the slate.
1.2.7 Tank tests - To the extent possible initial mission flow and functional testing will be done in the tank
1.2.8 Offshore tests (4 tests, 2 days each) - Sea trials locally in Monterey Bay to test full functionality.

1.3 USV Launch and Recovery Concept Design
As we seek to extend the observational capabilities of the LRAUV fleet further offshore we plan to investigate the concept of an un-crewed surface vessel launching and recovering AUVs. We envision autonomous launch and recovery being essential to any future basin scale operations. We are pursuing a NOAA funded effort with two industry partners so this effort would have an immediate technology export path.

2.) Autonomy and Export

2.1 Multi-Vehicle Collaboration
Collaborations between multiple autonomous vehicles (including LRAUVs) has been increasing over the past 3 years. These applications often rely on acoustic communications especially for positioning. In 2020 we demonstrated vehicle command and control via an acoustic gateway on both a mooring and a Wave Glider. We propose to extend this capability to allow for relative vehicle tracking to multiple assets from a single vehicle. This will allow for enhanced "formation" style flight across features to support applications like Terrain Relative Navigation or front/patch following. Additionally, further development in this area opens up the opportunity to have vehicles "hot swap" at a location as they run low on energy. While we've demonstrated nearly 100 hours of continuous underwater sampling/drift, having vehicles that are actively collaborating will enable continuous tracking of a feature for months on end.
2.1.1 Acoustic Comms (Benthos integration and test) - With continued assistance from Intuaware (Mike Godin) we plan to translate some of the WHOI Micromodem capabilities developed under the DHS project to the Benthos modems MBARI uses. This will allow more reliable command reception and data dissemination over the acoustic link.
2.1.2 Multi-vehicle tracking behavior to support TRN and relative formation – The existing behavior currently only supports tracking between two vehicles. We plan to extend this to allow for multiple vehicles to be tracked enabling relative formation awareness between vehicles.
2.1.3 Waveglider A-comms integration and test – We currently use a Benthos modem/DAT equipped Wave Glider to send commands to the LRAUVs manually. This process involves many human steps and is therefore error prone. We propose expanding this capability to acknowledge command receipt and also provide for LRAUV data ingest/relay.
2.1.4 Lagrangian hot bunking – This application allows one LRAUV to "replace" another while drifting in the water column. Vehicle A that is leaving station will wait to be

homed to by vehicle B. Upon reaching proximity, vehicle B will release A to depart and will take over sampling/drifting/observing at the station of interest. This type of application enables extended observations in a given area using multiple assets.

2.2 Back Seat Computer Support
To provide further control and computing power a second, independent computer can be installed in the LRAUVs. This Backseat Computer (BSC) communicates with the LRAUV's main computer to share vehicle data and could send it steering commands. This allows users to develop sophisticated and more computationally intensive algorithms on their own platforms without using up resources on the main CPU or risking changes to the main application codebase. As new users ramp up development of their own back seat applications, we propose hours to provide basic assistance as well as some time for development of data ingest coming from the backseat computer.

2.2.1 App ingest for BSC applications – Various applications running on the backseat computer provide data/commands back to the vehicle. This works covers implementation of that ingest and response via the existing BSC architecture.

2.2.2 ROS-LCM Bridge development and basic test - For BSC developers to make use of ROS, an LCM/ROS bridge is needed to "translate" between our middleware (LCM) and ROS. If the ROS Simulator project is funded, this task will be performed by OSR.

2.3 TethysL mission programming language

2.3.1 Refinement of the core code regarding semantics and execution to address a couple of important corner cases that require close revision and verification by mission authors and LRAUV experts so the translation from TethysL to XML conveys the exact semantics for execution. Per previous discussion with main LRAUV framework developer, Mike Godin, it is even possible that some changes in the framework itself be worth adjusting, not just for the sake of TethysL, but as general improvements.

2.3.2 Implement LSP server and extension for VS Code – Some TethysL users have expressed great interest in being able to use the system in typical editors and IDEs (i.e., not necessarily through the webapp). The modern and widely used mechanism to accomplish is to implement a server complying with the Language Server Protocol (LSP) (https://microsoft.github.io/language-server-protocol/). The open-source VS Code system is being selected as a specific initial target IDE because of its popularity, but the gained knowledge should facilitate targeting other editors as needed. Some very basic but promising prototype work for this has been done in 2020.

2.3.3 Adjustments in integration with LRAUV/TethysDash - This is closely related with the items above and involves revision of the current "Bitbucket connection" that allows to list and select the mission for editing depending on the selected remote repository by the user, and perhaps in the future (if needed) with ability to work with local files.

2.4 Outreach and export support. This is a task to cover time to pursue licensing opportunities, work with ITD in a MBARI booth and give invited lectures.

3.) Infrastructure Upgrades

3.1 Dash upgrades and support

3.1.1 Mission and Command Dash tabs – Further improvements and adjustments to the reimplementation of these pending tabs from the traditional TethysDash in Dash3.
3.1.2 Stable version of MXM interface for TethysDash – The LRAUV/TethysDash system is a key target for the Mission Execution Mediation (MXM) service being developed under CANON. As such development progresses, we will adjust the corresponding functionality and API in TethysDash.
3.1.3 LRAUV/Dash code maintenance, bug fixes, and watchstanding – Besides known entries in issue trackers, this is about addressing the occasional unexpected needs for adjustments and fixes that traditionally occur (here in particular regarding TethysDash/Dash3 and the ESP Component in LRAUV).
3.1.4 TethysDash/Dash3/TethysL documentation – Continue expanding https://docs.mbari.org/tethysdash/ and https://docs.mbari.org/tethysl/ for modified and new features.

3.2 Data Analysis: Throughout 2021 we will perform data analysis of science and engineering data for quality control and issue response
3.3 Intervention Reduction: In 2021 we will continue to review the main vehicle application software and make adjustments in order to reduce the number of unplanned operator interventions and minimize unnecessary communications with shore.
3.4 Thruster motor controller power reduction: This development project will significantly reduce thruster controller power consumption (~0.70 watts) compared to the existing COTS server controller and extend the range of the LRAUV.
3.5 Battery charger EOL redesign: The Ocean Server COTS battery chargers that are integrated into our battery packs are no longer available. While MBARI owns some spares, and have not had many failures, WHOI was forced to design a replacement charger for their new vehicles. We have worked closely with WHOI and now plan to develop a similar design for MBARI. Erik has led this effort will continue to refine and test the design.
3.6 App and Kernel Tuning: Throughout 2021 we will maintain and tune main vehicle application components and configuration files and provide support for the LPC3250 customized Linux kernel and root file system.
3.7 Ongoing Systems Support: Electrical and tech support for the platform throughout 2021

4.) Capabilities and Payloads

4.1 Propeller biolum instrument. This is a continuing project to add a low-power bioluminescence detector that we hope will be small and low power enough to be added to the core sensor suite of all the vehicles. A pair of very sensitive photo detectors will be mounted at the tail of the vehicle with one pointed into the propeller wake and the other collecting ambient light. This new instrument will be deployed alongside the commercial bathyphotometer UBAT to confirm valid measurements. Dr. Haddock has shown how pervasive bioluminescence is and along with Dr. Messie have demonstrated a method to identify taxa of plankton using the UBAT. Unfortunately, the UBAT takes up most of the payload volume and consumes 7 watts, or about seven times the power of all the other instruments combined so a small, low-power instrument would be valuable.

4.1.1 Electrical, Mechanical, and software integration into the LRAUV: We expect to complete prototype testing and plan to build a production board that combines both reporting channels, which will be installed in a small housing in early 2021.
4.1.2 Testing – Offshore testing and data analysis to validate bioluminescence detection as compared to the WetLabs UBAT instrument.

<u>**4.2** TRN and Low Altitude Bottom Following:</u> Dr. Rock's Precision Control project has developed Terrain Relative Navigation (TRN) system and transferred the capability to MBARI for routine use on our platforms. This task is to get TRN operational on the LRAUV's backseat computer. Another technology developed within Rock's Precision Control group is low-altitude bottom following using a forward-looking obstacle avoidance sonar. We plan to us TRN to determine where the AUV is relative to the terrain along with the reactive obstacle avoidance for safe low-altitude bottom following to begin flying the LRAUV within imaging range of the seafloor. We will continue to work with Dr. Rock to extend his TRN work to add a feed-forward terrain prediction to further increase the safety while flying low. An existing Imagenex multibeam sonar purchased for the Iceberg AUV is being used for this work.

4.2.1 By the end of 2020 we expect to have TRN and the reactive obstacle avoidance code, that was originally developed for Dorado, ported and running on a Jetson Nano BSC. This computer is more powerful than the normal low power BSC and is required for the Obstacle Avoidance Sonar (OAS) beam-former and TRN to run together. This task supports time in 2021 to finish the work started in 2020.
4.2.2 MB System mission planner to LRAUV missions. For AUV operations near the seafloor we'll us MB System to plan waypoints against know terrain maps and automate the task to take the 3D (Lat/lon/depth) route file and import it into a new LRAUV mission.
4.2.3 Develop bottom-following behavior – We'll extract the relevant code from Dorado and develop an application that runs on the BSC to ingest the OAS beam ranges that provide a profile of the seafloor ahead of the AUV. Vehicle control commands will be sent to the LRAUV over the LCM bus to maintain the commanded altitude and pitch up and/or stop the thruster if a collision is possible.
4.2.4 Bottom Following Software Simulator – Develop additional code that verifies 4.2.3 without requiring the vehicle. Then test with the vehicle and sonar.
4.2.5 Closed loop testing at Portuguese Ledge – Perform a series of ocean tests to first validate the control open loop, then if the results look good, allow the behavior to send commands to the AUV while slowly commanding lower and lower altitudes.

5.) Project Management

5.1. Meetings
5.2. Contingency time to respond to issues
5.3. Project Management

				500	494	275	135	0	345	60	25	100	130	60	205	685	510	565	310	0	0	0	0	0	0	0	0	200	320
			Totals	Kieft	Hobson	Mellinger	Erickson	SE	Klimov	Okuda	Jones	MT	ET	Machine	O'Reilly	Rueda	Raanan	McEwen	Henthorn	Martin	Trauschke	Wahl	Figurski	McCann	Cline		Roman	Erik T	Jensen
Persistence			Totals																										
	Description	Task ID																											
	Tow out & Tow in (2020 task postponed by COVID)	1.1																											
	Electro-Mechanical Integration of whisker box	1.1.1	35									10	25																
	Whisker box software Integration	1.1.2	40	40																									
	Tow-out surge dampening	1.1.3	10		10																								
	Testing / Mission iteration	1.1.4	40	20													20												
	AUV Docking	1.2																											
	Modify nose for NB charger parts and capture assy.	1.2.1	195		20		60					40	35	40															
	Add battery charge input to nose	1.2.2	28		8								20																
	Refine AUV docking behavior	1.2.3	100	20													80												
	Design and build weathervaneing modem on cable	1.2.4	56		16							10	10	20															
	Develop a new In-Dock mission	1.2.5	30	30																									
	System integration and testing	1.2.6	40	20	20																								
	Tank tests	1.2.7	30	20	10																								
	Offshore tests (4 tests, 2 days each)	1.2.8	100	40	20												40												
	USV AUV Launch and Recovery concept design	1.3	100		100																								
			804	190	204	0	60	0	0	0	0	60	90	60	0	0	140	0	0	0	0	0	0	0	0	0	0	0	0
Autonomy and Export			Totals																										
		Task ID																											
	Multi-vehicle Collaboration	2.1																											
	Acoustic Comms (Benthos integration and test) - O/S Intuaware	2.1.1	160	80													80												
	Multi Vehicle tracking behavior to support TRN and relative formation	2.1.2	40														40												
	Waveglider A-comms integration and test - + O/S Intuaware	2.1.3	100												100														
	Lagrangian drift sampling hot bunking	2.1.4	40	40																									
	Backseat computer (BSC)	2.2	0																										
	App ingest for BSC applications	2.2.1	90	10													80												
	ROS-LCM Bridge development and basic test?	2.2.2	80												80														
	TethysL mission programming language	2.3	0																										
	Revision of internals regarding semantics and execution	2.3.1	80													80													
	Implement LSP server and extension for VS Code	2.3.2	140													140													
	Adjustments in integration with LRAUV/TethysDash	2.3.3	80													80													
	Outreach and export support	2.4	40		40																								
	Total		850	130	40	0	0	0	0	0	0	0	0	0	180	300	200	0	0	0	0	0	0	0	0	0	0	0	0
Infrastructure Upgrades			Totals																										
	Description	Task ID																											
	Dash upgrades and support	3.1	0																										
	Mission and Command Dash tabs	3.1.1	120													120													
	Stable version of MXM interface for TethysDash	3.1.2	120													120													
	LRAUV/Dash code maintenance, bug fixes; watchstanding	3.1.3	70													70													
	TethysDash/Dash3/TethysL documentation	3.1.4	50													50													
	Data Analysis	3.2	30	10													20												
	Intervention Reduction	3.3	30	20													10												
	Thruster motor controller power reduction	3.4	320																										320
	Battery charger EOL redesign	3.5	160																									160	
	App and Kernel Tuning	3.6	40																									40	
	Ongoing systems support	3.7	350		10	200				60		40	40																
	Total		1290	30	10	200	0	0	0	60	0	40	40	0	0	360	30	0	0	0	0	0	0	0	0	0	0	200	320
Capabilities and Payloads																													
	Description	Task ID																											
	Propeller biolum	4.1	40														40												
	Refine and integrate test device on Tethys	4.1.1	270	30	40				200																				
	Testing	4.1.2	130	10					120																				
	TRN and Low altitude bottom following	4.2	0																										
	troubleshoot and refine TRN and BF code porting	4.2.1	160															120	40										
	MB System mission planner to LRAUV missions	4.2.2	180															80	100										
	Test BF with simulated data	4.2.3	120															40	80										
	Close the loop at Portuguese Ledge	4.2.4	400	10	10													300	80										
	Total		1300	50	50	0	0	0	320	0	0	0	0	0	0	0	40	540	300	0	0	0	0	0	0	0	0	0	0
Project Management																													
	Description	Task ID																											
	Meetings	5.1	335	50	50	25	25		25		25				25	25	50	25	10										
	Contingency to respond to issues	5.2	250	50	50	50	50										50												
	Project Management	5.3	90		90																								
	Total		675	100	190	75	75	0	25	0	25	0	0	0	25	25	100	25	10	0	0	0	0	0	0	0	0	0	0

Figure 1: Labor allocation table

Will novel intellectual property be developed and/or disseminated?
Dissemination includes patenting, licensing, and collaboration agreements.

Yes, we expect to develop novel IP. Docking and Niobicon related IP has been scoped as part of the Niobicon project.

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.

This development project anticipates using LRAUV Tethys for an average of two days per month, for a total of 24 days during 2021. One of the Wave Gliders will also be required for field-testing of the tow-out/tow in system for eight days.

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.

None

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.

N/A

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

No

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

N/A

Specific deliverables

The project will produce a new nose prototype payload assembly with the line capture whisker box that supports the power transfer system developed under project #902106 Niobicon-Based AUV Docking Development. An existing nose section will be modified to carry an obstacle avoidance sonar.

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

[Click here to enter text]

2021 Project Start Date: MM/DD/2021	**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	**Persistence**	**Autonomy**	**Infrastructure**	**Cap/Payload**	**Managment**	

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

Electrical Engineer			**580**	**320**	**125**	**1025**
Software Eng-Embedded	**330**	**510**	**60**	**930**	**260**	**2090**
Software Eng-Info Eng		**300**	**360**	**0**	**25**	**685**
Mechanical Engineer	**264**	**40**	**10**	**50**	**265**	**629**
Mechanical Eng-Division						
Mechanical Eng-Mfg						
Associate Engineer						
Electrical Tech	**90**		**40**			**130**
Software Tech						
Mechanical Tech	**60**		**40**			**100**
Machinist	**60**					**60**
Divers						

Budget justification

	Description	Price	Notes
1	Tow-out cable snubber	$250	
2	Dock charging bulkhead and cable	$650	
3	Syntactic foam for Docking Hardware	$2,000	
4	Outside Services (Intuaware)	$8,000	
5	Travel Domestic (Oceans San Diego)	$3,000	
6	Lab supplies	$2,000	
	Total =	$15,900	

1. Purchased material to attempt to solve the WaveGlider Tow-out shock loading problem.
2. A new high current connector is required to pass charge current through the front endcap.

3. To maintain neutral buoyancy, a floatation module will be required to offset the power transfer and docking hardware.
4. This charge to hire Mike Godin to work on the following items:
    a. Respond to questions from Carlos about large sections of the LRAUV code base that Mike developed.
    b. Continue to resolve acoustic communications issues
    c. Integrate a multi-dimensional variable for existing missions.
    d. Develop a way to directly execute Tethys-L code.
5. Travel expenses to participate in Oceans21 in San Diego where the PI will be available to help with a display booth for the LRAUV.
6. Misc. tools and consumables for the LRAUV lab

Project team
Brett Hobson, PI, ME – 494 hours
Brian Kieft, LE, SE – 500 hours
Ben Raanan, SE – 510 hours
Brent Jones, EE – 25 hours
Erik Trauschke, SE – Operations and General AUV expertise - 200 hours
Jon Erickson, ME – Line capture and Waveglider tow-in – 135 hours
Carlos Rueda, SE – Dash interface, TethysL programming – 685 hours
Denis Klimov, EE – General EE, Propeller Biolum -345 hours
Ed Mellinger, EE – General EE,– 275 hours
Scott Jensen, EE – Thruster driver – 320 hours
Craig Okuda, EE – RF Systems – 60 hours
Tom O'Reilly – LCM, Acomms – 205 hours
Rob McEwen, CE – Controls, TRN, Bottom Following – 565 hours
Rich Henthorn, SE – Backseat computer, TRN, LCM Bridge -310 hours

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.

The project team plans to use the existing shared engineering lab B224/B221

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.

We request 24 days of Paragon time to support monthly deployments, though we typically only require the boat for two hours per day.

Risk matrix (development and infrastructure projects only)

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

c) 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 export plans

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 export purchases planned
Yes, we contribute to the MBARI permit to operate the LRAUVs within the NBNMS.

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 https://mww.mbari.org/pco/permits/mbnms-2020-006_exp28feb2025.pdf. Please see Mandy Allen for questions.

Is a permit with MBNMS required for your work?

Yes, we contribute to the MBARI permit to operate the LRAUVs within the NBNMS.

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). If your work will be conducted in one of these areas, please indicate which area by number or name.

We plan to operate within both the Portuguese Ledge and Soquel Canyon SESAs

Anchors

*For activities conducted under MBARI's permit for the Monterey Bay National Marine Sanctuary, Paragraph 16, we are required to recover anchors weighing less than 500 pounds. Project proposals, which involve anchors weighing less than 500 pounds, shall specifically indicate cruise time allocated to anchor recovery. Lack of cruise time is not an acceptable reason for deeming an anchor less than 500 pounds "unrecoverable" under Paragraph 17 of MBNMS permit. Also under Paragraph 17, **ALL** anchors not recovered during the year must be reported detailing location, description of anchor, and reason not recovered. (Mandy Allen will collect this information from project teams to submit as part of the annual report to the Sanctuary.) Each ship will be tracking anchors deployed, duration of attempted anchor recovery, and anchors abandoned on the seafloor with the intent that they be recovered in the future as per MBNMS permit requirements.*

Will you be deploying equipment that will require anchoring? If so, please indicate approximate weight of anchors to be used and recovery plans.

We occasionally deploy a temporary mooring with a 45 lb anchor. We recover this anchor using the capstan on the Paragon

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 MaYesrine Protected Areas (MPAs). 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?(See link above for Statewide MPAs or this link for Central California MPAs.)

Yes, we plan to work at Portuguese Ledge MPA.

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.)

N/A

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

Yes

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

Brett Hobson or Brian Kieft

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.

We are not aware of any other permits that we are required to obtain.

Active Acoustics
We are keeping an inventory of acoustic instrumentation. The current list is posted here: https://mww.mbari.org/resources/2021_Proposal_Process/mbari_acoustic_instruments_updated_may_13_2020_ver_13.xlsx. If you have or plan to use equipment that is not already on this list, please be sure to include that information here.

Our active acoustic devices are on record.