Project Number: 901721

Project Start: Jan. 1, 2017 **Project Duration (in years): year 1 of 1**

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**[1]	**Research**	**Infrastructure**[2]	**Education**

[ ]	[ ]
Time Series	**Institute Initiative**

Project Manager[2]: Tom O'Reilly

Principal Investigator: Brian Kieft

Lead Scientist:

Lead Engineer:

Project Title: Hot Spot support

[1] Development and infrastructure projects must complete the risk matrix (see item #5 at the 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.

1) ABSTRACT (new projects only)

MBARI's Wave Glider Hot Spot provides invaluable communications relay and acoustic tracking capabilities to MBARI projects while saving significant ship time and cost. The Hot Spot's satellite, cellular, WiFi and acoustic links allow engineers on shore to interact in real-time with systems deployed on or below the ocean surface. Researchers gain near-real-time access to high-bandwidth AUV sensor data while vehicles are still deployed, through the Hot Spot's 'store-and-forward' data transfer mechanism. Hot Spot's ability to acoustically geolocate subsea targets provides monitoring capability, and its ability to autonomously follow moving underwater targets enables unique experiments that coordinate sampling activities between multiple autonomous vehicles and ships. Geolocation of subsea platforms prior to ship visits reduces search time by the ship and allows for more immediate recovery/turnaround of platforms at sea as well as platform health and status checks. The Hot Spot has provided these capabilities and ship-time savings to the Continental Margins (CCE BIN, BEDs), Pelagic-Benthic Coupling (Rover), CANON, and EcoHAB projects over the past three years through the Wave Glider project (901411). We are currently finishing project 901411 by developing the following capabilities for 2016: 1) automation for acoustic range-only geolocation of stationary targets, 2) BED detection, 3) acoustic reacquisition of moving AUV targets; 3) refined acoustic geolocation and tracking accuracy; 4) enable onboard sensor data to be transferred to shore through the Hot Spot's 'store-and-forward' service, 5) build of a 'standard' Hot Spot payload box, readily compatible with either an SV2 or SV3 vehicle. In this new project "Hot Spot support" (901721), we propose to develop capabilities that enable even more innovative and unique science at MBARI and elsewhere, will begin transition of Hot Spot operation to MBARI's DMO, and transfer technology to other institutions. Particular tasks include 1) implement acoustic transfer of short 'messages' containing commands, data, or notifications to and from submerged assets. This capability would be very useful to coordinate fleets of surface and submerged robots, e.g. to relay a bloom detection message to a submerged LRAUV which could adapt its mission accordingly; 2) Transfer Hot Spot technology to the University of Hawaii, support initial operations for UH coordinated operations of its MiVEGAS LRAUV fleet; 3) Investigate modems and services that will be provided by the Iridium Next satellite constellation, which will lead to significantly improved data transfer speed for over-the-horizon communications.

2) PROPOSAL

a) New Projects

Statement of the problem, why it is important

One of the major themes of MBARI's current research is the increasing dependence on real-time data for informed decision-making during the course of field experiments. To this end MBARI has invested considerable resources in related projects such as the Ocean Decision Support System (ODSS) for coordinated mission planning and data visualization, highly agile sampling platforms such as the LRAUV family of vehicles, and the development of sophisticated sampling algorithms for applications such as patch tracking. Adequate real-time data is the raw material for ODSS's visualization and decision-making tools for managing these types of missions and yet due to design or observational constraints many of our mobile assets have a very limited ability to bring back real time data. Experiments using AUV's that do push limits on data return quickly run into difficulties with too much AUV time spent on the surface and a large dollar cost for data return. A major reason for this is our historical reliance on the Iridium Satellite constellation for over-the-horizon communications. While the AUV Iridium satellite systems are required for command and status updates, are reliable and provide

worldwide coverage, they have a very limited data transfer rate and a large cost per byte. There is also need to decrease operational costs and ship time where possible, while at the same time not sacrificing science data return and increasing persistent presence.

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

Utilizing the Wave Glider as a Hot Spot "adapts innovative technologies" per the strategic plan. Moreover Hot Spot will be a basic at-sea communications infrastructure component, and can benefit any research activity that relies on near-real-time return of large data volumes from untethered underwater assets. Additionally, the Hot Spot is able to track and follow underwater assets making for more efficient use of other mobile platforms in a collaborative experiment and keeping stakeholders situationally aware. Thus Hot Spot is relevant to science problems within all four research themes in the technology roadmap, as well as marine conservation projects sponsored by the Packard Foundation's Ocean Grantmaking process.

How does it relate/contribute to the Packard Foundation's Ocean Visions Grantmaking policies?
(See http://mww.mbari.org/oed/OED_Documents.htm#Packard for documents.)

See above

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

See above

Approach to the problem

AUVs are typically equipped with Iridium modems; the vehicle periodically comes to the surface, establishes a link to the Iridium constellation, and sends science/engineering data through the 2400 bps Iridium link. The vehicle must remain on the surface during the transfer, which can take many minutes, and consumes power for the modem as well. Thus excessive surface time and power consumption may be incurred when sending large amounts of data. Another problem is that while underwater targets can be located acoustically from a crewed ship or boat using range-only or USBL systems, the associated ship time may be quite costly and limited by weather and sea state. Our solution to these problems is to utilize the Wave Glider ASV as a data relay and autonomous acoustic target locater/tracker whenever possible, in order to lower satellite telemetry costs, lower ship costs, and lower required AUV surface time. The Hot Spot acoustic, WiFi, Freewave, satellite and cellular modems enable these capabilities. When an AUV comes to the surface within Wifi or Freewave range of the Wave Glider Hot Spot, the Wave Glider can quickly pull AUV science and engineering data, store it, and forward it to shore when a shore link is available. Likewise commands can be sent from shore (or some other vehicle) to the Hot Spot and stored there until the intended destination vehicle is within range. In some cases an underwater asset can forward data to the Hot Spot via acoustic link; the Hot Spot then transfers that data to its intended destination when a link is available. Hot Spot can receive and store 'acoustic broadcast' data from submerged vehicles and re-broadcast it, enabling other submerged vehicles to hear it as well. Hot Spot can automatically geolocate underwater targets acoustically, utilizing its onboard acoustic modem

and MBARI-developed applications stored on the Hot Spot's onboard computer, thus eliminating the need for a crewed ship or time-consuming and tedious human interaction via satellite or RF link, resulting in lower operations costs.

Publications (from other projects over the last 5 years):
The following are publications resulting from project 901411, *Wave Glider Hot Spot*:

T. O'Reilly, B. Kieft, M. Chaffey, "Communications relay and autonomous tracking applications for Wave Glider," in *OCEANS 2015 MTS/IEEE*, Genova, Italy, 2015.

I. Masmitja, S. Gomarez, J. del Rio, B. Kieft, T. O'Reilly, "Range-only underwater target localization," in *Oceans 2016 MTS/IEEE*, Monterey, California, 2016, in press

I. Masmitja, S. Gomarez, J. del Rio, B. Kieft, T. O'Reilly, "Range-only benthic Rover localization off the Central California coast," in *Martech 2016*, in press

I. Masmitja, O. Pallares, S. Gomariz, J. del Rio, T. O'Reilly, B. Kieft, " Range-only underwater target localization: error characterization," *IMEKO 2016*, in press

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]

Significant changes from previous project proposal

[Click here to enter text]

Publications based on the results of this project only

[Click here to enter text]

c) New and Continuing Projects: Plans for 2017

Research Activities

N/A

Engineering/technology development

1. We propose to design and implement an automated acoustic data relay capability. Acoustic data

transfer through the Hot Spot is currently implemented as an interactive time-consuming process that involves a user who is logged into the Hot Spot cellular/satellite modem and also connected to the onboard acoustic modem. Automating these transfers are expected to lower operations costs and enable autonomous vehicle coordinated sampling. However acoustic communication links are very susceptible to data corruption and disruption; full automation of acoustic data transfers with guaranteed delivery is especially challenging, and may require complex and experimental protocols such as Disruption Tolerant Networking (DTN). We propose to automate a simpler system for 2017 that uses acoustic "broadcast": to distribute data rather than point-to-point transmission. Our broadcast-based system would not guarantee data reception, but we believe it could be made reliable enough for its intended application. Moreover the LRAUV project is expected to evaluate acoustic data communications in 2017 - perhaps including DTN - and we obviously don't want to duplicate that effort. The first application of the acoustic broadcast capability will involve one or more AUVs capable of vertical profiling (initially just LRAUV but eventually Spray Glider, Dorado, Coastal Profiling Float). Each of the vehicles will be equipped with a Benthos modem, as will the Hot Spot. The Hot Spot and each AUV listens for broadcast messages. One or more of the AUVs periodically computes the vertical temperature homogeneity index (VTHI), which is a simple metric that quantifies the water-column stratification, and broadcasts a message containing, VTHI, estimated vehicle latitude, longitude, and a 'repeat' flag. If the Hot Spot hears one of the messages, it stores and forwards the message to shore through cellular or satellite link; if the message has the 'repeat' flag set, Hot Spot repeats the message through its acoustic modem. If an AUV hears a VTHI message (either directly from another AUV, or repeated by the Hot Spot) it may decide to move near the location specified in the message to carry out additional measurements. Other sensor data useful to adaptive sampling could be acoustically broadcast as well, e.g. fluorescence or backscatter levels, and measurement depth would be included in the message as well. Since this design does not include message receipt acknowledgement, broadcasting AUVs may simply retransmit the message a limited number of times at a specified interval (consistent with power resources). We'll demonstrate the capability with two or more LRAUVs in 2017, with potential wider application to other AUVs in following years, and will collaborate with the LRAUV team to define message formats and operational protocols. It is possible that we will collaborate with Christoph Waldmann (MARUM, Germany) and/or Ivan Masmitja (SARTI, Spain) on design and implementation of this component.

2. We plan to investigate and evaluate communications services, bandwidth and cost associated with the new Iridium Next satellite constellation, which is scheduled to begin launching in 2016 and perhaps become operational in 2017. Iridium Next capabilities include:

- Circuit switched data 9.46-64 kbps (e.g. for Iridium 'console' connection)
- Iridium OpenPort 128-512 kbps
- Iridium OpenPort Aero 128-512 kbps
- L-Band high speed: Up to 512 kbps up/ 1.5 mbs down
- Broadcast 64 kbps (e.g. for SBD messages)

Compare these data rates to 2.4 kbps for the existing constellation. Thus Hot Spot could potentially establish a significantly faster link for over-the-horizon communication with shore or other vehicles. We'll investigate cost and hardware required for these higher bandwidths. We'll budget for Iridium Next modem and antenna and procure these if available and if we determine actual field tests are worthwhile.

We'll request EE tech resources, to be used if we determine that integration of Iridium Next hardware with the Hot Spot is worthwhile and feasible in 2017.

3. We will take steps necessary to move Hot Spot operation from Engineering to DMO. We'll complete the Hot Spot user guide, including sections on calibration and configuration, pre-deployment checklists, share the user guide with DMO, estimate manual operator time and cellular/satellite airtime required for particular missions.

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

We anticipate that Hot Spot will be a critical component of the Monterey Bay MiVEGAS vehicle deployment planned for May 2017. Hot Spot's role hasn't yet been specified, but both its data relay and acoustic geolocation capabilities could be utilized. Hot Spot will require the *RV Paragon* for launch and recovery during this program; Paragon and Wave Glider time for Hot Spot in this field program is being requested by the CANON project.

Hot Spot technology transfer to the University of Hawaii began in 2016 and will continue in 2017 to assist operation of their MiVEGAS vehicles. U. of H. will build a Hot Spot payload box - MBARI (Kieft) has provided them with Hot Spot mechanical drawings . We anticipate that U. of H. will utilize both the Hot Spot's data rely as well as acoustic geolocation capabilities. We will provide Hot Spot software and documentation to U. of H. in 2017, as well as technical support for initial deployment at Station ALOHA, currently planned for July. We expect U. of H. to provide any travel support needed.

Acoustic data transfer demonstration. We will demonstrate use of Hot Spot as an acoustic message logger and repeater, using two modem-equipped LRAUVs that broadcast and listen for VTHI messages. We request five days of *R/V Paragon* time to deploy and recover the Hot Spot Wave Glider and LRAUVs, and ten days of Wave Glider time.

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

1. Acoustic broadcast data relay capability

2. Report on Iridium Next capabilities and costs, possible integration with Hot Spot if available and appropriate.

3a. Hot Spot user guide for DMO and external users

3b. Hot Spot airtime and operator time estimates, for use by projects and DMO when budgeting deployments

Ship time summary
R/V Paragon - 5 days
Wave Glider - 10 days
LRAUVs (2) - 10 days

Milestones (see personnel classification list)

Labor BOE for operations:
Based on SV3 operations in 2015

Labor	Hours
Waveglider piloting (automated)	15 hrs/month deployed
Wave Glider human in loop data xfer	~2hrs/session (very data volume dependent)
Waveglider Launch/Recovery (including prep/post)	10 person hours

Milestones (resources in hours)

2017 Project Start Date: MM/DD/2017	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Total Resources[3]** for each resource category for all milestones listed here
Milestone Date	**6/2016**	**7/2016**	**9/2016**	**12/2016**	
Milestone Description	**User guide, documentation**	**Software transfer, tech support to U.H.**	**acoustic data transfer**	**Iridium Next evaluation**	
EE					
SE	**O'Reilly (40) Kieft (40)**	**O'Reilly (40) Kieft (80)**	**O'Reilly (240) Kieft (40)**	**O'Reilly (40) Kieft (40)**	**O'Reilly (360) Kieft (200)**
ME					
EE Tech				**40**	**40**
SE Tech					

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

ME Tech					
Machine Shop					
Divers					

Budget justification

CATEGORY	COST
Verizon CDMA modem airtime	500
Iridium / Globalstar satellite airtime	6200
Iridium Next modem and antenna	2000
Lab supplies	4000
TOTAL	12700

Project team

Brian Kieft, Tom O'Reilly

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.

Wave Glider shed, team personal offices

Data storage requirements (see Todd Ruston for assistance)

1 Gbyte

Data availability outside project team, uniqueness

Data generated from this project will be available to all associated MBARI investigators, their groups, and our collaborators. Access for other groups shall be provided conformant to MBARI's data sharing policies.

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.

Brian Kieft is an *R/V Paragon* operator, is generally available.

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

Ivan Masmitja Technological Development Center of Remote Acquisition and Data Processing Systems Universitat Politecnica de Catalunya (http://www.cdsarti.org/)

Christoph Waldmann University of Bremen MARUM, Bremen, Germany

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.

N/A

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. The Wave Glider is "discharged" from a boat; we operate under MBARI's existing MBNMS permit.

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 http://sanctuarysimon.org/maps/sesa/. (*Note: It may take a moment for the page to load, so please be patient. Also, if prompted for a login, hit "Cancel" and then you will be able to access page.*) To determine if your work will occur in a SESA, specific coordinates can be entered using the locator function (click on the red "target" button in the toolbar at the top of the map). If your work will be conducted in one of these areas, please indicate which area, by number.*

None

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.

N/A

Active Acoustics

We are compiling information on active acoustic use at MBARI. If the project involves using active acoustic instrumentation, please describe plans.

This project will utilize Benthos LF and MF modems, for data telemetry and ranging purposes. Transmissions will emanate from the Wave Glider as well as from one or more AUVs. Each transmission typically lasts several seconds, occurring at intervals of 30 seconds to several minutes.

Risk matrix (development and infrastructure projects only)

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