Internal Project Number: 901513

Project Start: 01/01/2015 **Project Duration (in years):** Year 3 of 3

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

Ship Time	ROV	AUV	Wave Glider	Mini ROV
		x	x	

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

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

Project Manager/PI: Yanwu Zhang

Lead Scientists: Francisco Chavez
Bruce Robison
John Ryan
Christopher Scholin
Robert Vrijenhoek

Project Title: Targeted Sampling by Autonomous Underwater Vehicles

1) ABSTRACT (new projects only)

[Paste abstract here]

2) PROPOSAL

a) New Projects

Statement of the problem, why it is important

[Click here to enter text]

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

[Click here to enter text]

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.)

[Click here to enter text]

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

[Click here to enter text]

Approach to the problem

[Click here to enter text]

Publications (from other projects over the last 5 years)

[Click here to enter text]

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

In 2016, we enabled the 3G-ESP LRAUV to carry out complex behaviors in drift-mode chlorophyll-patch tracking & sampling (Item 1). We have started to develop a method of using a Wave Glider to autonomously detect and track an upwelling front (Item 2). The VTHI (vertical temperature homogeneity index) algorithm, which we originally devised for AUVs, was ported to coastal profiling floats for measuring and reporting water-column stratification in real time. We designed hybrid sampling strategies for the Dorado gulpers to optimally achieve the scientific goals (Item 3).

1) 3G-ESP LRAUV complex behaviors in drift-mode chlorophyll-patch tracking & sampling

Based on our previous work, we enabled the 3G-ESP LRAUV to carry out complex behaviors in drift-mode chlorophyll-patch tracking & sampling. In a February experiment in Monterey Bay, the Makai LRAUV demonstrated peak acquisition, reacquisition, and sampling of a chlorophyll peak layer, as well as surfacing to report to shore, as shown in Fig. 1.

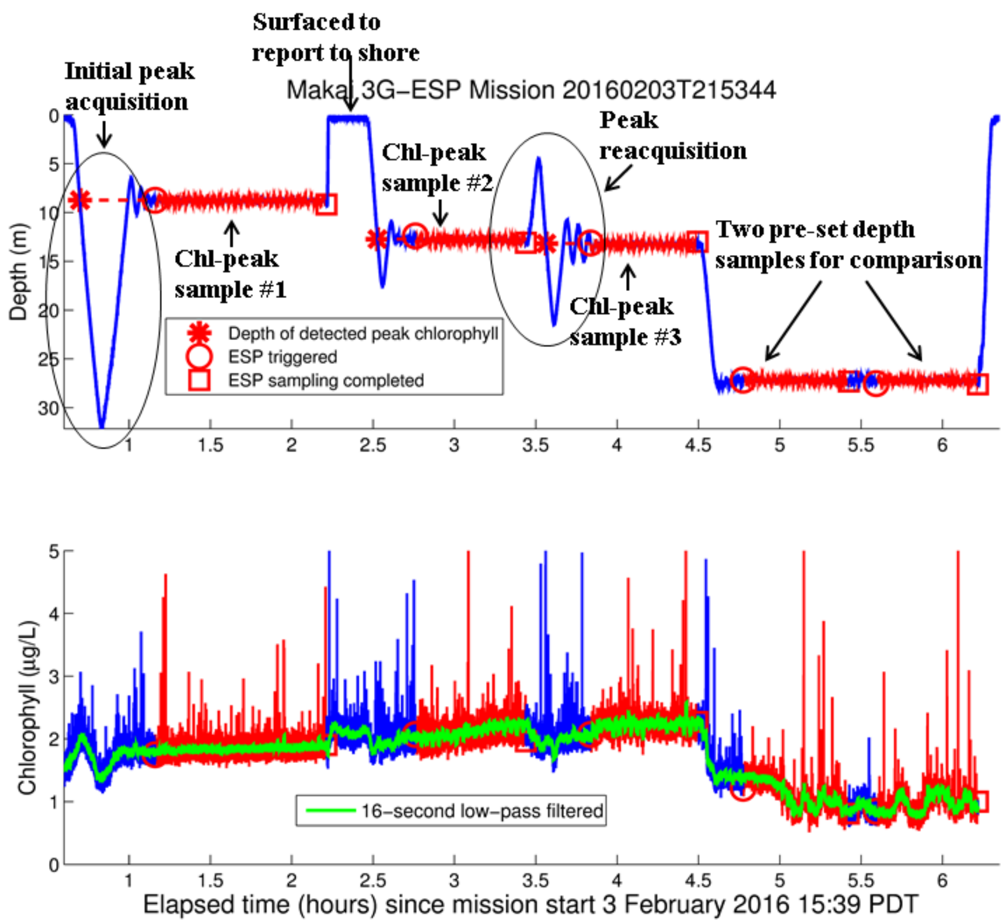

Fig. 1. The Makai 3G-ESP LRAUV demonstrated autonomous acquisition, reacquisition, and sampling of a chlorophyll peak layer (and surfacing to report to shore) in Monterey Bay in February 2016.

2) Using a Wave Glider to autonomously detect and track an upwelling front

Based on our AUV front-tracking algorithm, we designed a method of using a Wave Glider to autonomously detect and track an upwelling front. Unlike an AUV which runs on a yo-yo trajectory to measure vertical profiles of water properties, a Wave Glider's measurements are confined to the near-surface (from the ``float") and a fixed depth of only several meters (from the submerged ``glider"). However, an upwelling front presents a strong surface signature that a Wave Glider can utilize for detection. Because the upwelling process brings up cold water from depth, surface temperature in an upwelling region is considerably lower than that in stratified water. When a Wave Glider crosses the frontal zone (from warm stratified water to cold upwelling water), the near-surface temperature it measures will decrease steeply and persistently. Thus the Wave Glider can detect the upwelling front based on the horizontal gradient of the near-surface temperature: when the gradient is continuously high over some distance, the front is detected. Once front detection is achieved, the Wave Glider can closely track the upwelling front just as our AUV has demonstrated. One simulation result is shown in Fig. 2. We will soon run field experiments.

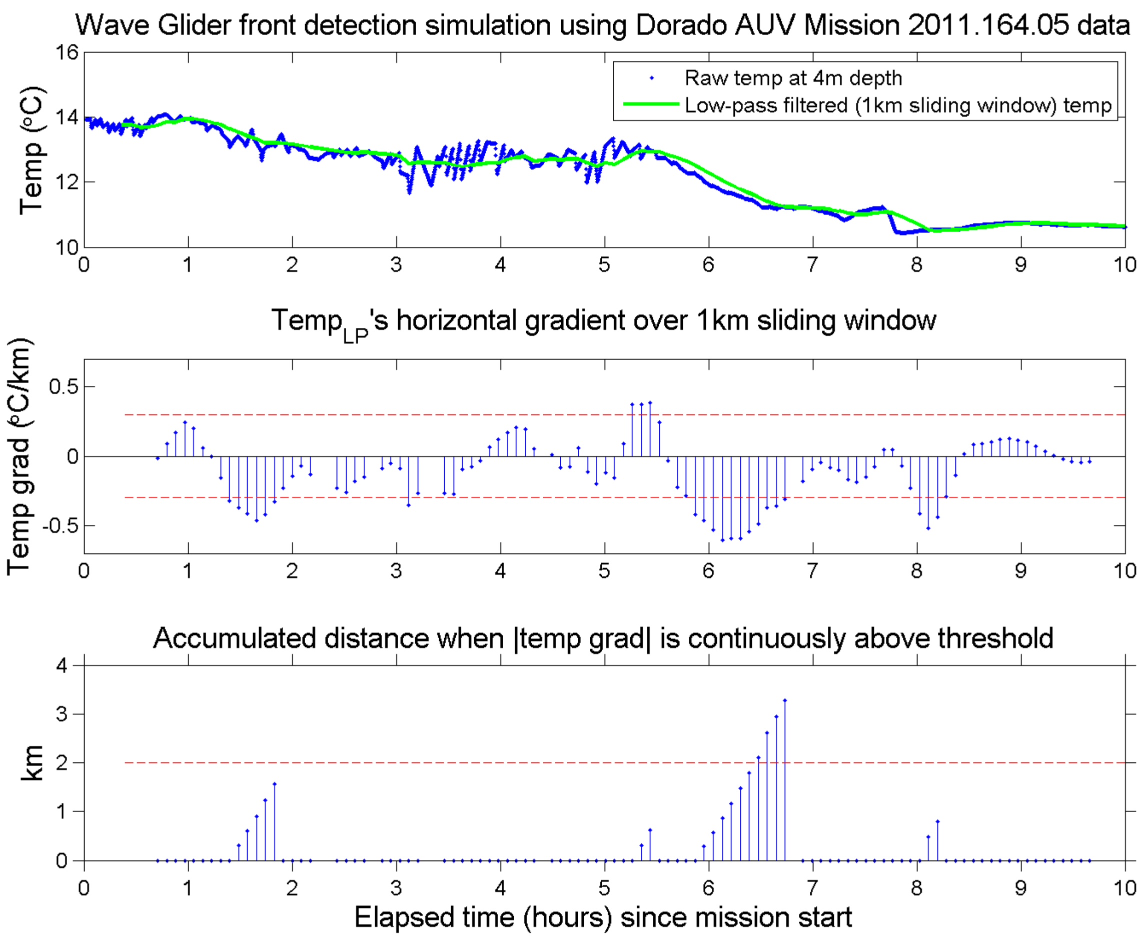

Fig. 2. Simulation of Wave Glider front detection on one transect across the front (from stratified water to upwelling water), using a previous AUV mission dataset. First panel: raw temperature (at 4 m depth) and low-pass filtered temperature (using a 1 km sliding distance window). Second panel: horizontal temperature gradient over 1 km distance. The gradient threshold is set to 0.3ºC. Third panel: accumulated distance when the horizontal temperature gradient is continuously above the gradient threshold. When the accumulated distance exceeds 2 km, front detection is declared.

3) Hybrid sampling strategies for Dorado gulpers

Doubling of the Dorado gulpers (from 10 to 20) offers the flexibility of firing the gulpers on a hybrid scheme --- some on adaptive sampling; the others on pre-programmed location/depth or water properties, to optimally serve the science goal. One example is shown in Fig. 3. In this CANON mission, the scientists designed a diamond-shaped Dorado track, with the east and west corners being the C1 and M1 stations, respectively. The scientists desired peak-chlorophyll samples on the four sides of the diamond to investigate the bay-wide distribution of phytoplankton communities. At the C1 and M1 stations, the scientists wanted samples from a series of depths (from surface to 60 m depth). We achieved the goal by carefully programming the adaptive sampling configuration file in coordination with the mission script.

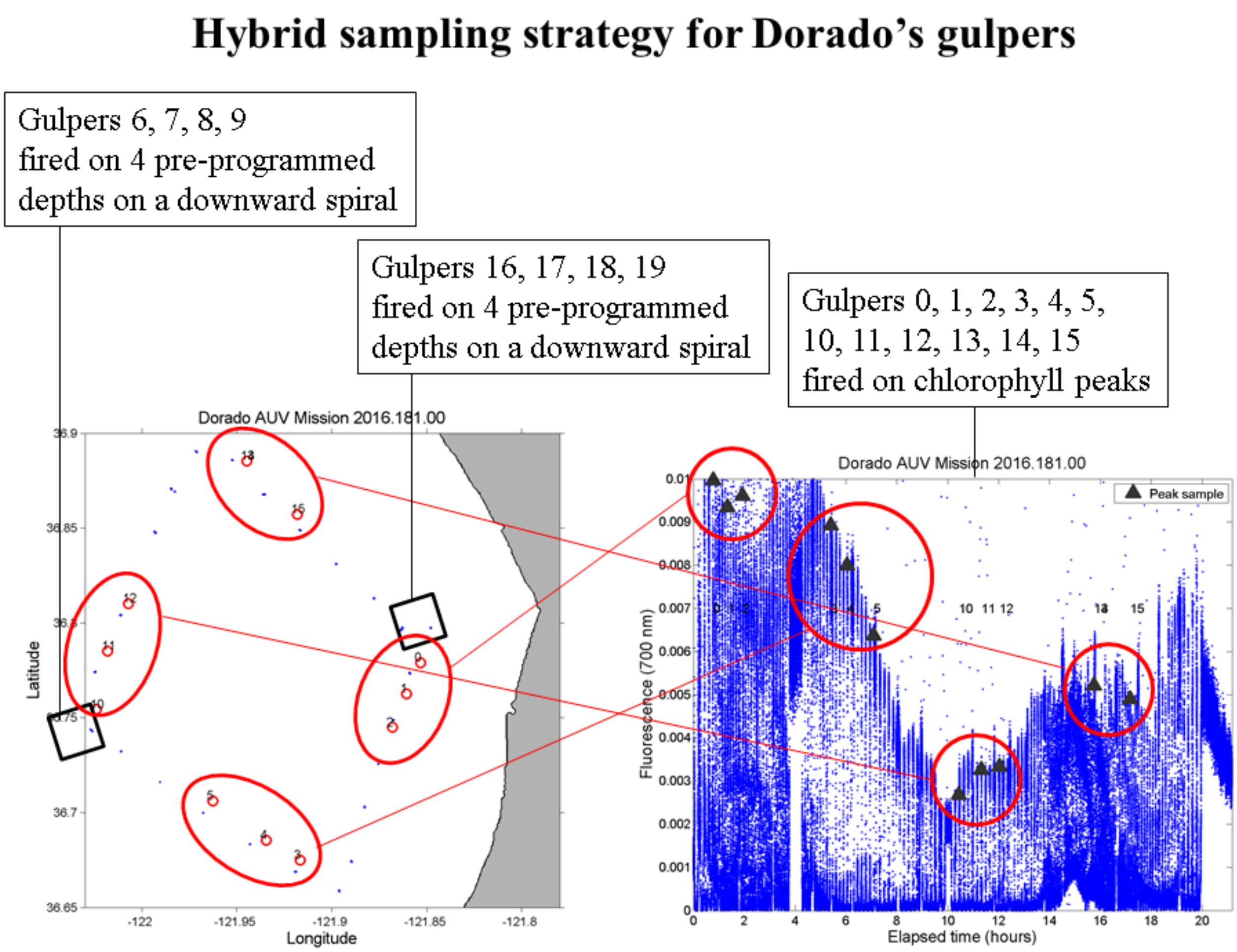

Fig. 3. Dorado gulpers' hybrid sampling in Monterey Bay in June 2016. On the four sides of the diamond-shaped track, 12 gulpers fired on chlorophyll peaks using the peak-capture algorithm. At each of the east and west corners (i.e., C1 and M1 stations), 4 gulpers fired at surface, 20 m, 40 m, and 60 m depths on a downward spiral (implemented in the Dorado mission script by Hans Thomas and Dorado team).

Significant changes from previous project proposal

Developing a method of using Wave Gliders to autonomously detect and track ocean features, e.g., an upwelling front (see paper No. 2 in Publications). This work is based on our previously developed methods for AUVs. Wave Gliders are long-duration autonomous surface vehicles. Currently their deployments are on pre-programmed survey paths. Enabling Wave Gliders to intelligently detect and follow ocean features will greatly enhance their capabilities and usefulness, which will constitute a major contribution to the community. At MBARI, this work in combination with the Wave Glider hotspot project will expand the role of a Wave Glider from an information gateway to a smart gateway & tracker, which will greatly facilitate and strengthen multi-vehicle collaborations.

Publications based on the results of this project only (in the last 5 years)

1. Y. Zhang, B. Kieft, M. J. Stanway, R. S. McEwen, B. W. Hobson, J. G. Bellingham, J. P. Ryan, T. C. O'Reilly, B. Y. Raanan, M. Messié, J. M. Smith, and F. P. Chavez, "Isotherm Tracking by an Autonomous Underwater Vehicle in Drift Mode," *IEEE Journal of Oceanic Engineering*, in revision.
2. Y. Zhang, B. Kieft, C. Rueda, T. C. O'Reilly, J. Ryan, T. Maughan, C. Wahl, and F. Chavez, "Autonomous Front Tracking by a Wave Glider," *IEEE/MTS Oceans'2016*, (abstract accepted, full paper due in August 2016).
3. B. Hobson, B. Kieft, M. J. Stanway, Y. Zhang, "Collaborating Ocean Robots for in-situ microbial observation," *IEEE/MTS Oceans'2016*, (abstract accepted, full paper due in August 2016).
4. Y. Zhang, "Autonomous Underwater Vehicles Lead to Scientific Discoveries in the Oceanic Wilderness," *Journal of Engineering Studies* (Chinese journal with English abstracts), Vol. 8, No. 2, pp. 201-207, April 2016.
5. 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*, Vol. 33, No. 1, pp. 67-81, January 2016, DOI: 10.1002/rob.21617.
6. Y. Zhang, J. G. Bellingham, J. P. Ryan, and M. A. Godin, "Evolution of a physical and biological front from upwelling to relaxation," *Continental Shelf Research*, Vol. 108, pp. 55-64, October 2015, DOI:10.1016/j.csr.2015.08.005.
7. Y. Zhang, B. Kieft, R. McEwen, J. Stanway, J. Bellingham, J. Ryan, B. Hobson, D. Pargett, J. Birch, C. Scholin, B. Jones, L. Bird, and F. Chavez, "Tracking and Sampling of a Phytoplankton Patch by an Autonomous Underwater Vehicle in Drifting Mode," *IEEE/MTS Oceans'2015*, pp. 1-5, Washington D.C., U.S.A., October 2015.
8. B. Y. Raanan, J. Bellingham, Y. Zhang, B. Kieft, M. J. Stanway, R. McEwen, B. Hobson, "A Real-time Vertical Plane Flight Anomaly Detection System for a Long Range Autonomous Underwater Vehicle," *Proc. MTS/IEEE Oceans'15*, pp. 1-7, Washington D.C., U.S.A., October 2015.
9. D. Pargett, C. Scholin, J. Birch, S. Jensen, B. Roman, C. Preston, W. Ussler, K. Yamahara, and Y. Zhang, "Development of a Mobile Ecogenomic Sensor," *IEEE/MTS Oceans'2015*, pp. 1-6, Washington D.C., U.S.A., October 2015.
10. J.P. Ryan, J. B. J. Harvey, Y. Zhang, and C. B. Woodson, "Distributions of invertebrate larvae and phytoplankton in a coastal upwelling system retention zone and peripheral front," *Journal of Experimental Marine Biology and Ecology*, Vol. 459, pp. 51-60, 2014.
11. J.P. Ryan, M.A. McManus, R.M. Kudela, M. Lara Artigas, J.G. Bellingham, F.P. Chavez, G. Doucette, D. Foley, M. Godin, J.B.J. Harvey, R. Marin III, M. Messie, C. Mikulski, T. Pennington, F.

Py, K. Rajan, I. Shulman, Z. Wang, and Y. Zhang, "Boundary influences on HAB phytoplankton ecology in a stratification-enhanced upwelling shadow," *Deep Sea Research II*, Vol. 101, pp. 63-79, 2014.

12. Y. Zhang, J. G. Bellingham, J. P. Ryan, B. Kieft, and M. J. Stanway, "Two-Dimensional Mapping and Tracking of a Coastal Upwelling Front by an Autonomous Underwater Vehicle," *Proc. MTS/IEEE Oceans'13*, pp. 1-4, San Diego, CA, U.S.A., September 2013.
13. D. Thompson, D. Caress, D. Clague, D. Conlin, J. Harvey, E. Martin, J. Paduan, C. Paull, J. Ryan, H. Thomas, and Y. Zhang, "MBARI Dorado AUV's Scientific Results," *Proc. MTS/IEEE Oceans'13*, pp. 1-9, San Diego, CA, U.S.A., September 2013.
14. Y. Zhang, "Adaptive Ocean Observation," *Advances in Earth Sciences* (Chinese journal with English abstracts), Vol. 28, No. 5, pp. 537-541, May 2013.
15. Y. Zhang, J. P. Ryan, J. G. Bellingham, J. B. J. Harvey, and R. S. McEwen, "Autonomous detection and sampling of water types and fronts in a coastal upwelling system by an autonomous underwater vehicle," *Limnology and Oceanography: Methods*, Vol. 10, pp. 934-951, 2012.
16. B. Hobson, J. G. Bellingham, B. Kieft, R. McEwen, M. Godin, and Y. Zhang, "Tethys-Class Long Range AUVs - Extending the Endurance of Propeller-Driven Cruising AUVs from Days to Weeks," *Proc. IEEE AUV'2012*, pp. 1-8, Southampton, U.K., September 2012.
17. J. Harvey, Y. Zhang, and J. P. Ryan, "AUVs for Ecological Studies of Marine Plankton Communities - Intelligent Algorithms on Dorado and Tethys AUVs Enable Precise Water Sampling for Plankton Research," *Sea Technology*, Vol. 53, No. 9, pp. 51-54, September 2012.
18. Y. Zhang, M. A. Godin, J. G. Bellingham, and J. P. Ryan, "Using an Autonomous Underwater Vehicle to Track a Coastal Upwelling Front," *IEEE Journal of Oceanic Engineering*, Vol. 37, No. 3, pp. 338-347, July 2012.
19. Y. Zhang, J. G. Bellingham, M. A. Godin, and J. P. Ryan, "Using an Autonomous Underwater Vehicle to Track the Thermocline Based on Peak-Gradient Detection," *IEEE Journal of Oceanic Engineering*, Vol. 37, No. 3, pp. 544-553, July 2012.

c) New and Continuing Projects: Plans for 2017

Research Activities

Targeted sampling research activities in 2017 are outlined in Fig. 4.

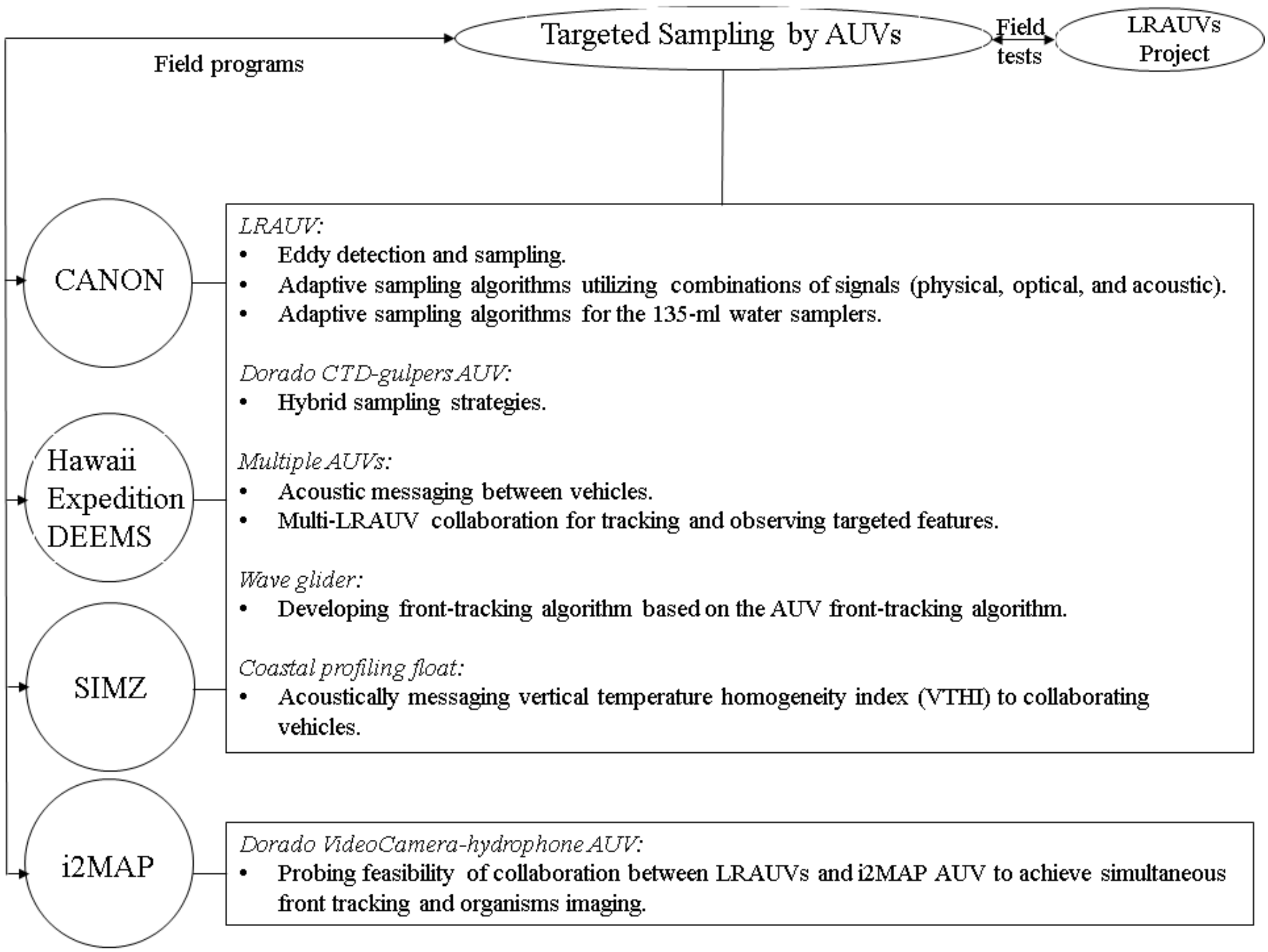

Fig. 4. Targeted sampling research activities in 2017, as related to collaborating projects.

Engineering/technology development

Please refer to Fig. 4 for the engineering development items. Explanatory notes are as follows:

1) Eddy detection and sampling

Mesoscale (~100 km) eddies influence physical and nutrient properties of the water column, thereby impacting biological activities [DeLong et al. 2016, D'Asaro et al. 2011, Mahadevan et al. 2012]. When eddies propagate in the ocean, they impact productivity and biogeochemical cycling in the marine ecosystem [DeLong et al. 2016]. This motivates the DEEMS (Determining the Effects of Eddies on Microbial Systems) leg of the 2017 MBARI HI Expedition. Eddy characterization and tracking is also an emerging science goal of the CANON project (in collaboration with a Keck Foundation funded project).

For the HI DEEMS leg, pre-cruise satellite altimetry plus glider and wave glider data will be used to characterize the eddy field and direct deployment of the 3G-ESP LRAUVs to the approximate region of eddies. To enable the LRAUVs to accurately locate and sample the eddies, we will design methods of AUV autonomous eddy detection and targeted sampling. Fig. xxx shows a University of Hawaii Seaglider survey across two adjacent eddies (southern anticyclonic and northern cyclonic) near Station Aloha. Salinity demonstrated a strong horizontal gradient at the eddy boundary, as the isohalines domed up toward the northern cyclonic eddy center (due to Edman pumping) [DeLong et al. 2016]. We can extend our previously developed upwelling-front detection algorithm to detecting this salinity gradient. Strong current velocity on the eddy's rim [D'Asaro et al. 2011] is also a useful signal for eddy detection. Inside the northern cyclonic eddy there was a peak-chlorophyll layer indicating intensification of biological activities in the deep euphotic zone. The 3G-ESP LRAUVs can run the peak-capture algorithm to trigger sampling in peak biomasses. To develop robust algorithms, we will look into various data sets to extract consistent features of eddies that can be utilized by AUVs in real time.

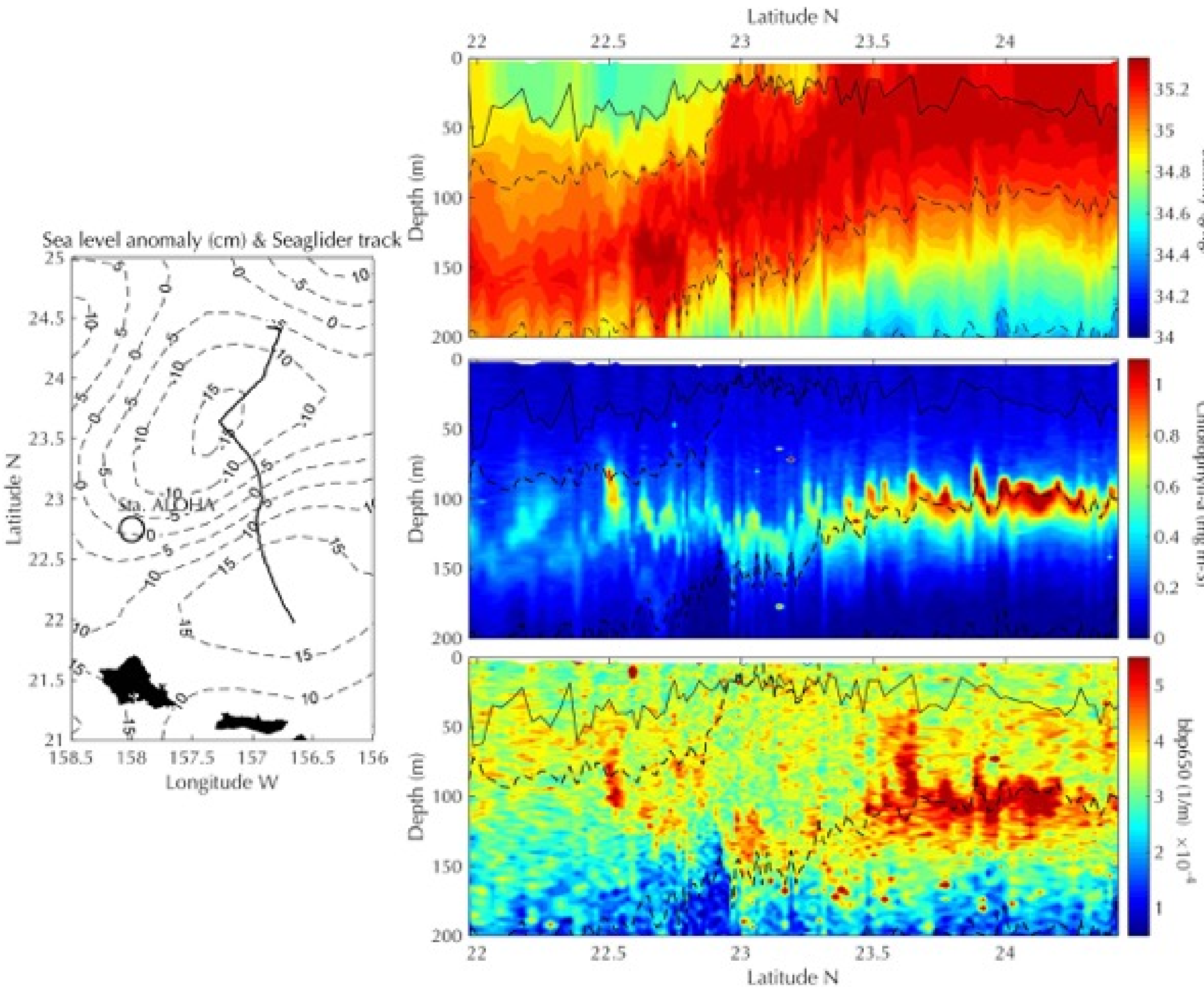

Fig. 5. (Figure and caption both from DeLong and Scholin, "Determining the Effects of Eddies on Microbial Systems (DEEMS) Cruise Plan", 2016) University of Hawaii Seaglider transect across two adjacent mesoscale eddies near Station Aloha in spring 2016. Left: Seaglider track (solid line) superimposed sea level anomaly contours showing the crossing of an anticyclonic (south) and a cyclonic

eddy (north). Right: salinity contours (top panel), chlorophyll *a* concentration (middle panel), and particle backscattering coefficient (bottom panel); the solid line depicts the mixed layer depth and the dashed lines are depths of isopycnal surfaces.

2) Autonomous vehicle-to-vehicle collaboration based on acoustic messaging of key information

Autonomous multi-platform collaboration (with no or minimal human intervention) relies on underwater acoustic messaging between platforms. Fig. 6 depicts a scenario of employing multiple platforms to track and observe a phytoplankton patch. AUV#1 tracks the center of a phytoplankton patch, and observes the boom and bust of the biomass. AUV#2 yo-yos in the neighboring waters to search for other patches. When the chlorophyll patch tracked by AUV#1 fades out, and AUV#2 identifies a more intensive patch, AUV#2 will transmit the key information of the new patch (patch center location/depth, and chlorophyll signal level) to AUV#1. AUV#1 will then fly to the new patch center and start a new round of tracking and observation. When the distance between the two vehicles is out of the acoustic communication range, wave gliders and satellites can serve as gateways to relay the messages. A plan is made to implement vehicle-to-vehicle (e.g., between LRAUVs, or between an LRAUV and a Wave Glider) acoustic messaging using Benthos acoustic modems (which are installed on LRAUVs, Wave Gliders, and coastal profiling floats). This work is in close collaboration with Project 901717 (LRAUV Operations Support) led by Hobson and Project 901411 (Wave Glider Hot Spot) led by Kieft and O'Reilly.

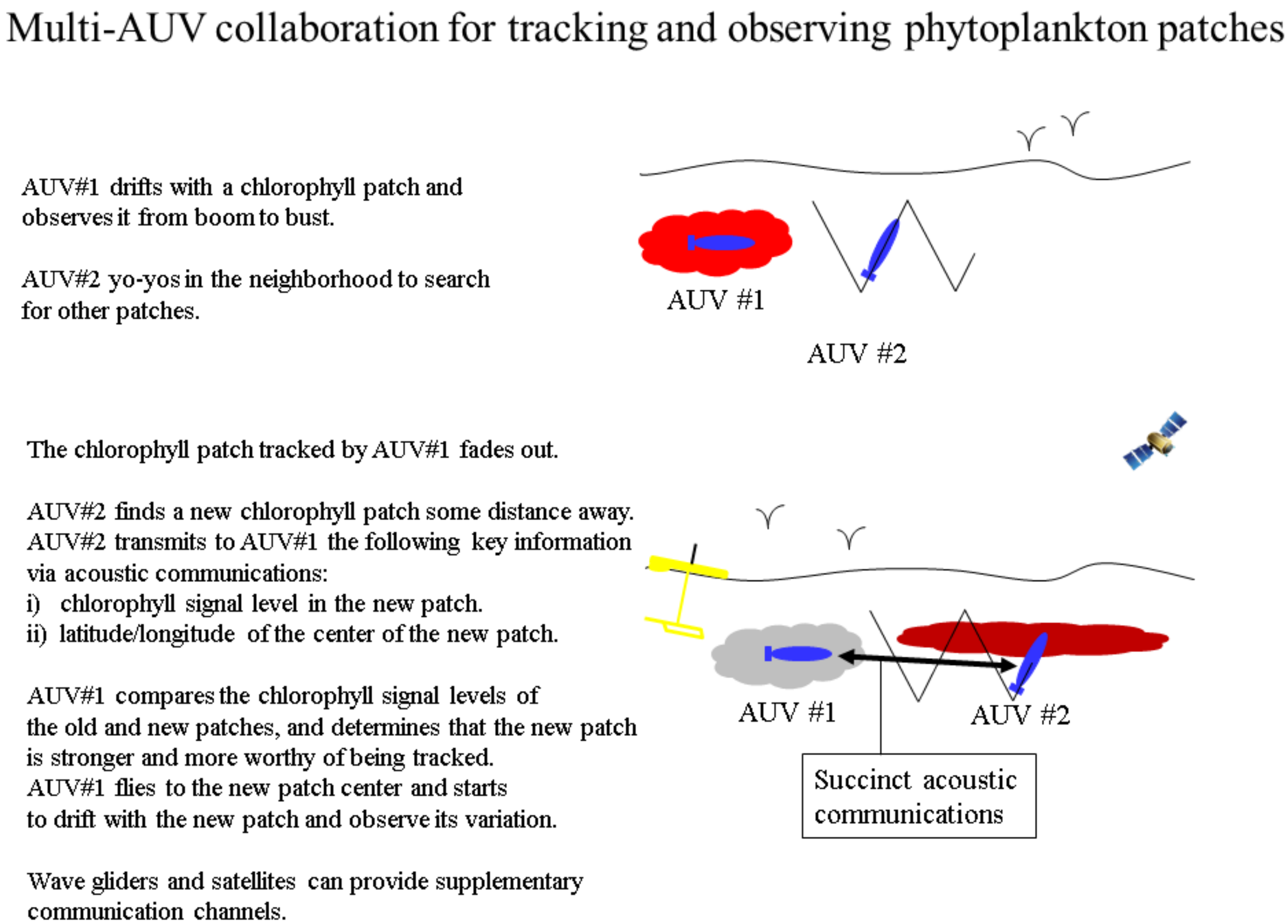

Figure 6. Multi-platform collaboration for organism-centric observation and tracking.

3) Ratio-based zoning of AUV optical signals for real-time classification and adaptive sampling of phytoplankton populations.

A next-level task is to enable AUVs to classify different groups of phytoplankton in real time, and accordingly adapt vehicle/sampler behavior to sample the targeted group, aiming at identifying and assessing marine ecosystem patterns and changes. Because optical sensors (fluorescence, backscatter, bioluminescence) are becoming a routine payload on AUVs, it is desirable to use proxies derived from optical signals for classification. For example, the ratio of fluorescence to backscatter is useful for indicating the likelihood of diatoms versus dinoflagellates or sediment [McCann et al. 2015]. Messié's proposal 901707 (Evaluating the potential for phytoplankton taxa proxies from satellite & autonomous sensors) investigates the feasibility and capability of using optical proxies for robust classification of phytoplankton. Instead of waiting for complete answers, we decide to implement preliminary classification algorithms on AUVs, starting with using the fluorescence/backscatter ratio, as illustrated in Fig. 7. The zoning algorithm serves as a preliminary step toward AUV real-time phytoplankton classification.

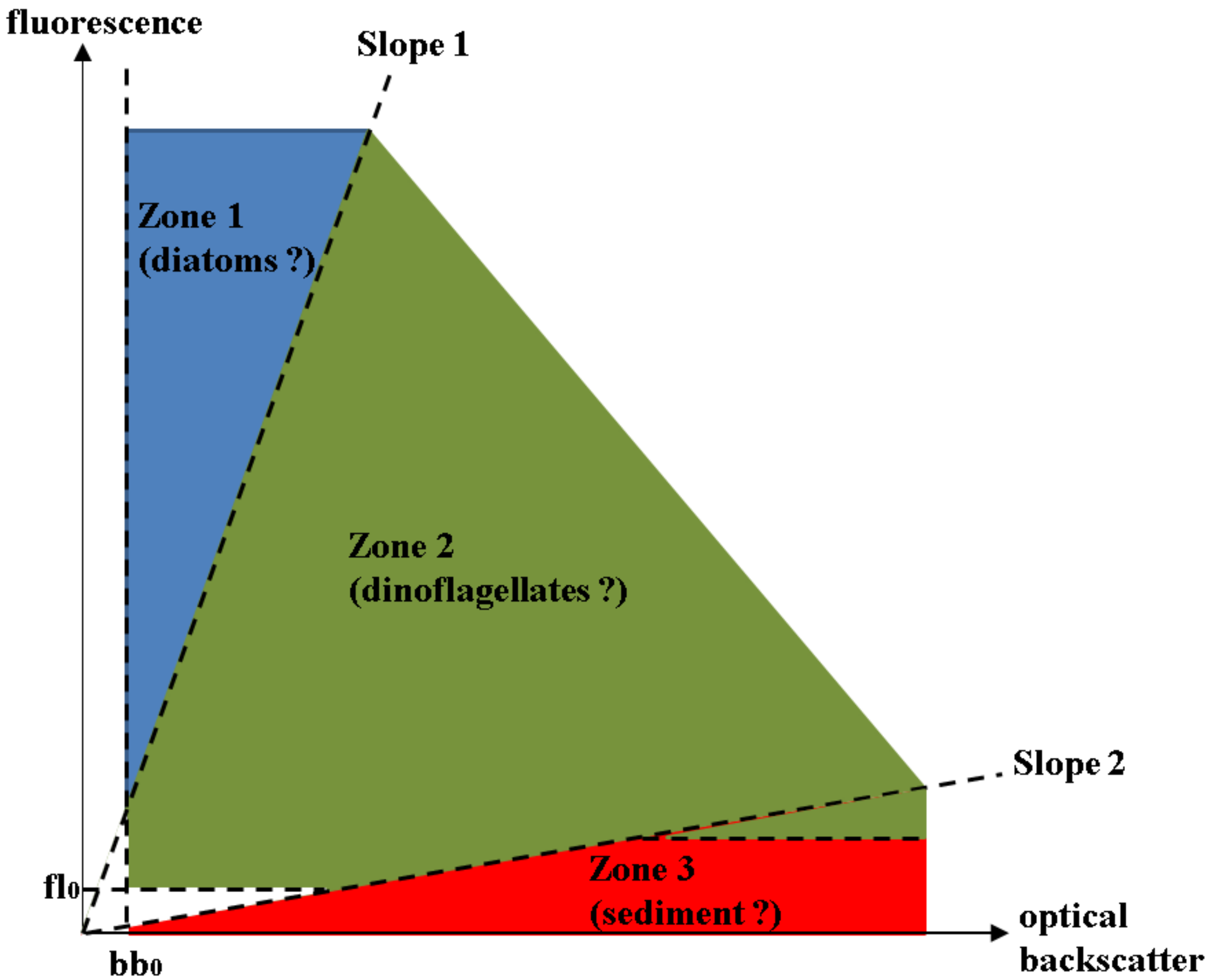

Figure 7. Partitioning AUV optical signals into different zones, based on the fluorescence/backscatter ratio. The zoning algorithm serves as a preliminary step toward AUV real-time phytoplankton classification.

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

1) LRAUV watch-standing labor is requested out of this project. However, the requested 12-day LRAUV time will be allocated from Proposal 901717 (LRAUV Operations Support) led by Hobson, and please cross-reference to that proposal.
2) We request 6 days of Wave Glider (with Hot Spot payload) time for testing the front-tracking algorithm.

This project does not make separate requests of Dorado gulper AUV time and the corresponding ship time; those requests are covered under related projects and associated field programs (see below).

The developed methods outlined above will be used in the following field programs:

- MBARI Hawaii Expedition DEEMS leg, using the 3G-ESP LRAUVs.
- CANON experiment using the LRAUVs, the Dorado gulper AUV, and Wave Gliders.

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.

No isotope usage.

Specific deliverables

1. Targeted sampling methods and computer code for the 3G-ESP LRAUVs, the gulper Dorado AUV, and the Wave Gliders, successfully used in field programs.
2. Methods and field results presented at conferences and published in high-rank peer-reviewed journals.

Milestones (see personnel classification list)

2017 Project Start Date: 01/01/2017	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Total Resources**[1] for each resource category for all milestones listed here
Milestone Date	**3/31**	**6/30**	**9/30**	**12/31**	
Milestone Description	**1. vehicle-to-vehicle acoustic messaging that passes key oceanographic information.** **2. Designing AUV autonomous eddy detection and tracking algorithms**	**1. Field tests of AUV eddy detection and tracking** **2. Field tests of Wave Glider front detection and tracking**	**Field tests of multi-platform collaborations.**	**1. Testing improved algorithms.** **2. Publications.**	
EE	**7 hrs (Mellinger)** **7 hrs (Klimov)**	**7 hrs (Mellinger)** **7 hrs (Klimov)**	**7 hrs (Mellinger)** **7 hrs (Klimov)**	**4 hrs (Mellinger)** **4 hrs (Klimov)**	**25 hrs** **25 hrs** 50 hrs
SE	**40 hrs (Rueda)** **10 hrs (McEwen)** **30 hrs (Kieft)** **30 hrs (Stanway)** **15 hrs (O'Reilly)**	**60 hrs (Rueda)** **10 hrs (McEwen)** **30 hrs (Kieft)** **20 hrs (Stanway)** **15 hrs (O'Reilly)**	**40 hrs (Rueda)** **10 hrs (McEwen)** **30 hrs (Kieft)** **20 hrs (Stanway)** **5 hrs (O'Reilly)**	**20 hrs (Rueda)** **10 hrs (McEwen)** **10 hrs (Kieft)** **10 hrs (Stanway)** **5 hrs (O'Reilly)**	**160 hrs** **40 hrs** **100 hrs** **80 hrs** **40 hrs** 420 hrs
ME	**8 hrs (Hobson)**	**8 hrs (Hobson)**	**8 hrs (Hobson)**	**6 hrs (Hobson)**	**30 hrs**

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

EE Tech					
SE Tech					
ME Tech					
Machine Shop					

Budget justification

Attending Oceans'2017 conference: travel & lodging $2200 + registration fee $600 = $2800

Project team

Brian Kieft (100 hours)
i) 60 hours: Assisting implementation of targeted sampling algorithms using LRAUVs, on mission script level and vehicle behavior code level; assisting targeted sampling experiments using LRAUVs and Wave Gliders.
ii) 40 hours: LRAUV operations for testing targeted sampling algorithms.

Jordan Stanway (80 hours)
i) 40 hours: Assisting implementation of targeted sampling algorithms using LRAUVs, on mission script level and vehicle behavior code level; assisting targeted sampling experiments using LRAUVs.
ii) 40 hours: LRAUV operations for testing targeted sampling algorithms.

Carlos Rueda (140 hours):
i) 100 hours: Coding (using Python) and testing the wave glider front detection & tracking algorithm; Debugging in field experiments.
ii) 60 hours: Assisting the work of progressively moving some core logics of targeted sampling algorithms from LRAUV mission scripts to new behaviors.

John Ryan (160 hours):
i) 120 hours: designing AUV autonomous eddy detection and tracking algorithms; devising field experiments.
ii) 40 hours: data processing and publications.

Tom O'Reilly (40 hours):
i) 20 hours: Field tests of vehicle-to-vehicle acoustic messaging.
ii) 20 hours: Field tests of Wave Glider front tracking.

Chris Wahl (20 hours): Field tests of Wave Glider front tracking.

Robert McEwen (40 hours):

i) 20 hours: Assisting debugging of vehicle control problems in developing and testing targeted sampling algorithms on LRAUVs and Dorado gulper AUV.
ii) 20 hours: Assisting porting and improvement of the front-tracking algorithm from LRAUV to Dorado gulper AUV.

Ed Mellinger (25 hours):
LRAUV watch-standing.

Denis Klimov (25 hours):
LRAUV watch-standing.

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.

No lab space requested. Instrument installations on Dorado and LRAUVs will use the respective AUV lab space.

Data storage requirements (see Todd Ruston for assistance)

No data storage request. Dorado and LRAUVs data are stored on respective data servers.

Data availability outside project team, uniqueness

Field experiment data will be accessible through ODSS (Oceanographic Decision Support System) and STOQS (Spatial Temporal Oceanographic Query System).

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.

This project does not make separate requests of Paragon time.

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 collaboration.

Travels for international conferences or lab visits possible, but on conditions of 1) The conferences or lab visits are very beneficial for MBARI research and is of high academic caliber, 2) Attending as an invited speaker and the host will cover travel expenses. International travel for continued academic exchanges is possible in 2017.

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.

<u>Monterey Bay National Marine Sanctuary (MBNMS)</u>

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?

No.

SESAs (General map)
*Projects will need to indicate whether or not work will be conducted within one of the Monterey Bay National Marine Sanctuary's Ecologically Significant Areas (SESAs). An interactive map can be found on the Sanctuary's SIMoN webpages at 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.

<u>Authorizations/Permits from other Agencies or Organizations</u>
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 compiling information on active acoustic use at MBARI. If the project involves using active acoustic instrumentation, please describe plans.

None.

Risk matrix (development and infrastructure projects only)

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