Project Number: 901009

Project Start: Jan. 1, 2016[1] **Project Duration (in years): 2 of 5[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[2]**	**Research**	**Infrastructure[2]**	**Education**	**Time Series**	**Institute Initiative**

Project Manager[3]: Francisco Chavez

Principal Investigator: Francisco Chavez, Chris Scholin, Robert Vrijenhoek, Alex Worden

Lead Scientist: Francisco Chavez

Lead Engineer: Yanwu Zhang

Project Title: Controlled, Agile and Novel Observing Network (CANON)

[1] This date and number should remain the same for the duration of the project. If your project start date for 2017 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 item #5 at the 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.

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

CANON is directed at understanding ecosystem processes that are critical to sustaining and conserving ocean health as well as emerging threats posed by climate change. To do this CANON is developing

systems that provide persistent presence focused on studying biogeochemical transformations, the biological pump and ecosystem processes including forage species. The combined science and engineering team continues to make steady progress on these goals. Short, weeklong experiments, approximately once per month, have been used for scientific discovery and for system development and testing. We are on target for our intensive Fall experiment. Key accomplishments are as follows:

AUVs, gliders and targeted sampling – Tethys, Dorado and Wave glider have been used routinely during the weeklong experiments to test samplers, test deployments from shore, develop new algorithms and study harmful algal bloom (HAB) development. After the large 2015 HAB event that closed the lucrative crab fishery, there has been concern of another outbreak. The CANON assets have been used to detect and understand a HAB outbreak – to date Pseudo-Nitzschia have been detected but no large toxic bloom is apparent. We do not plan any vehicle development as part of CANON in 2017. Targeted sampling will be an important focus in 2017 and that work is described in the Zhang et al. proposal.

Floats and lagrangian sediment traps – Successful testing of floats has occurred in conjunction with the weeklong experiments. We are on track to having Lagrangian Sediment Traps ready for deployment during the Fall intensive experiment.

ESP and water sampler – We have been using the water sampler routinely during the weeklong experiments. We continue to find causes for failures and sub-optimal water volume collection. Sampler development will continue and be expanded for other platforms (including wave glider) under the MBTS proposal (Jones lead). We have not yet had access to ESP pending continued development by that team. Below we propose to use this device heavily in 2017.

Information management and planning – We continue to develop ODSS and STOQS and to use these heavily during our experiments. We hope to wrap up most of the development on these two systems and transition to routine operation in 2017 with the understanding that some engineering work will be required. We propose to focus more heavily on planning (both before and after deployment of assets) during 2017.

HiPP – CANON HiPP 'deepdark'computer built in 2015 was enhanced with 4 GTX Titan X GPU cards bringing its performance equivalent to the NVidia Digits DevBox. Several iterations of deep neural net models were trained using stock images from ImageNet and some learning about configuring and optimizing deep neural nets. Hardware and software for Xilinx Zynq for computer vision was evaluated and determined that Zynq was presently not viable for automated plankton identification 'at sea', but will continue watching FPGA development. Worked with Yogesh Girdhar on use his unsupervised learning software on embedded system Tegra X1 which is the hardware platform planned for second half of 2016. Will work with the Working Group led by Jules Jaffe on plankton image processing and classification. Will begin work on integration of Tegra X1 on Wave Glider.

Significant changes from previous project proposal

None

Publications based on the results of this project only

Aylward, F.O, J. M. Eppley, J. M. Smith, F. P. Chavez, C. A. Scholin and E. F. DeLong (2015), Microbial community transcriptional networks are conserved in three domains at ocean basin scales. Proceedings of the National Academy of Sciences, 112 (17) 5443-5448; doi:10.1073/pnas.1502883112.

Berdalet, E, MA McManus, ON Ross, H Burchard, FP Chavez, JS Jaffe, IR Jenkinson, R Kudela, I Lips, U Lips, A Lucas, D Rivas, MC Ruiz-de la Torre, J Ryan, JM Sullivan, H Yamazaki (2014) Understanding harmful algae in stratified systems: Review of progress and future directions. *Deep Sea Research II* 101: 4-20. doi: 10.1016/j.dsr2.2013.09.042.

Chavez, F. P. (2012) Climate Change and Marine Ecosystems. Proceedings of the National Academy of Sciences, 47, 19045-19046, doi: 10.1073/pnas.1217112109.

Das, F. Py, T. Maughan, T. O'Reilly, M. Messié, J. Ryan, G. S Sukhatme K. Rajan (2012) Coordinated Sampling of Dynamic Oceanographic Features with Underwater Vehicles and Drifters J, Intnl. Journal of Robotics Research 31(5) 626–646.

Doney, S., A. Rosenburg, M. Alexander, F. Chavez, C.D. Harvell, G. Hoffman, M. Orback, and M. Rucklehaus (2014). Chapter 24. Oceans and Marine Resources. *Climate Change Impacts in the United States: The Third National Climate Assessment*, Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., U.S. Global Change Research Program, 557-578. doi:10.7930/J0RF5RZW.

Fiechter, J., E. N. Curchitser, C. A. Edwards, F. Chai, N. L. Goebel, and F. P. Chavez (2014) Spatiotemporal variability of air-sea CO2 exchange in the California Current. Global Biogeochemical Cycles, 28, 371-385.

Frolov, S., J.P. Ryan and F.P. Chavez (2012) Predicting euphotic-depth-integrated chlorophyll-a from discrete-depth and satellite-observable chlorophyll-a off central California. Journal of Geophysical Research, 117, C05042, doi:10.1029/2011JC007322

Frolov, S., J. Paduan, M. Cook, J. G. Bellingham (2012) Improved statistical prediction of surface currents based on historic HF-radar observations, Ocean Dynamics, Vol. 62, No. 7, pp. 1111-1122.

Garcia-Olaya, A., F. Py, J. Das and K. Rajan An Online (2012) Utility-Based Approach for Sampling Dynamic Ocean Fields in IEEE J. of Oceanic Engineering 37(2), 185–203

Godin, M., Y. Zhang, J. P. Ryan, T. Hoover, and J. G. Bellingham (2011) Phytoplankton Bloom Patch Center Localization by the Tethys Autonomous Underwater Vehicle, Proc. MTS/IEEE Oceans'11, pp. 1-6, Kona, HI, U.S.A.

Gonzalez, J., I. Masmitja, S. Gomariz, E. Molino, J. del Rio, A. Manuel, J. Busquets, A. Guerrero, F. López, M. Carreras, D. Ribas, A. Carrera, C. Candela, P. Ridao, J. Sousa, P. Calado, J. Pinto, A. Sousa, R. Martins, D. Borrajo, A. Olaya, B. Garau, I. Gonzalez, S. Torres, K. Rajan, M. McCann, J. Gilabert (2012) AUV Based Multi-vehicle Collaboration: Salinity Studies in Mar Menor Coastal Lagoon IFAC Workshop on Navigation, Guidance and Control of Underwater Vehicles (NGCUV), Porto, Portugal.

Gottlieb, J., R. Graham, T. Maughan, F. Py, G. Elkaim and K. Rajan (2012) An Experimental Momentum-based Front Detection Method for Autonomous Underwater Vehicles, International Conf. on Robotics and Automation (ICRA), St. Paul, Minnesota,

Graham, R., F. Py, J. Das, D. Lucas, T. Maughan and K. Rajan (2012) Exploring Space-Time Tradeoffs in Autonomous Sampling for Marine Robotics, 13th Int'l Symp. on Experimental and Robotics (ISER), Quebec City, Canada.

Hales, B., P.G. Strutton, Saraceno, Letelier, Takahashi, Sabine, Feely and F. Chavez (2012). Satellite-based prediction of pCO2 in coastal waters of the eastern North Pacific. Progress in Oceanography, 103, 1-15, doi: 10.1016/j.poocean.2012.03.001

Harvey, J.B.C, J.P. Ryan, R. Marin III, C.M. Preston, N. Alvarado, C.A. Scholin, R.C. Vrijenhoek. (2012) Robotic sampling, in situ monitoring and molecular detection of marine zooplankton. Journal of Experimental Marine Biology and Ecology 413: 60–70

Hughes, B.B., M.D. Levey, M.C. Fountain, A. B. Carlisle, F. P. Chavez and M.G.Gleason (2015). Climate mediates threats to fish diversity and nursery function at the land-sea interface. Proceedings of the National Academy of Sciences USA. 112:8025-8030.

Jolliff, J.K., R.W. Gould Jr., B. Penta, W.J. Teague, S. deRada, F.P. Chavez, R.A. Arnone (2012) Water mass bio-optical properties in the Monterey Bay region: Fluorescence-based inference of shifts in phytoplankton photophysiology Journal of Geophysical Research, 117, DOI: 10.1029/2011JC007568.

Kumar, S., S. Celorrio, F. Py, D. Khemani and K. Rajan. Optimizing Hidden Markov Models for Ocean Feature Detection, 24th Int'l. Florida AI Research Society (FLAIRS) conference, Palm Beach, FL.

Lin, G., F. Chai, P. Xiu, Y. Liu, S. Rao, and F.P. Chavez (2014) Seasonal dynamics of physical and biological processes in the central California Current System: A modeling study. Ocean Dynamics. http://dx.doi.org/10.1007/s10236-014-0721-x.

Messié, M. & Chavez, F. P. (2015) Seasonal regulation of primary production in eastern boundary upwelling systems. *Progress in Oceanography*, 134(0)**,**1-18.

Muller-Karger, F.E., M.T. Kavanaugh, E. Montes, W.M. Balch, M. Breitbart, F.P. Chavez, S.C. Doney, E.M. Johns, R.M. Letelier, M.W. Lomas, H.M. Sosik, and A.E. White (2014) A framework for a marine biodiversity observing network within changing continental shelf seascapes. Oceanography 27(2): 18–23, http://dx.doi.org/10.5670/oceanog.2014.56.

Ottesen, E. A., C. R. Young, J. M. Eppley, J. P. Ryan, F. P. Chavez, C. A. Scholin, and E. F. DeLong (2013) Pattern and synchrony of gene expression among sympatric marine microbial populations. PNAS www.pnas.org/cgi/doi/10.1073/pnas.1222099110.

Ottesen E.A., Young, C.R., Gifford, S.M., Eppley, J.M., Marin III, R., Schuster, S.C., Scholin, C.A., DeLong, E.F. (2014) Multispecies diel transcriptional oscillations in open ocean heterotrophic bacterial assemblages. *Science* 345: 207-212. (DOI: 10.1126/science.1252476).

Py, F., J. Das, and K. Rajan (2012) An Online Utility-Based Approach for Sampling Dynamic Ocean Fields A. Garcia-Olaya, IEEE Journal of Oceanic Engineering, 37(2), 185–203.

Robidart, J.C., Church, M.J., Ryan, J.P., Ascani, F., Wilson, S.T., Bombar, D., Marin, R III, Richards, K.J., Karl, D.M., Scholin, C.A., Zehr, J.P. (2014) Ecogenomic sensor reveals controls on N2-fixing microorganisms in the North Pacific Ocean. *The ISME Journal* **8,** 1175–1185 (doi:10.1038/ismej.2013.244).

Ryan, J. P., Y. Zhang, H. Thomas, E. V. Rienecker, R. K. Nelson, and S. R. Cummings (2011) A High-Resolution Survey of a Deep Hydrocarbon Plume in the Gulf of Mexico during the 2010 Macondo Blowout, Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise (Editors: Y. Liu, A. MacFadyen, Z.-G. Ji, and R. H. Weisberg), Geophysical Monograph Series , Vol. 195, Washington, D.C.: AGU.

Ryan, J. P., 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. Messié, C. Mikulski, T. Pennington, F. Py, K. Rajan, I. Shulman, Z. Wang, Y. Zhang (2013). Boundary influences on HAB phytoplankton ecology in a stratification-enhanced upwelling shadow. Deep Sea Research Part II: Topical Studies in Oceanography, http://dx.doi.org/10.1016/j.dsr2.2013.01.017.

Ryan, JP, CO Davis, NB Tufillaro, RM Kudela, BC Gao (2014) Application of the Hyperspectral Imager for the Coastal Ocean to Phytoplankton Ecology Studies in Monterey Bay, CA, USA. *Remote Sens*. 6: 1007-1025.

Ryan, JP, JBJ Harvey, Y Zhang, B Woodson (2014) Distributions of invertebrate larvae and phytoplankton in a coastal upwelling system retention zone and peripheral front. *J. Exp. Mar. Biol. Ecol*. 459:51-60.

Ryan, JP, MA McManus, RM Kudela, M Lara Artigas, JG Bellingham, FP Chavez, G Doucette, D Foley, M Godin, JBJ Harvey, R Marin III, M Messié, C Mikulski, T Pennington, F Py, K Rajan, I Shulman, Z Wang, Y Zhang (2014) Boundary influences on HAB phytoplankton ecology in a stratification-enhanced upwelling shadow, *Deep Sea Research II* 101: 63-79. doi: 10.1016/j.dsr2.2013.01.017.

Santora, J. A., Sydeman, W. J., Messié, M., Chai, F., Chao, Y.; Thompson, S. A., Wells, B. K. and Chavez, F. P. (2013) Triple check: observations verify structural realism of an ocean ecosystem model. Geophysical Research Letters, 40(7), 1367-1372. doi:10.1002/grl.50312

Scholin, C. 2013 Ecogenomic Sensors. In: Encyclopedia of Biodiversity, 2nd Edition, Volume 2, pp. 690-700. Waltham, MA: Academic Press. Invited contribution.

Seegers, B.N., Birch, J.M., Marin, R. III, Scholin, C.A., Caron, D.A., Seubert, E.L., Howard, M.D.A., Roberston, G.L., and Jones, B.H. **(in review)**. Subsurface seeding of surface harmful algal blooms observed through the integration of autonomous gliders, moored Environmental Sample Processors, and satellite remote sensing in Southern California. *Limnol. Oceanog.*

Sevadjian, JC, MA McManus, JP Ryan, AT Greer, RK Cowen, CB Woodson (2014) Across-shore variability in plankton layering and abundance associated with physical forcing in Monterey Bay, California. *Cont. Shelf Res.* 72: 138-151.

Sevadjian, J. C., Mcphee-Shaw, E. E., Raanan, B. Y., Cheriton, O. M. & Storlazzi, C. D. (2015) Vertical convergence of resuspended sediment and subducted phytoplankton to a persistent detached layer over the southern shelf of Monterey Bay, California. *Journal of Geophysical Research: Oceans*,120(5)**,** 3462-3483.

Smith, J. M., K. L. Casciotti, F. P. Chavez and C. A Francis (2014) Differential contributions of archaeal ammonia oxidizer ecotypes to nitrification in coastal surface waters. The ISME Journal. doi:10.1038/ismej.2014.11.

Smith, J.M., F.P. Chavez and C.A. Francis (2014) Ammonium uptake by phytoplankton regulates nitrification in the sunlit ocean. PLoS ONE 9(9):e108173. doi:10.1371/journal.pone.0108173.

Sudek,S, Everroad, RC, Gehman A, Smith JM, Poirier C, Chavez FP & AZ Worden (2015). Cyanobacterial distributions along a physico-chemical gradient in the northeastern Pacific Ocean. *Environmental Microbiology*. doi: 10.1111/1462-2920.12742.

Timmerman, A. H. V., Mcmanus, M. A., Cheriton, O. M., Cowen, R. K., Greer, A. T., Kudela, R. M., Ruttenberg, K. & Sevadjian, J. (2014) Hidden thin layers of toxic diatoms in a coastal bay. *Deep Sea Research Part II: Topical Studies in Oceanography*, 101(0)**,** 129-140.

Xu, Y., K.A. Rose, F. Chai, F. P. Chavez, and P. Ayon (2015): Does spatial variation in environmental conditions affect recruitment? A study using a 3-D model of Peruvian anchovy. Progress in Oceanography, 2015, doi:10.1016/j.pocean.2015.04.013

Zehr, J.P., J. Robidart and C. Scholin. 2011. Marine microorganisms, biogeochemical cycles, and global climate change. Microbe 6(4) 169-175 (http://microbemagazine.org/index.php/01-2011-home/3280-marine-microorganisms-biogeochemical-cycles-and-global-climate-change)

Zhang, Y., R. S. McEwen, J. P. Ryan, J. G. Bellingham, H. Thomas, C. H. Thompson, and E. Rienecker. July/August 2011. *A Peak-Capture Algorithm Used on an Autonomous Underwater Vehicle in the 2010 Gulf of Mexico Oil Spill Response Scientific Survey*, Journal of Field Robotics, Vol. 28, No. 4, pp. 484-496.

Zhang, Y., M. A. Godin, J. G. Bellingham, and J. P. Ryan. July 2012. *Using an Autonomous Underwater Vehicle to Track a Coastal Upwelling Front*, IEEE Journal of Oceanic Engineering, Vol. 37, No. 3, pp. 338-347.

Zhang, Y., J. G. Bellingham, M. A. Godin, and J. P. Ryan. July 2012. *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.

c) New and Continuing Projects: Plans for 2017

Research Activities

Our scientific interests remain on the intermittent and heterogeneous nature of the ocean environment. For example, observed abundances of foragers in coastal upwelling systems cannot be explained on the basis of the average concentration of their prey. Predators require more energy to search for their prey than what they can gain by consuming it. The average therefore is not a faithful representation of either the temporal or spatial distribution of prey implying it is patchy and that there are times and regions where resources are highly concentrated relative to the mean. Consumers have learned to rapidly exploit these enhanced areas. The term "hotspot" has been used in the literature to describe times and places were resources are concentrated. Hotspots permeate the ecosystem at all levels: 1) microbes that sporadically encounter increases in their favored substrates; 2) phytoplankton that encounter increased nutrient concentrations due to upwelling; 3) small pelagic fish that find increased concentrations of crustaceans associated with bathymetric features; to 4) top predators that forage on anchovies or sardines. Our understanding of these ecosystem processes that lead to these hotspots and the biological responses has been limited by our inability to find and follow the development, maturation and decay of the hotspots. There are three research activities/experiments focused on hotspots proposed for 2017:

1) **Spring experiments** that utilize multiple AUVs with ESPs and samplers. We have a unique opportunity to utilize the MiVegas fleet to study ecosystem processes in Monterey Bay prior to their delivery to the University of Hawaii. This is a win-win situation since similar multi-vehicle experiments are planned in Hawaii (in conjunction with the Hawaii expedition) under logistically more difficult circumstances. Gaining experience in Monterey Bay will be of great value. We will follow a similar plan as during 2016 with short experiments at approximately monthly intervals to test planning, operations and targeted sampling leading up to a combined exercise with the Western Flyer and the NOAA rockfish cruises in May 2016. The Rockfish surveys have identified recurrent krill hotspots in the Monterey region. Krill are a primary food source for both fish and mammals. We propose to use our fleet and work in tandem with our NOAA colleagues to: 1) find and adaptively sample areas of enhanced phytoplankton activity and microbial response (in a similar manner as planned in Hawaii); 2) find and adaptively sample areas with enhanced concentrations of krill; and 3) coordinate traditional net samples taken by our NOAA

colleagues with visual observations by our mini-ROV and with eDNA samples collected by our LRAUVs.

2) **Fall experiment** to continue studies of ecosystem hotspots as during the Fall of 2015 and 2016. We will pick up the weekly experiments in August leading to a shorter 4-5 day cruise on the Western flyer in early October 2017. These studies attempt to link oceanographic processes with high concentrations of predators and their prey in the Año Nuevo region.
3) **January experiment** in Peru in collaboration with German and Peruvian scientists. Ulf Riebesell is leading a mesocosm experiment to look at the effects of different N:P ratios on pelagic ecosystems (Figure 1). The hypothesis is that the mesocosms will mimic conditions expected in a future ocean and hence give a window into how ocean ecosystems will respond. They require knowledge of the in-situ conditions prior to the collection of waters from the oxygen minimum zone (OMZ) off Peru. LRAUV with T, S, O2, NO3, Fl/BB would be an ideal candidate for collecting these initial conditions. Experiment start date is January 30, 2017 and the mesoscosms will incubate for two months with samples taken from them every other day. LRAUV deployment proposed for late January. Riebesell has pledged 20K to cover shipping, and personnel transportation and per diem. They will also cover costs of a customs agent that would be responsible for import and export of the vehicle. Our collaborators have graciously agreed to collect eDNA samples from the mesocosms – will hotspots develop in the mesocosms in a manner similar to how they develop in nature?

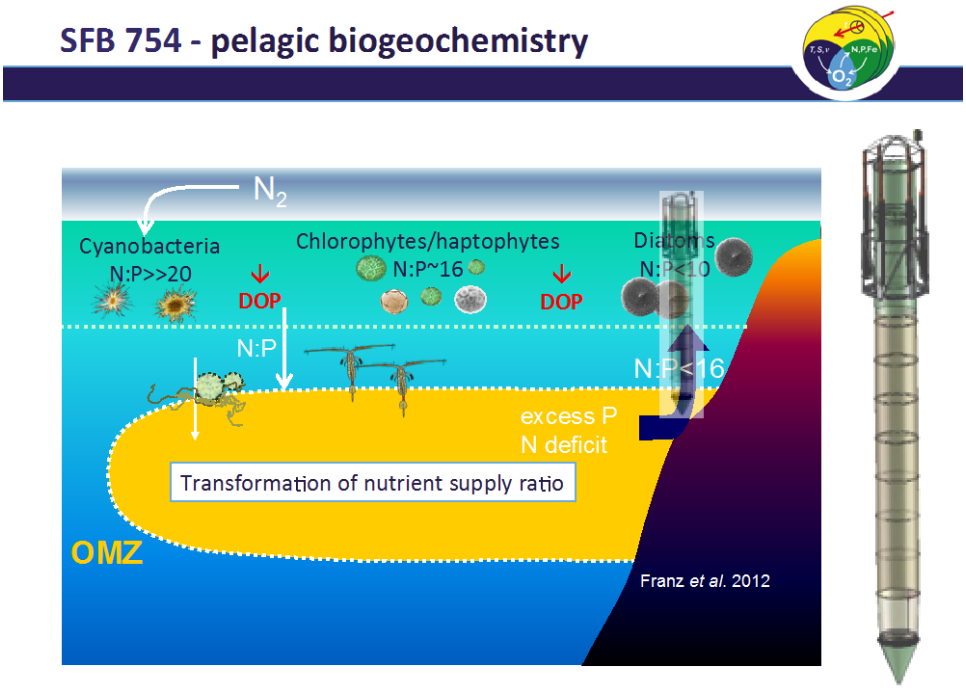

Figure 1. Conceptual model of mesocosm experiment for Peru, January 2017.

Engineering/technology development

Floats and lagrangian sediment traps

For 2017 we are planning 3 activities associated with the floats and associated sediment traps: 1) Improved operations (requires 21 days Paragon and 40 hours machine shop); 2) Development and implementation of a float low power mode (requires 200 hrs EE, 200 hrs ME and 120 hrs Machine shop); and 3) Revisions and upgrades of sediment trap. Brent Jones is leading this effort and proposes to spend 35% of his time on this activity (accounted for in 901112).

Information management and planning

We continue to develop ODSS and STOQS and to use these heavily during our experiments. The goal for the remaining work in 2016 is to complete major feature development for the following areas: 1. Implement situational awareness improvements (vehicle tracking, mapping overlays, ease of use); 2. Implement physical sample tracking platform (both web and mobile based); 3. Implement experiment 'summary' that contains experiment information and a user-curated catalog of the best data sets related to the experiment; 4. Implement authentication and authorization. We plan to wrap up most of the development on these two systems and transition to routine operation in 2017 with the understanding that some engineering work will be required. For the ODSS and STOQS components we are expecting some hours in 2017 to implement small feature requests and bug fixes, but the majority of the hours requested will be for supporting these systems for the field experiments (Gomes 160 hours, Cline 100 hours, Edgington 120 hours and McCann 80 hours).

MBARI's ODSS currently provides a 'situational awareness' view of MBARI's autonomous platforms and ships; this capability has proven invaluable to field programs such as CANON. In addition to situational awareness, there is a compelling need for more tools that support mission planning and execution, and we have been advancing these capabilities within ODSS and evaluating third-party tools as well. Rueda first implemented a vehicle scheduling calendar tool for ODSS in 2015; this prototype allows users to schedule asset deployments in a timeline view along with associated map-based approximate trajectories and patterns, and is currently being used and evaluated by scientists and operations personnel. Rueda is refining the vehicle calendar in 2016 based on planned work and user feedback. O'Reilly is collaborating with LSTS at the University of Porto to evaluate the Neptus graphical vehicle graphical planning tool. Neptus provides a map-based interface that allows users to specify mission characteristics, simulate those missions, translate them to specific 'native' commands recognized by specific vehicles, and then upload the commands to the vehicle. O'Reilly is collaborating with LSTS to demonstrate integration of MBARI's LRAUV with Neptus this year. We are also collaborating in 2016 with the Keck Institute for Space Science (KISS). The KISS team is developing software that utilizes ROMS model predictions to determine sampling locations within dynamic mesoscale features in order to maximize information gain, and translates these sampling locations to 'waypoint' commands that can be issued to a heterogeneous fleet of AUVs, ASVs, and UAVs. We are exploring the design and capabilities of the KISS software in 2016, through telecons and engagement in the 2016 KISS field program in Monterey Bay.

We propose to take next key steps toward realizing the promise of computer-assisted mission planning and coordinated and autonomous execution with the following tasks for 2017:

1. Refine Neptus to enable operators to efficiently and effectively command multiple LRAUVs during

the spring 2017 deployment in Monterey Bay

2. Demonstrate autonomous commanding of multiple vehicles including LRAUVs, sea gliders and Wave Gliders using KISS mission refinement algorithms, during the spring 2017 deployment in Monterey Bay.

3. Design and implement interfaces between ODSS, Neptus, and the KISS planner, allowing information exchange and interoperability between these tools. We envision the design of these programmatic interfaces to also allow ODSS interoperability with other tools and systems, both internal (e.g., LRAUV Dashboard) and external, as deemed useful or necessary.

We propose that O'Reilly be allocated 40 days and Rueda 45 days for these tasks (i.e. a total of 85 days). This work will build on MBARI's ODSS, and will leverage the work of collaborators at KISS and LSTS wherever possible, with potential major benefits for MBARI in the form of improved mission planning user interface capabilities, as well as automated command generation and mission execution by a fleet of autonomous vehicles.

HiPP

Plans for 2017 include:1) an upgrade of the deep learning embedded system hardware from the Maxwell based Tegra X1 to the Pascal based Tegra (P1) contingent on power/performance alignment with Waveglider 2) maintenance of DeepDark server; 3) software infrastructure upgrades for improving both server based training and running neural models at sea; 4) collaboration with the Video Tag, and the Automated Plankton Identification Working Group lead by Jules Jaffe, and 5) collaboration with Sergey Missan of 4Deep on GPU processing along with the imaging cytometer project lead by Tom O'Reilly (320 hours Maughan).

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

We are requesting Western Flyer with ROV for 7 days in Spring to coincide with NOAA Rockfish cruises and 5 days in the Fall. We are requesting Paragon and Wave glider to support these experiments.

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.

Covered in MBTS (901112) proposal

Specific deliverables

[Click here to enter text]

Milestones (see personnel classification list)

[Click here to enter text]

2017 Project Start Date: MM/DD/2017	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Total Resources**[4] for each resource category for all milestones listed here
Milestone Date						
Milestone Description						
EE						
SE						
ME						
EE Tech						
SE Tech						
ME Tech						
Machine Shop						
Divers						

Budget justification

[Click here to enter text]

Project team

Francisco Chavez (oceanography and biogeochemistry), Chris Scholin (ESP, HABs), Bob Vrijenhoek (zooplankton, molecular techniques) and Alex Worden (phytoplankton, molecular techniques) – Scientists who will contribute to intellectual leadership of CANON

Monique Messie (Res. Spec.) – Works on determining classification algorithms, top predators and LRAUV data (220 hours)

John Ryan (Res. Spec.) – Works on physical-biological coupling, science planning (320 hours)

Larry Bird (Mech. Eng.) – Works on LSTs (280 hours)

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

Danelle Cline (Soft. Eng.) – Works on ODSS (100 hours)

Duane Edgington (Soft. Eng.) – Works on ODSS, project management (120 hours)

Kevin Gomes (Soft. Eng.) – Leads ODSS development (160 hours)

Brett Hobson (Mech. Eng.) – Leads LRAUV development, time requested for operational support (15 hours)

Brian Kieft (Soft. Eng.) – Works on LRAUV development, time requested for operational support in MB and Peru (160 hours)

Denis Klimov (Elec. Eng.) - Time requested for LRAUV operational support (15 hours)

Tom Maughan (Soft. Eng.) – works on HiPP development (320 hours)

Paul McGill (Elec. Eng.) – Works on LST electronics (200 hours)

Mike McCann (Soft. Eng.) – Works on STOQs development (80 hours)

Ed Mellinger (Elec. Eng.) - Time requested for LRAUV operational support (15 hours)

Tom O'Reilly (Soft. Eng.) – Works on planning (320 hours)

Carlos Rueda (Soft. Eng.) – Works on planning (360 hours)

Chris Wahl (Wave Glider ops) – 120 hours

Erich Rienecker (CTD tech) – 100 hours

Jared Figurski (Paragon) – 100 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.

[Click here to enter text]

Data storage requirements (see Todd Ruston for assistance)

[Click here to enter text]

Data availability outside project team, uniqueness

[Click here to enter text]

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.

Jones, Kieft, Hobson, Wahl and Figurski are requested and can operate the Paragon

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

Peru

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.

Peru, under MBARI control. No export, there and back.

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?

No or under existing 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.

[Click here to enter authorizations needed, if applicable, or enter "None"]

Active Acoustics

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

[Click here to enter text]

Risk matrix (development and infrastructure projects only)

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