Project Number: 901206

Project Start: Jan. 1, **2015**[1] **Project Duration (in years):** **3** [1]

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

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]: Gene Massion

Principal Investigator:

Lead Scientist: Ken Johnson

Lead Engineer: Gene Massion

Project Title: Coastal Profiling Float

[1] This date and number should remain the same for the duration of the project. If your project start date for 2015 is not January 1, please indicate the start date in the first cell of the milestone chart.
[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)

The current Coastal Profiling Float (CPF) project ends this year (2014) and this proposal describes our next phase of work. The theme of the 2015 project is essentially the same as the 2014 project. For completeness we have included the overall project abstract from the previous proposal in the next paragraph. The subsequent 2 paragraphs provide an overview of the work we propose for the 2015 project.

A warming climate, increased use of nitrogen fertilizers, acidification, loss of sea ice, decreasing oxygen concentrations and a variety of other processes are expected to impact coastal waters. Since much of the global ocean carbon cycling occurs in relatively shallow coastal waters where nutrients are upwelled to the surface, an observing system that can be distributed on a global scale is needed to provide assessments of the effects of these processes on fundamental biogeochemical processes such as net community production and carbon export. We propose an effort to develop a profiling float optimized for use in coastal waters that can serve as the basis of an economically sustainable coastal observing system. The goal is to provide the kind of “salient, credible and legitimate”[1] knowledge that can strengthen the role of science in public policy and decision making. Our approach is to extend the reach of the existing, successful global Argo array into the coastal zone by modifying existing Argo profiling float technology for operation in coastal waters. Our unique contribution would be twofold. First, development of a platform with a bottom “parking” mode optimized to increase the profiler residence times in the coastal zone. Second, this platform will be optimized to ease integration of sensor suites specifically targeting coastal issues e.g., pH, nitrate, oxygen and bio-optical sensors

As of late July 2014 we have completed a bench top prototype, a shallow water prototype primarily intended for use in our test tank and the first go-to-sea prototype. We’ve successfully completed extensive testing on the bench top and test tank prototypes and 2 very successful at-sea tests with the go-to-sea prototype. The first round of testing was focused on proving the core functionality. Subsequently, we have integrated an Aandera Optode, a Wetlabs fluorometer and backscatter sensor, an Iridium modem/GPS module along with internal pressure, temperature and humidity sensors. In addition, we have added the ability to run the CTD in continuous profiling mode. We are currently testing in the test tank and expect to start the second round of at sea testing in the next few weeks. The viability of our basic design got an additional boost when the CANON team asked if they could use our CPF for their fall 2014 deployment and we are working with their team to make this happen.

The continuing project will have twin foci. The first will be deploying CPFs in coastal oceanographic environments to acquire real world science and engineering data with the intent of understanding the strengths and weaknesses of our current design. The second focus of the new project will be continual refinement of the design to address the issues we uncover in this testing. One issue we know needs further refinement is improving the energy efficiency of the current design and we have several strategies we will be testing. Our end goal for the continuing project is a robust, well tested CPF with the capability to support multi-year biogeochemical missions.

We are requesting funds to build one additional CPF in this proposal. Our expectation is that future science programs that may require additional profilers will do so through external funding sources.

[1] David & Lucille Packard Foundation Science Strategy: Linking Knowledge with Action

2) PROPOSAL

a) New Projects

Statement of the problem, why it is important

A warming climate, increased use of nitrogen fertilizers, acidification, loss of sea ice, decreasing oxygen concentrations and a variety of other processes are expected to impact coastal waters. An observing system that can be distributed on a global scale is needed to provide assessments of the effects of these processes on fundamental biogeochemical processes, such as net community production and carbon export. There are no such coastal observing systems that are now available. Coastal moorings are typically expensive, require a skilled labor force for continual maintenance, and are quite susceptible to damage from vessel traffic and fishing. Gliders are also expensive, require a highly trained group to service them between missions, and they carry few sensors.

The Argo array, based on a network of 3000+ profiling floats distributed throughout the open ocean, has been, arguably, the only successful model for global scale sensor arrays in the ocean. The main focus of Argo is to provide a measurement of the changing heat content of the global ocean. The profiling floats used by Argo are optimized for deployment in waters deeper than their 2000 meter maximum profiling depth. Argo has not focused on the coastal zone simply because shallow coastal waters hold little heat. We are now successfully equipping profiling floats with biogeochemical sensors with a goal to provide similar assessments of the time variations in open ocean cycles of carbon, nitrogen and oxygen. However, in contrast to heat, much of the global ocean carbon cycling occurs in shallow coastal waters where nutrients are upwelled to the surface. Thus assessments of the changing elemental cycles in the open ocean will require sensor arrays that can be economically deployed in large numbers for decades throughout the coastal regions of the world. We believe that profiling floats are best suited for this type of global observing system for several reasons. They are relatively low cost and do not require continual service, as do gliders and moorings. For example one glider costs roughly $150K and it typically requires approximately $60K per year to operate a glider (based on conversations with O. Schofield, C. Lee and D. Rudnick). Over 5 years, this represents a cost of $450k. A profiling float costs approximately $50K and, based on current Argo statistics, is essentially maintenance free for 3-5 years. Nine profiling floats can be deployed for every glider over a 5 year period. At a 9 to 1 ratio, the economic advantage of a profiling float array is clear.

Figure 1 is an example of the kind of data product currently possible from the global Argo array and provides approximately 9 years of O_2 and temperature data for an area near Hawaii. We believe the proposed project could generate similar plots in 4 dimensions economically sustainable over decades for not only O_2 and temperature but also a range of other parameters, e.g. pH and nitrate that are critical to understanding and managing coastal zones.

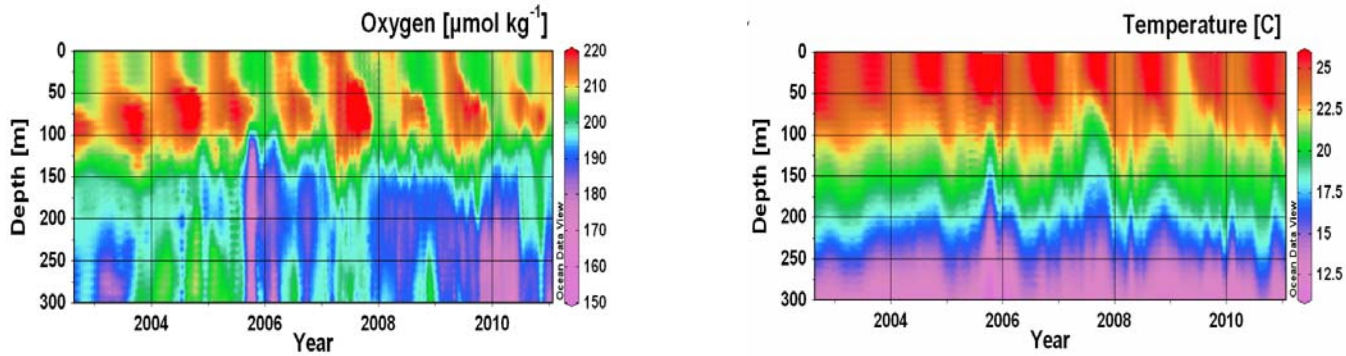

Figure 1 Nine years of O2 and temperature data collected near Hawaii by profiling floats deployed by the University of Washington

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

This proposed project relates and contributes to MBARI's mission and strategic plan at several levels. At the highest level relative to MBARI's mission statement, this project is a symbiotic collaboration between MBARI Engineering and MBARI's Chemical Sensor lab to develop a unique instrumentation system capable of providing economical measurements of fundamental properties required to understand natural phenomena in the critical coastal zone and how human activities are affecting these phenomena. More specifically, the proposed project directly addresses all 3 of the overarching goals in the 2011 strategic plan:

1. Develop or adapt innovative technologies that allow researchers to identify and resolve important questions and advance our understanding of the ocean.

2. Utilize those developments to explore and understand how natural ocean systems operate and how they respond to natural and anthropogenic change.

3. Transfer the knowledge gained, solutions devised, and the technology developed to communities outside of MBARI researchers, educators, policy makers, resource managers, industry, and the general public.

1) We are adapting innovative Argo technology to better understand important coastal processes. 2) We will utilize this technology with a targeted science field program throughout the project to validate the operation of the system, although the real benefit will be long term when large arrays of coastal profiling floats can be deployed. 3) Because the technology is an extension of the existing Argo technology, we have an existing community of users and commercial vendors to transfer the technology to.

In addition, the proposed project directly addresses the Ocean biogeochemistry 2011-2020 research theme identified in the Strategic Plan. In this section of the strategic plan measurements of ocean acidity, oxygen, temperature, density, nutrient density and trace metals are identified as major influences on ecosystem structure and function. The Chemical Sensor Lab had demonstrated the ability to measure all of these parameters on other platforms. This effort will move at least the first 5 of these measurements onto a platform that can be deployed in arrays across the coastal regions of the world. These measurements will also be of fundamental usefulness in project addressing the Ecosystem Dynamics 2011-2020 Research theme.

How does it relate/contribute to the Packard Foundation's Ocean Visions Grantmaking policies?

The Packard Foundation Strategic Framework for Oceans Grantmaking "concentrates on three interlinked objectives … Restoration of ecologically important fisheries, Improved coastal management; and, Enhanced scientific understanding of the functioning of marine ecosystems". The long term products of this project; economically sustainable 4D records of important coastal ocean parameters are critical input to the kind of policy making the Packard Foundation is explicitly supporting. More specifically, the Packard Foundation Science subprogram describes a "growing body of knowledge that can help determine the most effective strategies to strengthen the role of science in decision making". Their document *Science Strategy: Linking Knowledge with Action* describes the kind of knowledge required by policy and decision makers as 1) Legitimate 2) Salient and 3) Credible. We believe the global data currently generated by the Argo program meets all 3 criteria for several reasons. More than 5000 floats have been deployed since 2000. Two global data centers provide quality controlled data within 24 hours of reception. There is a large, global community of researchers using Argo data publishing over 100 papers per year. In addition, at least 16 operational centers around the world currently produce regional and global products based on Argo data. We expect the data generated by the proposed coastal profiling floats can be integrated into the proven Argo data system with all the advantages described above.

Does it relate to the Technology Roadmap? If so, please describe how.

The CPF project supports the Technology Roadmap (TR) in several ways. The most obvious is the CPF is being designed specifically to meet the TF initiative of "Advancing a persistent presence" by supporting experiments aimed at understanding biogeochemical cycles (also identified in the TR as a target challenge) in the coastal zone. Clearly, the CPF has applications outside our specific target science. The TR identifies Ecosystem processes as another target challenge. The CANON team will be borrowing the existing first article CPF for the fall 2014 CANON Ecosystem process experiment and we are supporting their efforts to build 2 more CPFs for their future use. The TR also identifies Ocean Visualization as another target area. We just started a conversation with the the midwater group about how they might be able to move the visualization technology they are currently developing for the LRAUV onto a CPF.

Approach to the problem

At this point we believe the current design meets the requirements we've defined for the CPF with the exception of 4 significant issues we still have to address and discuss below. The buoyancy engine works very well at moving the CPF through the water column with good velocity and depth control (see figure 2 and 3). We have enough reserve buoyancy to anchor and more importantly de-anchor. The housing design is easily scalable in length to support heavier or lighter payloads. The software architecture we've implemented has proven very flexible and extensible to support new functionality and there is a significant amount of reserve computer resources to handle additional sensors. The computer hardware and software development environment we are using has been exceptionally effective at getting us to where we are today.

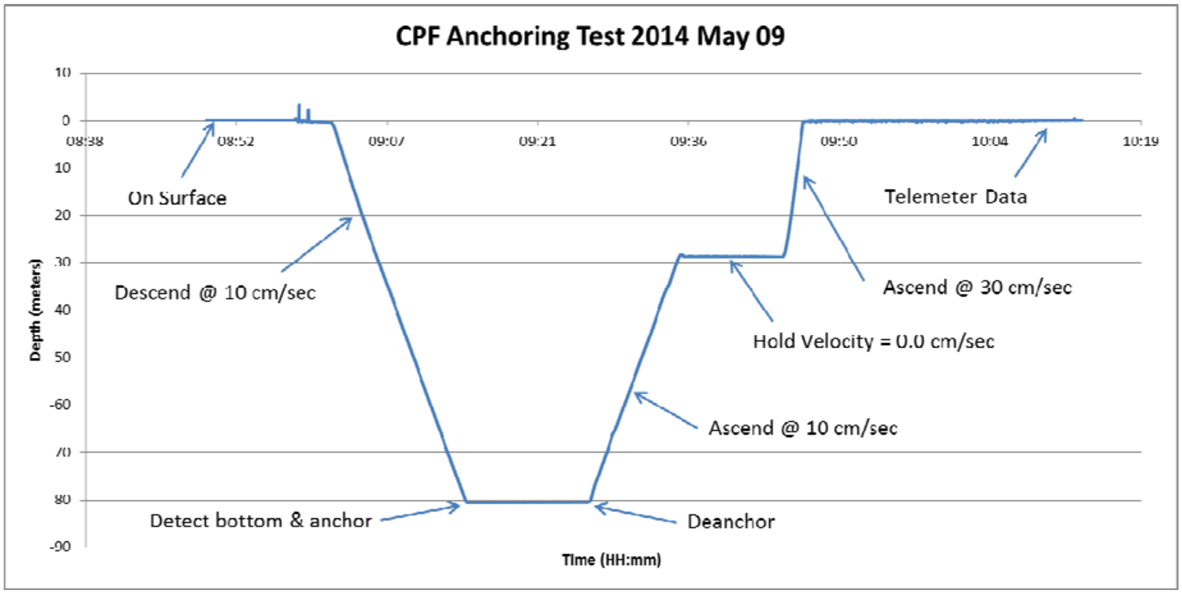

Figure 2 Results from Rachel Carson Dive May 2014

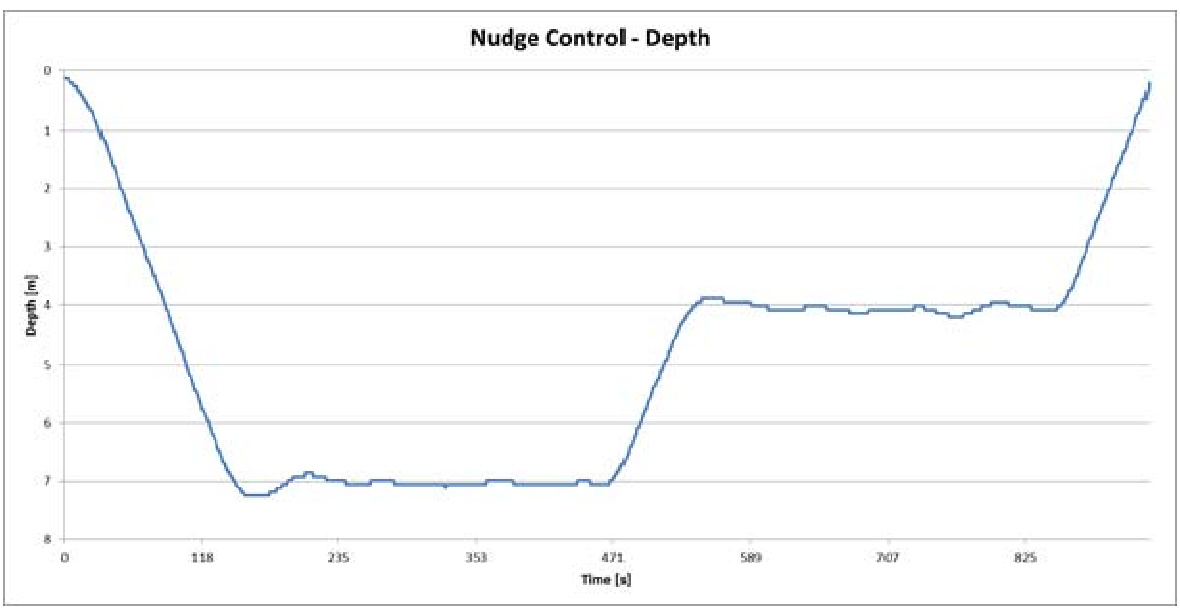

Figure 3 Closed Loop Depth Control Results from Tank Tests July 2014

The 4 outstanding issues we still have to address are as follows.

1) Can we keep a fleet of CPFs in the desired measurement volume without (too many) drifting ashore or out to sea.

We have 3 strategies to address this first issue. A) Anchor on the bottom so we minimize drift while not actually profiling. We demonstrated this capability during our May Rachel Carson dive (Figure 2). However, we have not yet conducted a long-term anchoring experiment to demonstrate that the float holds position. This is one of our objectives in the remainder of 2014. B) Profile quickly. During the May Carson dive we easily profiled at 30 cm/sec, 3 times the nominal Argo profiling rate. The upper rate limit is still to be determined but should be in excess of 50 cm/sec. C) Make use of the ROMS operational modeling capability for the West Coast to park the CPF in a serendipitous current. For example, if a particular profiler is drifting east and ROMS predicts a current drifting west in a specific depth band, we can park that profiler at that depth. While we've developed the tools we need to use ROMS for this purpose, discussions with other ROMS users make it unclear whether we will be using data from ROMS to tactically position our profilers or providing data to the ROMS group to help calibrate their model. In any event, our ability to answer this question can only be demonstrated with time in the water and at-sea testing is one of the primary objectives for the proposed work.

2) Can we improve the energy efficiency of the platform to meet the desired mission duration?

Although both the hardware and software we are using are specifically designed for low power operations, we have consciously put off detailed work on improving energy efficiency in order to concentrate on the riskier elements of this project. Our current design has good power monitoring capabilities and we have a good idea where the heavy power consumers are in our system. The work we need to do to improve energy efficiency is pretty well understood and we intend to use the usual techniques of switching off sensors that aren't active and putting the processor to sleep whenever possible.

3) Demonstrating reliable, bi-directional communication and tracking from our CPF using IRIDUM and GPS

We have just begun integrating 2-way Iridium communications to the CFP. This will be essential to establishing reliable tracking, data transmission, control and recovery of prototype systems. While integrating the Iridium modem and GPS receiver is straightforward, our previous experience with GPS and Iridium on small, ocean going floats has clearly demonstrated the deleterious effect of platform motion on communication reliability. Again, this issue will be addressed during our at sea testing in 2014 and 2015.

4) Prevention of sensor bio-fouling when operating for extended periods in productive waters on the continental shelf.

When working in the coastal zone, there is always the question of how bio-fouling will affect our system. Again, we need time in the water to begin understanding how this issue will affect the

CPF but we are not currently proposing any work in this area until we see how severe the effects might be. This will become apparent as we continue deployments in 2014 and 2015.

At the end of this 3 year effort we expect to have a profiling float with a demonstrated ability to support regional scale coastal oceanographic applications. The Chemical Sensor Group has already commercialized the ISUS nitrate sensor, the DuraFET pH sensor and the LOBO mooring system We expect to pursue a similar commercialization process by the end of this proposed 3 year effort.

Publications (from other projects over the last 5 years)

Paerl, R. W., K. S. Johnson, R. M. Welsh, A. Z. Worden, F. P. Chavez and J. P. Zehr. 2011. Differential distributions of *Synechococcus* subgroups across the California current system. Frontiers in Microbiology, 2, 59, doi: 10.3389/fmicb.2011.00059.

Cullison Gray, S. E., M. D. DeGrandpre, T. S. Moore, T. R. Martz, G. E. Friederich and K. S. Johnson. 2011. Applications of in situ pH measurements for inorganic carbon calculations. Marine Chemistry, 125, 82-90.

Plant, J. N., K. S. Johnson, S. E. Fitzwater, C. M. Sakamoto, L. J. Coletti, and H. W. Jannasch. 2010. Tidally oscillating bisulfide fluxes and fluid flow rates observed with in situ chemical sensors at a warm spring in Monterey Bay, California. Deep-Sea Research, I, 57, 1585-1595.

Johnson, K. S., S. C. Riser and D. M. Karl. 2010. Nitrate supply from deep to near-surface waters of the North Pacific subtropical gyre. Nature. 465, 1062-1065.

Martz, T. R., J. G. Connery and K. S. Johnson. 2010. Testing the Honeywell Durafet® for seawater pH applications. Limnology and Oceanography: Methods, 8, 172-184.

Moisander, P. H., R. A. Beinart, I. Hewson, A. E. White, K. S. Johnson, C. A. Carlson, J. P. Montoya and J. P. Zehr. 2010. Unicellular cyanobacterial distributions broaden the oceanic N_2 fixation domain. Science, 327, 1509-1511.

Johnson, K. S. 2010. Simultaneous measurements of nitrate, oxygen and carbon dioxide on oceanographic moorings: Observing the Redfield ratio in real-time. Limnology and Oceanography, 55, 615-627.

b) Continuing Projects

c) New and Continuing Projects: Plans for 2015

Research Activities

None

Engineering/technology development

As we've described above, the major development efforts for this proposal are

1) Field the CPF and address the issues we know will crop up.
2) Improve the energy efficiency.

In addition, we have started the process of "robustifying" the existing design and will continue this process as part of this proposed work. While the COTS "Gadgeteer" microprocessor hardware has been exceptionally effective at rapidly moving our first article into the water, we have now started the design of a controller board optimized for our needs. The Gadgeteer development model supports this process very nicely as the core electronics module used on the Gadgeteer board we are using now is also available as a small SOM (system on module) designed for integration into OEM systems. The design task for the new controller board is mostly putting the SOM on a board with connectors specifically laid out for our sensors and with a form factor optimized to fit in our housing. Most importantly, all the code we've developed to date for the Gadgeteer board should work without modification on the new board. (at least it says so in the manufacturer's glossy sales brochure). Similarly, Ed Mellinger is just starting a redesign of our current power distribution board adding the power switching capability we need to improve energy efficiency.

A fairly detailed WBS of the significant development tasks for the proposed work is provided here.

1. Software
   - 1.1. Improve error handling
   - 1.2. Harmonize queue calling methods
   - 1.3. Harmonize log file formatting
   - 1.4. Harmonize serial port event handlers
   - 1.5. Clean up hierarchical states
   - 1.6. Integrate SPI UARTs
   - 1.7. Work on energy saving
   - 1.8. "Instrument"" the software
     - 1.8.1. GC probes
     - 1.8.2. Performance profiler
   - 1.9. Fix issues that pop up
   - 1.10. Improve Google Earth navigation app

2. Electrical
   - 2.1. Finish the Power Distribution board
   - 2.2. 2nd spin of the controller board

3. Mechanical

   3.1. Improve buoyancy engine efficiency
   3.2. General packaging
   3.3. Deployment aids

4. System Integration
   4.1. Integrate pH
   4.2. Integrate Nitrate
   4.3. Integrate Accelerometer

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

We are planning roughly 8 single day Paragon test days as well as 2X five day deployments. The 5 day deployments will require a Paragon day for deployment and a Paragon day for recovery for a total of 9 days. In addition, we are requesting a Rachel Carson/Ventana day in the event we have to recover a lost profiler. The plan for a lost CPF is to use the Paragon to locate the wayward CPF by tracking the USBL beacon on the profiler. Assuming we find the wayward profiler, we would use the Carson/Ventana day to recover the CPF. If we haven't used the Carson in this way, we would still use the day to evaluate our adaptive anchoring strategy by using Ventana to nudge the profiler while it is in anchor mode and observe the anchoring algorithm response.

Specific deliverables

Development during the 2012-14 project has resulted in the following deliverables:

1) A bench top prototype buoyancy engine that we have early in the program for proof of concept testing.
2) The test tank prototype (TTP) which has been updated to closely resemble the go to sea prototype with the major difference being an industrial pressure sensor is used on the TTP instead of a CTD. We expect to keep using the TTP as a simulator in the test tank to allow long term, shallow water testing to proceed without tying up our go to sea prototypes. In addition, the TTP is currently being used by Laughlin Barker, our summer intern, to develop and refine our depth holding capability.
3) The first article, go to sea prototype.

We are currently working on the design for the second generation go to sea prototype. This version has the external bladder moved to the top of the housing in order to minimize sediment accumulation and the internal subsystems have been repackaged to fit in a shorter housing. In addition, the 2G unit will have the new controller and power distribution circuit card assemblies mentioned earlier. We expect to finish the fabrication, build and test of the 2G unit we have started in 2014 and build up one additional 2G CPF as part of the proposed 2015 work. Our goal is to have successfully demonstrated in-situ the performance of these CPFs to a point where we will be able to discuss commercialization with qualified companies.

Milestones (see personnel classification list)

2015 Project Start Date: 01/02/2015	**2G #1 Starts Tank Tests**	**First 5 day Test**	**2G #1 Starts Tank Tests**	**Finish Year 1 Testing**	**Milestone 5**	**Total Resources**[4] for each resource category for all milestones listed here
Milestone Date	**April 01**	**July 15**	**October 1**	**December 1**		
Milestone Description						
EE	**150**			**50**		**200**
SE	**300**	**150**	**100**	**150**		**700**
ME	**400**	**300**	**400**	**180**		**1280**
EE Tech	**100**	**50**	**100**	**50**		**300**
SE Tech						
ME Tech	**100**		**100**	**40**		**240**
Machine Shop	**80**		**120**	**40**		**240**
Divers						

Budget justification

Funds are requested in 2015 to minimally instrument the 2G CPF we have started this year along with funds to build a second 2G CPF in the second half of 2015. This last float will give us a total of 3 go to sea units, one 1G and two 2G. Three seems like the minimum number we need to properly test the ability to keep CPFs in a coastal measurement volume, allow test and development to go on in parallel and ensure we can still make progress in the event of a lost profiler. We do not anticipate requesting funds to build any more profilers on this project. Since the instrumentation to fully populate a profiler with our biogeochemical instrument suite is expensive (more expensive than the profiler itself), we are only requesting the core instruments for the first 2G CPF in this 2015 budget and will spread the remaining instrument purchases over the last 2 years of this proposal.

Funds are also requested for general expenses. This includes software support for Gene's Solidworks, Matlab and Labview licenses along with an IEEE membership. We have included a request for travel funds as we hope to have enough data for Gene to present a paper at the 2015 Ocean Sciences meeting.

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

Project team

Gene Massion, Ken Johnson, Embedded Software Engineer, Ed Mellinger, Paul Coenen, Mike Parker

Project lab space

No lab space outside of the Chemical Sensor Lab is anticipated

Data availability outside project team, uniqueness

All our data is available inside MBARI and to qualified external users although I'm not sure how applicable this is for the near future.

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

No

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

Monterey Bay National Marine Sanctuary SESAs (General map)
Projects will need to indicate whether or not work will be conducted within one of the Monterey Bay National Marine Sanctuary's Ecologically Significant Areas (SESAs). An interactive map can be found on the Sanctuary's SIMoN webpages at http://sanctuarysimon.org/maps/sesa/. (*Note: It may take a moment for the page to load, so please be patient.*) 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.

It is possible a CPF will drift into area 6 or 8 and even touch down. We are tracking the floats in near real time and we are prepared to recover a float drifting toward a SESA should that be necessary. We could use some guidance about what criteria would trigger a float recovery.

Risk matrix (development and infrastructure projects only)

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