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				
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: Gene Massion

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 2016 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) PROPOSAL

a) New Projects

b) Continuing Projects

Current status of project and results to date

We've just successfully completed a series of 3 one day at-sea tests of the prototype CPF running typical science missions. In the first 2 days, the CPF mission was a) descend to 60 meters, b) park at 60 meters for 5 minutes and c) ascend to the surface. Science instruments were sampled according to a user defined schedule. The CTD, optode and chlorophyll fluorescence/backscatter (FLBB) instruments were sampled once a minute during the park phase. During the ascend phase, the CTD was sampled every second and the O_2 and FLBB sensors were sampled every 5 meters from 60 to 20 meters and then every 2 meters to the surface. Detailed engineering data was acquired continuously during the entire mission. 10 profiles were planned and completed on each of these 2 days. A "first look" example of science data from one of 10 successive profiles run off the Paragon on 9 July 2015 shown in Figure 1. A waterfall plot showing all 10 fluorescence profiles as a function of time and depth is shown in Figure 2. The 3rd day of this test cycle ran the same mission as the previous 2 days but the test was run in 30 meters of water in order to test the CPF bottom detection and anchoring functionality. 3 profiles were planned for this day of testing, however the weather was good and everything looked to be working well so we completed 5 profiles during the day. All of these tests were done with the CPF running up and down a safety line. The immediate goal for this year is to continue testing until we have enough confidence to run the same tests without any safety line. After that, we will progressively increase the mission length.

Our test process is an iterative cycle of a) bench test with simulated pressure and fix any issues b) test in the test tank and fix any issues c) test at sea. Issues uncovered at sea are addressed and tested on the bench and in the test tank before going to sea again. In 2014, we conducted dozens of profiles at the lab bench with simulated pressure and 100s of profiles in the test tank. We had the first test at-sea test we considered successful in November of last year. We spent the last part of 2014 and the first half of 2015 adding new functionality and improving some weak elements of the system. We repeated the cycle of bench, tank and at-sea testing which culminated in the successful July tests described above. We're pleased that the state machine architecture we've implemented generally allows us to correct issues pretty quickly. For example, we uncovered a situation in a June at-sea test where a "bellows position limit" error was detected and dealt with properly but resulted in the state machine not uploading the profile data from the CTD at the end of the profile ascend phase in certain situations. The engineering log had the detailed history of what happened so identifying the issue was straight forward. Changing the state machine sequence to ensure whatever data was available was downloaded from the CTD and logged to disk took less than a day (along with a few other minor issues) and we were back into the test cycle.

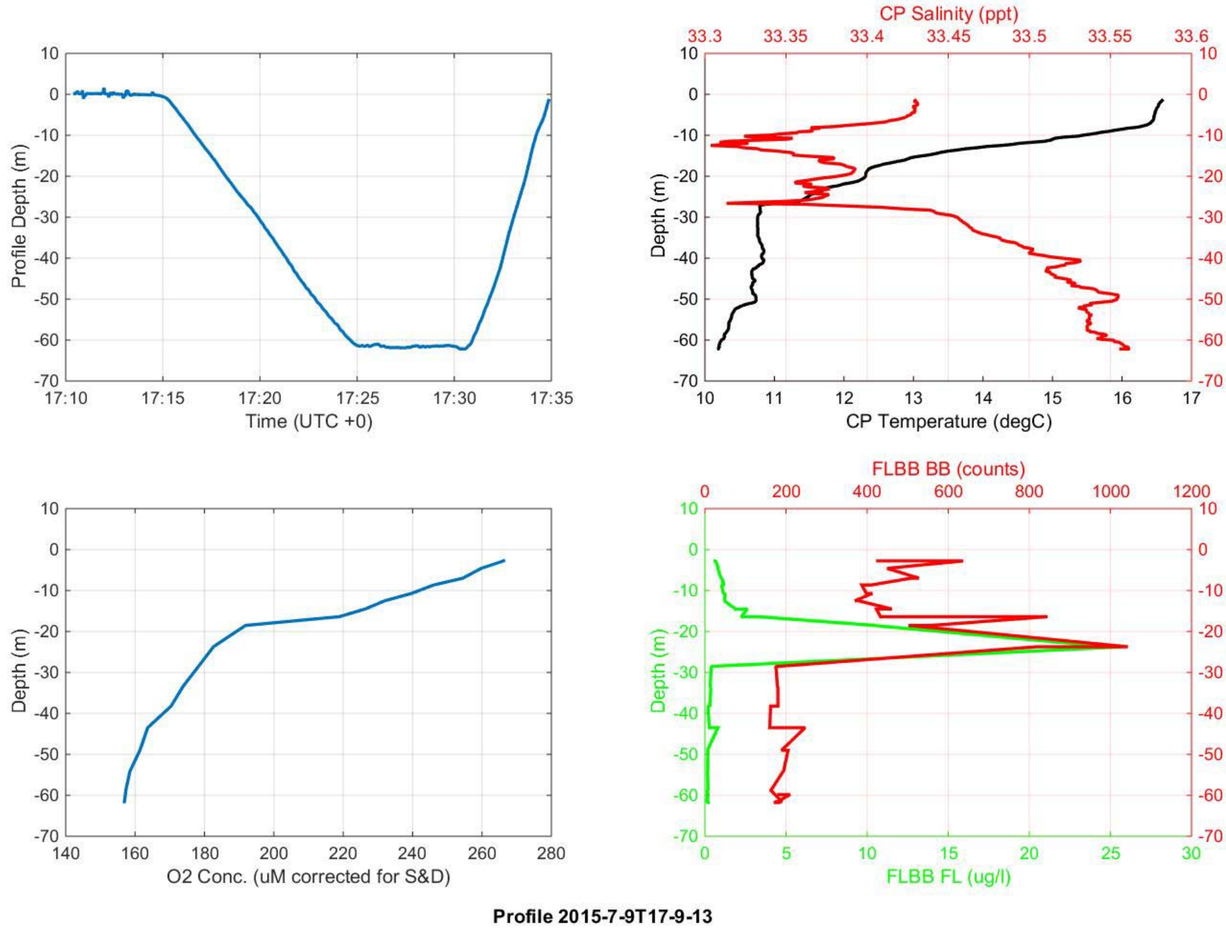

Figure 1

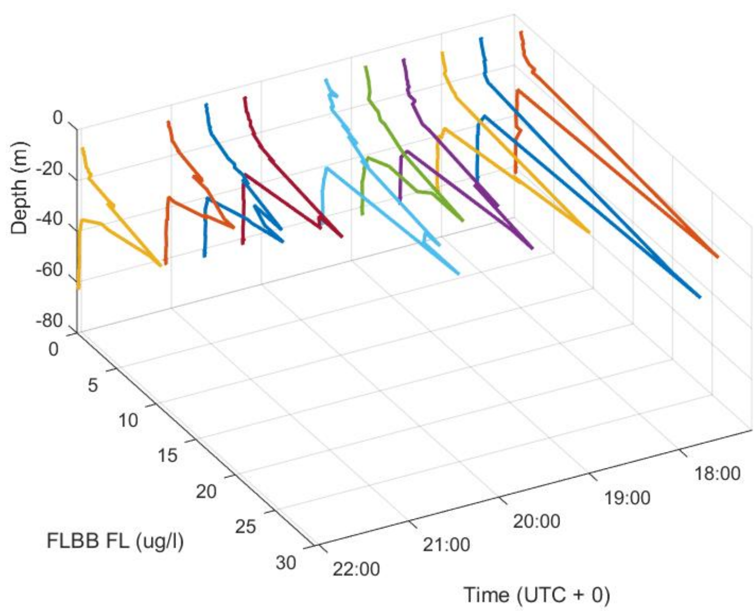

Figure 2

Mechanically, the current design is pretty stable. We haven't made any significant changes to the mechanical design since the CPF prototype was built. The only change to the buoyancy engine has been to simplify the plumbing between the shutoff valve and the external bladder. We've been pleased that the initial buoyancy engine control loop has been working quite well to date although a lot more in water profiles will have to be accumulated before we really can say how well the buoyancy engine is working. While our goal is to minimize the size of the CPF and the next version of the CPF will do this, the current design can support different science missions with greater or lesser payload requirements and/or greater or lesser volume change requirements by simply changing the housing length. Based on our initial calculations, we designed for a 3 liter volume change capability to allow the float to auto-ballast to neutral buoyancy and have at least 1 kg of anchoring force. In contrast, the Webb Apex float has a volume change of only 0.26 liters and properly ballasting by hand is essential before deployment. The large buoyancy change we've designed in is a significant driver of the housing size. Our current housing is 122 cm long. This includes 25 cm over and above what is required for the 3 liter volume change requirement and the current weight of the system to give us some margin for our initial design and carry 4 kgf of ballast to compensate. While we will be shrinking the housing length in the next design, other science missions can take advantage of this scalability to meet requiring for higher profiling speeds, greater anchoring forces, heavier payloads or missions where the actual weight of the system changes during the mission possibly as a result of sample acquisition or expelling material during a perturbation type experiment.

Electrically, we've been working on replacing the COTS prototype hardware we've used to date with a set of circuit cards we're designing specifically for the CPF. The new mother and daughter boards use the same microcontroller and peripherals as the current prototype hardware so almost no changes will be required to port the existing software to the new circuit cards. As of mid-July 2015, the motherboard is in layout and we hope to have the daughter cards in layout by early August. We expect to be testing the new design by the end of 2015.

To date, our Iridium communications have been sporadic and we have not focused on remedying the situation while we operate with the float tethered on a down line. Improving this aspect of the CPF is our immediate highest priority. Mike McCann was able to get the Iridium SBD messages sent by the CPF after each profile into SDSS so the CPF position can be visualized and downloaded like other MBARI platforms.

A major effort this year was refactoring our current software with the express goals of making it more robust, easier to test and easier to maintain. As part of the refactoring process, we were able to get some of Eric Martin's time for a software review and to help better engineer the software to accomplish our goals particularly with respect to taking better advantage of the inherent object oriented nature of C#, the language we are currently working with. Laughlin Barker (a term hire for 700 hours in 2015) was specifically tasked to implement the new software design concentrating on the state machine part of the software. Laughlin revived our test tank prototype for testing with the newly refactored code which began in the tank the first week of July. We're pleased to report that we ran the successful anchoring tests described above with the new code. At this point, we expect all future work to be done with the new software base.

One of the tasks we had for 2014 was to design Version B of the CPF prototype. The goal of the redesign is to incorporate the lessons we've learned with Version A and just as importantly shrink the overall size. We finished the design of Version B with the exception of a few design details and ordered most of the material to build the new design in 2014. However, we've been in an intensive test cycle since the middle of 2014 and had put off the final design details and build until we finish the current test cycle. We were pleased to get some of Farley Shane's time earlier this year and he has been finishing the last details and getting drawings into the shop while we concentrate on the testing. Farley is also currently tasked with building up and testing the buoyancy engine for the new design when the parts come out of the shop Q3 2015.

We have a range of unit and functional tests built into the software framework. We've discovered that accurately simulating the CTD behavior in software to allow accurate testing would require a significant amount of reverse engineering so we've built a pneumatic pressure simulator that applies an actual pressure at the CTD port. We can control the pressure to simulate the actual pressure the CTD would see during an at-sea mission profile. The pneumatic simulator currently requires an operator to start and stop the simulator at the appropriate point in a CPF mission. However, we have made the first steps in making the simulator run hands off during a mission and hope to have this task complete by the end of 2015.

We've been working with the CANON project, Brent Jones and Chris Wahl in particular, to help them build up 2 more CPFs for their Fall 2015 experiment. The first of the CANON units is currently being tested in the CANON lab.

Significant changes from previous project proposal
None.

Publications based on the results of this project only
None.

c) <u>New and Continuing Projects: Plans for 2016</u>

Research Activities

Although this project falls in the development category, we are looking at the data we acquire from every profile to ensure the data makes sense, i.e, there are no obvious anomalies that can be attributed to the CPF. We're automating the process of analyzing data so it can easily be ingested by the existing FloatViz package.

Engineering/technology development

Engineering development for the last half of 2015 and 2016 is primarily continuing the current test cycle with 2 major milestones. The first is to accumulate enough experience with the current CPF prototype to have the confidence to start testing without the current safety line. The second milestone is to run at least one month long, untethered deployment.

Additional engineering tasks include the following.

1. Software development
    a. Add the ability to use the more efficient Iridium RUDICS networking capability for data download
    b. Make the existing error detection and correction functionality consistent across all our classes.
    c. The current prototype hardware supports 6 serial ports. The new mother/daughter board electrical design supports 12 total serial ports. We have developed a prototype driver for the additional 6 ports that will have to be integrated into the existing software and tested.
    d. As mentioned above we currently have an "operator in the loop" pneumatic pressure simulator and hope to have the simulator running "hands off" by the end of 2015. We'd like to extend our current software test framework to work in conjunction with the pneumatic simulator to automate all or at least most of our shore-side testing process. With this capability, we'd be able to automate software unit and functional tests as well as inject faults and anomalous but real events that may happen during an actual at-sea mission in order to rigorously test the CPF software and more generally, the complete CPF system against specific mission scenarios. In addition, we'd be able to use this test fixture for the kind of long term (many months) testing that is so expensive to do at sea.
    e. Build a science mission planner GUI.
    f. Continue addressing issues as they come up in the test process.
2. Electrical
    a. Finish testing and integrate the new mother/daughter board design.
    b. Develop an accurate energy budget for all CPF functions and instruments
    c. Investigate more energy efficient buoyancy engine approaches as required.
3. Mechanical
    a. Evaluate new concepts that may significantly decrease the size of the CPF.
4. System
    a. Finish the design, build and test of the second CPF prototype
    b. Evaluate the efficacy of the ROMS model to identify currents that we can park the CPF in to help keep the CPF in the desired measurement volume.

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

We expect to do all our testing in 2016 off the Paragon and are requesting 20 days. However, given our plans for untethered testing we'd like to request a contingency day on the Carson to recover an inadvertently permanently anchored float. Given this is a contingency day, it isn't clear whether it makes sense to actually put it on the schedule or just deal with the situation when or if it arises.

Specific deliverables

By the end of 2016 we expect to have tested and proven the CPF prototype to the point we can start discussions with potential commercial partners.

The complete list of products developed on the CPF project to date is as follows.

To date

1. A benchtop buoyancy engine test fixture with Labview controller
2. A benchtop CPF prototype running the go to sea software but only a subset of the go to sea instrumentation suite.
3. The initial proof of concept CPF designed for use in the test tank.
4. The prototype go to sea CPF version A.
5. A pneumatic simulator for benchtop testing of all prototypes with actual pressure profiles.
6. Matlab scripts to extract relevant data from the ROMS ocean model to help CPF mission planning

By the end of 2016

7. The prototype go to sea CPF Version B serial number 001 and 002
8. A full benchtop test fixture for complete, long term and mission specific CPF testing.

Milestones (see personnel classification list)

Please note I added an EM Tech row inside the EE Tech row to account separately for Paul Coenen.

2016 Project Start Date:	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Total Resources** [4] for each resource category for all milestones listed here
Milestone Date	**June 2016**	**July 2016**	**Nov 2016**	**Nov 2016**	**Nov 2016**	
Milestone Description	**New elex integrated**	**Software tasks a-c**	**Proto. BB S/N 002 done**	**Software tasks d-f**	**Sea tests done**	
EE	**200**					**200**
SE		**180**		**300**		**480**
ME			**400**			**400**
EE Tech **EM Tech**	**40** **40**		**120** **40**		 **120**	**360**
SE Tech						
ME Tech			**80**		**80**	**160**
Machine Shop			**160**			**160**
Divers						

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

Budget justification

Given the amount of testing we're planning for 2016, we think it is prudent to expect that the loss of one of our prototypes is reasonably likely. We are requesting funds to build serial number 002 of our second prototype to cover that possibility, but also to increase our capability for testing and operations in the equally likely event that we don't lose any platforms. In addition, the budget includes software support for the various tools we use as well as money for spares and a modest contingency for small parts.

Project team

The core project team to date has been Gene Massion and Ken Johnson with the addition of Laughlin Barker in 2014. Brent Jones is responsible for getting 2 new CPFs running for the Fall 2015 CANON experiment and we've successfully integrated him into our team also. We've gotten significant and invaluable technician support from Mike Parker, Paul Coenen and all the e-Techs.

Unfortunately for us, Laughlin is moving on to graduate school with Lou Whitcomb at JHU. Laughlin has been invaluable in many areas but there are 2 in particular we need to fill in for next year, software engineering and all around technical support for tank and at-sea testing. Although we believe our current software design is reasonably stable and won't require significant changes, we do need to add some additional functionality particularly with respect to improving our test process (described above in the engineering/technology development section) and, as is usual for development projects of this type, there are always software issues that need to be addressed. For this reason we'd like to replace Laughlin with a MBARI software engineer. Eric Martin had some previous experience with C# and was able to perform a very effective design review for us. That fact and the interest he has expressed in the CPF project makes him an excellent choice from our perspective. There is little doubt in the mind of our project manager (Gene) that Eric will be a far more effective software engineer for the CPF than our current software engineer (also Gene). Rich Henthorn has also been working on the CPF software as part of the CANON project and would also be a good choice.

We've been using Paul Coenen for a variety of technical support tasks both electrical and mechanical and he is up to speed on many aspects of the CPF design. In addition, we have a lot of at-sea testing planned for next year and Paul had excellent at-sea experience. For these reasons, we'd like to include Paul as an integral member of the CPF team.

As mentioned early, we were able to get some of Farley's time this year and have included him on our team for next year.

Project lab and office space requirements

Doug Au was gracious enough to get us some space in the AUV lab by the test tank. Since tank testing before at-sea testing is an integral part of our test cycle, this has made testing infinitely more convenient and we hope to continue making use of this space.

Data storage requirements (see Todd Ruston for assistance)

The standard project library disk allocation should be sufficient.

Data availability outside project team, uniqueness

All of the data we're acquiring during our testing will be publically available through FloatViz in a non-quality controlled state.

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)

5, 6, 7, 8

Risk matrix (development and infrastructure projects only)

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