Deep Profiler for the Ocean Observatories Initiative Regional Scale Nodes:

Rechargable, Adaptive, ROV Servicable

Tim McGinnis, Nick Michel-Hart
Applied Physics Lab
University of Washington
Seattle, WA USA

Michael Mathewson, Tim Shanahan
McLane Research Laboratories, Inc.
East Falmouth, MA USA
mclane@mclanelabs.com

***Abstract*— As part of the National Science Foundation (NSF) Ocean Observing Initiative (OOI) Regional Scale Nodes (RSN) project, the University of Washington Applied Physics Lab (APL) plans to install a Deep Profiler System that includes a modified McLane Research Labs (MRL) McLane Moored Profiler (MMP). The profiler modifications will include those necessary to operate on a 9/16" diameter electrical-mechanical cable, powered by a rechargeable battery system, and allow installation and removal from the mooring cable by ROV. The rechargeable battery pack will be housed in a third glass flotation sphere and the standard profiler frame will be extended by 12". The inductive charging coupler will be mounted at the base of the profiler and the charging electronics will interact with the profiler electronics to optimize science operations. The modified profiler will have eight science instruments, a dedicated pressure sensor for profiling, continuous data communication using an inductive modem, and high speed data communication when in the charging dock. All sensors will have high accuracy time stamping on the data. This modified profiler will also be deployed and recovered in-situ from the mooring wire by ROV to permit profiler maintenance and instrument calibration without requiring the entire mooring to be recovered.**

Keywords— wire following profiler; inductive communication; inductive charging; observatories; OOI; RSN

I. INTRODUCTION

As part of the National Science Foundation (NSF) Ocean Observing Initiative (OOI) Regional Scale Nodes (RSN) project, the University of Washington Applied Physics Lab (APL) plans to install a Deep Profiler System that includes a modified McLane Research Labs (MRL) McLane Moored Profiler (MMP).

The MMP modifications will include those necessary to operate on a 0.56" diameter electrical-mechanical cable, draw power from rechargeable batteries, charge batteries inductively, transmit data inductively while profiling, time-stamp all data at time of acquisition, and install/remove the MMP using an ROV. The final design of the MMP (Figure 1) includes the following sensors: Falmouth Scientific ACM Plus, Seabird 52MP CTD, Aanderaa Optode, Wetlabs AC-S Spectrophotometer, Wetlabs FLNTURTD, and Wetlabs FLCDRTD.

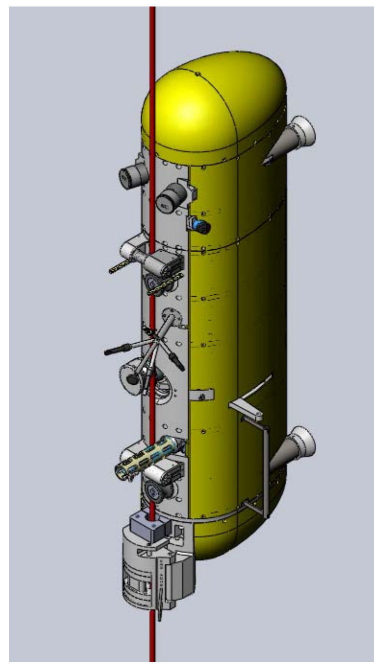

Fig. 1. Solid model of RSN Deep Profiler.

II. ELECTRONICS

A. Inductive Power System

The Inductive Power System (IPS) will allow power to be transmitted from a shore-side power supply, via a seafloor cable to an inductive power transfer system. This connection will allow charging a rechargeable battery pack on the Deep Profiler without the requirement of a direct electrical connection. The seafloor cable will provide 375VDC (nominal) power to a dock assembly fixed to the bottom of the mooring cable. The dock housing will contain the DC-HFAC Converter electronics that will convert the 375VDC to high-frequency AC (HFAC). The primary coupler will transmit the HFAC across a seawater gap to the secondary coupler that will be mounted to the lower end of the profiler. The secondary coupler will transfer the HFAC to the HFAC-DC rectifier that

978-0-933957-40-4 ©2013 MTS

will convert the power back to DC and will regulate the voltage so that it can be used to charge a rechargeable Lithium Ion battery pack.

The IPS will operate similarly to an uninterruptable power supply. When the profiler is in the charging dock, power will be transmitted inductively via the inductive couplers and electronics. The Lithium Ion batteries will be charged and the DC power supply for all of the loads (controllers and sensors) will be supplied from the battery charger. When the profiler leaves the dock and starts profiling, the DC power supply will switch instantaneously over to the batteries. The sensors, controllers, and motor should not notice the power supply switch except for a slight change in the voltage level.

B. *Dual Controllers*

In order to meet the requirements for the number of instruments, power delivery, and time-stamping, the science instrument interface is handled by the APL Deep Profiler Controller (DPC) interfaced to an atomic clock module. The DPC consists of a stack of 3 PC-104 boards (CPU, 8 port serial interface, 8 port FET power switching) that are able to switch power to the instruments, manage the serial data communications, time-stamp the instrument data at acquisition, format and buffer the data, and transmit the data to the server on shore. The McLane Profiler Controller (MPC), a Persistor CF2 with custom interface boards, will manage the movement of the profiler via the user schedule, control the motor, monitor the docking limit switch, read and send pressure to the DPC, receive commands for profiling and docking, and send engineering data files to the DPC. The MPC will also accept and implement new schedules as needed for adaptive profiling.

The use of dual controllers allows for an increased duty cycle and rapid profiling. Normally, a single controller cannot send data inductively while efficiently conducting motor operations. The additional controller (DPC) can easily manage data communications and sensors while the MPC drives the motor, checks the CPT 6180 pressure sensor, and follows the chosen deployment schedule.

Standard communication speeds via inductive modem are expected to reach a maximum of 1200 bps. While docked, the DPC will be able to communicate at WiFi speeds. Acceptable WiFi links have been demonstrated by APL to a distance of 20cm in seawater.

The power budget of the profiler is dominated by the Wetlabs AC-S and its pump, which is expected to draw 13 W while operating. The remaining sensors draw a total of 4 W and each controller (DPC and MPC) draws 3.5 W, including the estimated motor current. As a result, the expected endurance of the rechargeable battery pack with AC-S turned on is 1.5 days. Without AC-S, the expected endurance increases to a maximum of 3.8 days between charges.

III. MECHANICAL

A. *ROV deployment and recovery*

One of the OOI requirements for the RSN Deep Profiler is that it be installable and removable by ROV – which allows the mooring, dock assembly, and seafloor cables to remain in place when the profiler is removed for service and instrument calibration.

APL has designed an ROV installation and removal system consisting of a cradle that mounts to the ROV and matching modifications to the MMP. The MMP modifications include: adding two sockets on the rear of the MMP that will accept the ROV ‘stab’ latches; modifying the MMP motor mount so that it can be moved to the side; and modifying the MMP cable mounts so that they can be opened and closed by the ROV.

The cradle is mounted to the front of an ROV and provides a means of interfacing the ROV with the profiler. The cradle has two stab tubes with hydraulically operated latches to match the MMP sockets. This provides a means for the ROV to capture the profiler and manipulate it during deployments and recoveries. There are also two guide plates, above and below the cradle, which assist with alignment of the mooring cable to the profiler and protects the sensors on the front panel.

In addition, there is an ROV operated release handle on the port side of the profiler which simultaneously moves the motor mount away from the mooring cable and opens the two cable mounts when actuated, thereby allowing the profiler to be installed on or released from the mooring cable.

The typical recovery procedure is for the ROV to approach the profiler from the downstream side while the profiler is stationary. Depth and profiler status is known in real time through the RSN network, which greatly reduces ROV search time. The ROV would approach slowly, aligning the lower stab tube and socket first. The lower stab is longer than the upper stab to allow the stabs to be aligned one at a time. When both stabs are fully engaged the guide plates mounted to the ROV will come hard against the mooring cable. Then, the hydraulically operated latches are engaged and the Deep Profiler is locked to the ROV. The ROV then operates the release handle on the port side and frees the profiler from the mooring cable. Finally, the ROV slowly thrusts away from the mooring cable and removes the profiler from the mooring cable. Deployment is a similar procedure in reverse order.

Moreover, sensor placement becomes critical for successful ROV operations. The front panel, the most desirable location for sensors, must also be clear of wire obstructions. As a result, the transducer sting for the acoustic current meter is oriented 25 degrees to port, the Wetlabs optical sensors are on either side of the wire and oriented outward. The Aanderaa Optode is located to port near the optical sensors. The intake and exhaust tubes for the Wetlabs AC-S protrude from the front panel on either side of the wire and are connected to the sensor, which is located in the frame of the profiler behind the glass flotation (Fig 2). The Seabird CTD is in the standard location just below the drive motor. The inductive coupler for communications is down near the bottom of the front panel adjacent to the inductive charging probe.

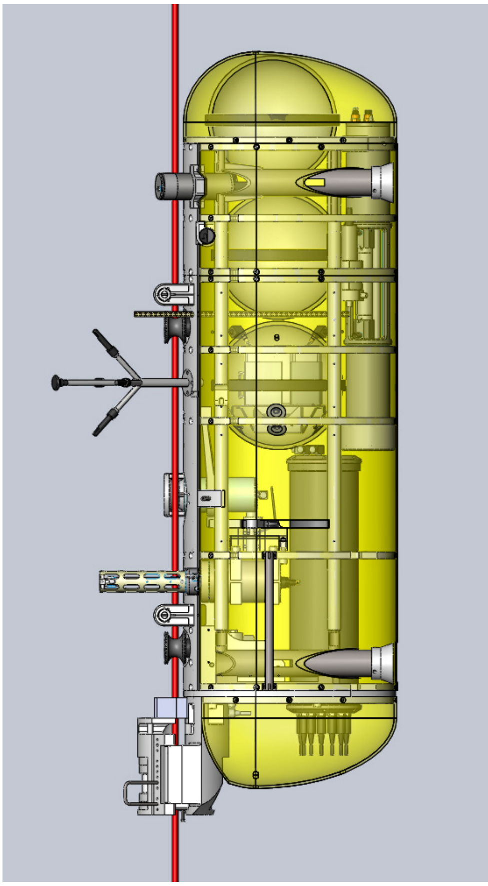

Fig. 2. Solid model of RSN Deep Profiler showing the sensor and components inside the skin.

B. *Computational Fluid Dynamics*

Calculations were made in ANSYS to generate longitudinal and cross section images of the flow field for each sensor based on CFD of the Deep Profiler. Each sensor received two calculations, one for the ascending profile and one for the descending profile. Thorough computational fluid dynamics analysis was done on the profiler design to ensure that the new sensor locations would provide high quality data and not be influenced by flow disturbances caused by profiler movement. Analysis was performed for ascending and descending cases. Figures 3 and 4 show the flow field in plane with the centerline of the ACM, and show that the ACM measurement volume is not affected by the profiler flow field or influenced by the flow disturbances of any of the other sensors.

All analysis was done at 25 cm/s profiling speed (ascent or descent), with zero ocean current. Note that zero ocean current is the worst case for profiler induced flow disturbances affecting sensor measurement.

IV. DEPLOYMENT

The Deep Profiler is expected to be deployed on RSN during the Summer 2014. A test deployment with other sensors and nodes is planned for Fall 2013 at Friday Harbor Labs in the San Juan Islands.

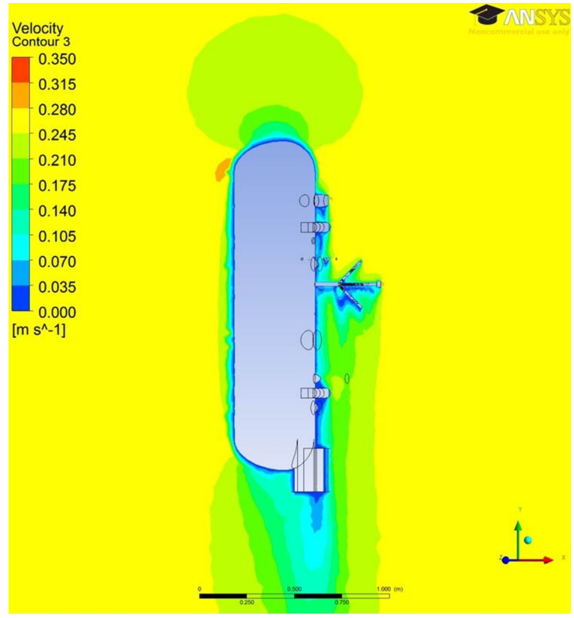

Fig. 3. Flow field at ACM centerline for Deep Profiler descending at 25cm/s and 0cm/s ocean current.

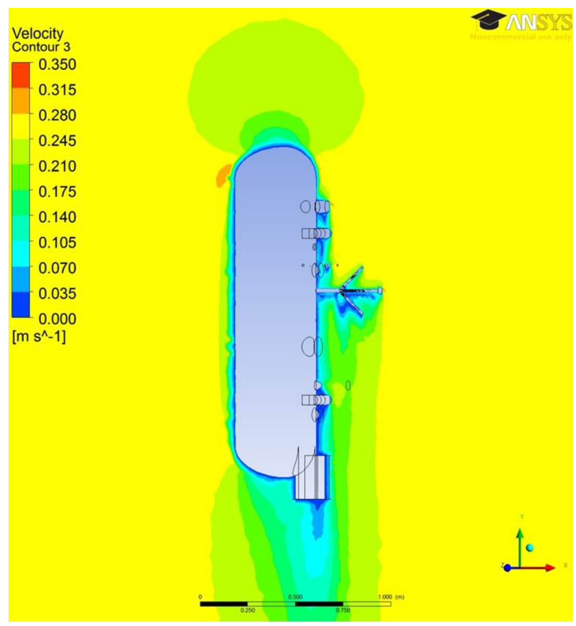

Fig. 4. Flow field at ACM centerline for Deep Profiler ascending at 25cm/s and 0cm/s ocean current.

ACKNOWLEDGMENT

The authors would like to acknowledge the support of the engineers, staff, and management at Applied Physics Lab – University of Washington and McLane Research Laboratories Inc for their commitment and dedication to the success of the moored profiler in general and the OOI RSN Deep Profiler contract specifically. This material is based upon work supported by the National Science Foundation under Cooperative Agreement 0964093, subaward SA-9-09.

References

[1] --, McLane Moored Profiler User Manual, Rev F, September 2013.

[2] McGinnis, T. ; Henze, Christopher P. ; Conroy, Karl; Inductive Power System for Autonomous Underwater Vehicles; Conference Proceedings, OCEANS2007, Vancouver, B.C., 20078 10.1109/ OCEANS.2007.4449219.

[3] M. Mathewson, C. Zani, “Wire-following Profiler for the Ocean Observatories Initiative”, Sea Technology Magazine, Feb 2013, pp 15-18.

[4] T. McGinnis, B.M. Howe, “ALOHA Observatory Moored Sensor Network with Adaptive Sampling” ONT/MTS Buoy Workshop Proceedings, USF, St. Petersburg, FL, March 2004.

[5] Howe, B. M. , Y. Chao , P. Arabshahi, S. Roy, T. McGinnis and A. Gray(2010). A Smart Sensor Web for Ocean Observation: Fixed and Mobile Platforms, Integrated Acoustics, Satellites and Predictive Modeling, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 3, 4, 507-521, DOI: 10.1109/JSTARS.2010.2052022 2010.

[6] Howe, Bruce M., Timothy McGinnis, Harold Kirkham, Gene Massion, "Sensor Networks for Cabled Ocean Observatories", Proceedings of the IEEE Workshop on Scientific Submarine Cable 2003 Conference, The University of Tokyo, 25-27 June 2003.

[7] B.M Howe, T. McGinnis, J. Gobat, "Moorings for Ocean Observatories: Continuous and Adaptive Sampling", Proceedings of the IEEE Workshop on Scientific Submarine Cable 2006 Conference, 172-181, Marine Institute, Dublin Castle, Dublin, Ireland, 7-10 February 2006.