Project Number: 900827

Project Start: Jan. 1, **2008** **Project Duration (in years):** **3**

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

[ ]	[x]	[ ]	[ ]	[ ]
Feasibility/Scoping [Less than 100 days effort]	**Development**[1]	**Research**	**Infrastructure**[1]	**Education**
	[ ]	[ ]		
	Time Series	**Institute Initiative**		

PI: Kim Reisenbichler, Kurt Buck
Project Manager/: Mike Risi

Project Title: Modification of in situ respirometers for ocean acidification studies

[1] Development and infrastructure projects must complete the risk matrix (see item #5 at the end of the proposal form).

1) ABSTRACT (new projects only)

We propose to modify the existing benthic respirometer systems (BRS) and midwater respirometer system (MRS) for ocean acidification studies by;

- Increasing the number of chambers to reduce ship time requirements
- Adding the capacity for accurate sample injection / withdrawal during incubations,
- Use gas impermeable materials for chamber construction to reduce oxygen influx into chambers from wall material,
- Modify the controller hardware and software to accommodate the increased number of sensors, pumps, and stirrers.

The expanded capacity of the systems will increase the number of replicate measurements during each deployment (at sea or in the lab), thereby decreasing the requirements for ship-time, ROV-time, and period required for assessment of CO2 tolerance for any species. The number of chambers for the MRS was previously limited by ROV swing arm load capacity which is no longer an issue, as a new mounting method has been devised.

Modifications of the BRS and MRS are coordinated to increase uniformity among systems to reduce total engineering effort.

2) PROPOSAL

a) The problem addressed

Statement of the problem

In addition to contributing to our understanding of the ocean carbon cycle by identifying the pathways and rates of organic carbon fluxes in ocean ecosystems, studies of metabolic rates and oxygen consumption of individual organisms are an important component of research addressing the biological impacts of ocean acidification. Oxygen consumption is expected to increase in response to hypercapnic (high-CO2) stress, as animals spend extra energy to maintain or restore internal acid/base balance. Such research is one element of our field and laboratory studies.

The measurements of respiration rates of midwater organisms, both in situ and in the laboratory, can be adapted for investigating the influence of reduced pH on a variety of midwater species. Modification of the MRS to include the capability of water chemistry manipulation will enable the midwater group to join the efforts outlined in project 900815, the MBARI initiative directed at Ocean in a High CO_2 World. Toward this end the Midwater Ecology group will expand their investigations of the physiology of midwater animals to coordinate with the experimental work of Jim Barry and Peter Brewer in that project.

The existing BRS and MRS used for these studies have too few chambers to efficiently assess the response of animals to hypercapnia in field experiments. There are only 3 chambers on the existing BRS and 4 in the MRS. One chamber is used as a control (i.e. no animals are placed in the chamber). Because responses to CO2 stress are variable, we must have 3+ replicates for each species at each CO2 concentration tested (2-4 CO2 levels [e.g. 280, 750, 1500 ppm CO2]). Thus, a complete data set for a single species requires a minimum of approximately 12 replicates (e.g. 3 replicates + 1 control x 3 treatments = 12 replicate measurements). With the currently available respirometersthis would entail 4 cruises.

Increasing the number of chambers for the BRS and MRS is more complex than simply adding more chambers and sensors, due to the limitations of the existing hardware and software architecture. Control for the systems is based on the Ocean Acquisition System for Interdisciplinay Science (OASIS) mooring controller. Due to obsolescence, scarcity of parts, and the limitations of the I/O capabilities of the OASIS mooring controller, it is impractical to use this controller for more than 3 chambers. Instead, we are proposing to work with engineering (Mike Risi, Craig Okuda, and Bob Herlien) to modify the existing controller and create new, more generic, software that could accommodate the needs of the benthic and midwater respirometry research programs.

Although the controller hardware and software are the major issue involved in upgrades to the MRS and BRS, we also propose to make several other improvements to the BRS system at this time. First, the acrylic used for the BRS & MRS is gas permeability and acts as an oxygen source during the first 1-2 days of deployment. The relatively higher concentration of gas that has equilibrated with the acrylic prior to deployment diffuses into chambers during the initial incubation period. The severity of this problem depends upon the ambient oxygen levels at the deployment depth and is most severe during studies in low-O2 waters. For the BRS, correction for this problem requires long deployment periods (>5 d), use of one chamber as a measure of chamber effects, and / or the use of impermeable materials for the chambers. While this is also an issue for the MRS, the bulk of this issue is corrected for by the use of a captive control sample. Second, we do not have the ability to withdraw fluid samples from the chambers during experiments. Such samples would be used for various purposes:

- Assessment of actual chamber volume after injecting tracers – this is important for core-type chambers which penetrate the sediment to an estimated depth
- Withdrawal of samples for estimates of nutrient or elemental fluxes (other than oxygen)
- Estimates of nitrogenous waste production by animals
- "Ground-truthing" chamber sensors (especially pH).

Third, we would replace the existing pumps used for the injection of high-CO2 seawater or other tracers (e.g. BaSO4 used for estimation of actual chamber volume) with more accurate pumps (e.g. peristaltic pumps). The pumps used presently cannot be controlled to a sufficient precision. And fourth, we would be able to devote one optode to measure the ambient O2 concentration enabling us to employ the current "intelligent purging" we use with the infaunal respirometer. This allows us to better control the internal chamber O2 concentration when we purge after a given threshold (85%) has been reached inside the chamber. This additional feature saves power and allows a more efficacious experiment.

Why it is important

The awareness and understanding of ongoing ocean acidification is increasing rapidly. Ocean acidification research is a new field of ocean science that has now produced many workshop reports defining directions and urgent needs for an increased understanding of the consequences for ocean ecosystems. A core requirement for comprehensive understanding of the effects of lower pH on the various ecosystems of the marine environment is experiments that dose either composite communities such as the benthic infauna or individual taxa (e.g. megafauna) with known changes of pH. This topic, like global warming, is likely to be a central science issue of the 21st century, and is discussed more thoroughly in the CO2 initiative projects (900815).

Modifications of the respirometry systems to enable more effective experimental studies concerning the biological impacts of increasing ocean carbon levels will promote MBARI's research contributions concerning this important issue.

Cost Benefit Analysis of Respirometer Upgrade.

The existing Benthic Respirometer has 3 chambers for measurements of metabolic rates of individual animals. The total number of measurments required to characterize the response of a species to various levels of ocean acidification is a function of the number of treatments (T) and replicates (R). The product TxR is the total measurements (M) required, and the number of respirometer deployments (D) is simply M/C, where C is the number of chambers on the respirometer. The number of ship days is D x 2, since the respirometer requires deployment and recovery, each using a single ship day.

Figure 1, on the following page, illustrates the effect of the number of chambers (C) and treatments (T) on ship days, assuming 4 replicate measurements per treatment (3 to 5 are typical minima). For example, if we were to increase the number of chambers (now 3) on the existing respirometer to 8 chambers, we would reduced the number of ship days for a single experiment (characterization of a species) from 12 days to 4 days, assuming 4 treatments and 4 replicates. Because we expect to evaluate the metabolic responses to ocean acidification for as many species as possible, the proposed upgrades to the respiration systems should result in a large savings in ship time. Additional ship days will be saved by using a benthic elevator system for deployment and recovery of the respiration system. Thus, the ROV is required for deployment, but the BRS can be recovered without the ROV by simply releasing the elevator using the acoustic release. This will increase ROV time for other activities during each cruise. Although a ship day will be required for recovery, no ROV dive will be required,

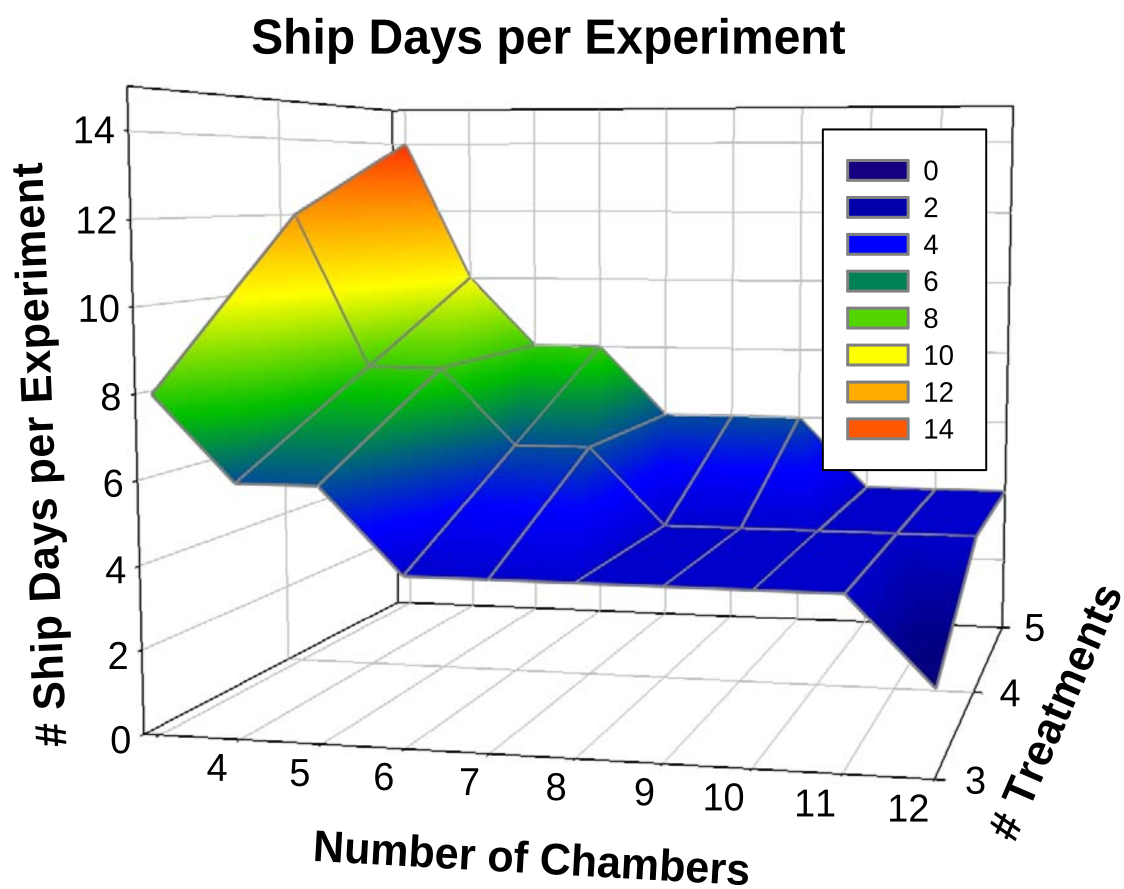


Figure 1. The number of ship days per experiment for a range of C (number of chambers per respirometer) and T (Number of treatments). This figure assumes 4 replicates per measurement. Note that the existing respirometer has 3 chambers.

The benefits of expanding the MRS will be similar. However, due to the constraints of vehicle payload while working in the midwater environment, we are proposing to only increase the total MRS chamber capacity to 6 units.

Present state of art/understanding

Information concerning the state of understanding of the ocean acidification issues is presented in the CO2 initiative project (900815).

Sensors, pumps, and stirrers in the BRS and MRS are controlled using modified OASIS mooring controller electronics and software. By using the OASIS electronics and software small respirometery systems could be quickly built up and deployed. Both systems, however, are at the limit of their I/O capabilities. The BRS has no more serial I/O available which means no more O2 optodes or pH sensors can be added. The MRS does not have any more high power I/O available for powering more flushing and stirring pumps.

This existing controller connects to sensors on a one-to-one relationship with serial ports. This means that each sensor on the BRS requires dedicated cabling (2-3 wires) from the controller through the bulkhead of the controller housing, on out to the chambers. Increasing the number of chambers, each with an O2 sensor, pH sensor, injection pump, sample withdrawal pump, stirring motor, and perhaps other elements, would require an unfeasible number of cables.

The OASIS mooring controller uses a multithreaded operating system that is ideal for logging data from multiple mooring sensors. The OASIS operating system does not work well if a thread needs to use several serial ports (e.g. several sensors) in concert. Bob Herlien is presently modifying the OS for the OASIS controller that will resolve this problem for the BRS and MRS by allowing for the creation of generic threads that can use one or many serial ports as shared resources. Once the modified OASIS operating system is available, Mike Risi would be able to write generic I/O drivers for the sensors and actuators on both BRS and MRS, with much more flexibility in both the number of sensors possible to sample and independent control of each actuator (e.g. pumping one chamber at a time rather than all simultaneously).

The new system would continue to use the OASIS CPU but the I/O system would be modified to better suite the needs of respirometry experiments rather than the needs of a generic mooring controller. The portions of the OASIS software that have benefited both systems will continue to be used. The modified respirometry I/O system would also be sufficiently scalable and flexible enough to meet the future needs of both the MRS and BRS systems. Both systems will also continue to benefit from the interchangeability of electronics and software. The continued use of common components will not be possible by simply addressing the I/O shortfalls of each system separately. The time required to maintain and develop two different systems will soon out-pace that required to develop and maintain a common respirometer design.

Although the MRS and BRS systems may not have the same number of sensors and actuators, they will share the same control architecture and software, and will have nearly identical sensor types. The development effort for 2008 will be divided as follows: 70-80 % of the engineering effort will be shared between MRS and BRS due to the use of the common electronics and software; 10--15% of the engineering effort will be MRS-specific, to include such things as the frame, hydraulics, etc; 100 % of proposed e-tech and mech tech time will be used for the fabrication of the MRS electronics, frame and hydraulics. Ten to fifteen percent is expected to be BRS specific, for the design of chambers, etc.

How it relates/contributes to MBARI's mission and strategic plan

Considering its high societal importance, the theme of ocean acidification is positioned centrally within MBARI's strategic plan. Modification of the respirometry systems (BRS and MRS) will allow progress in understanding the consequences of ocean acidification.

b) Approach to the problem (new and continuing projects)

Plans for 2008

Engineering/technology development

We plan a 2-3 year project to modify the BRS and MRS. Initial activities for scoping the project are occurring in the latter part of 2007 and early 2008. The initial scoping required to generate this proposal has provided the proposed BRS/MRS system layout and software architecture, seen below.

Figure 2. Drawing of the proposed BRS/MRS system layout

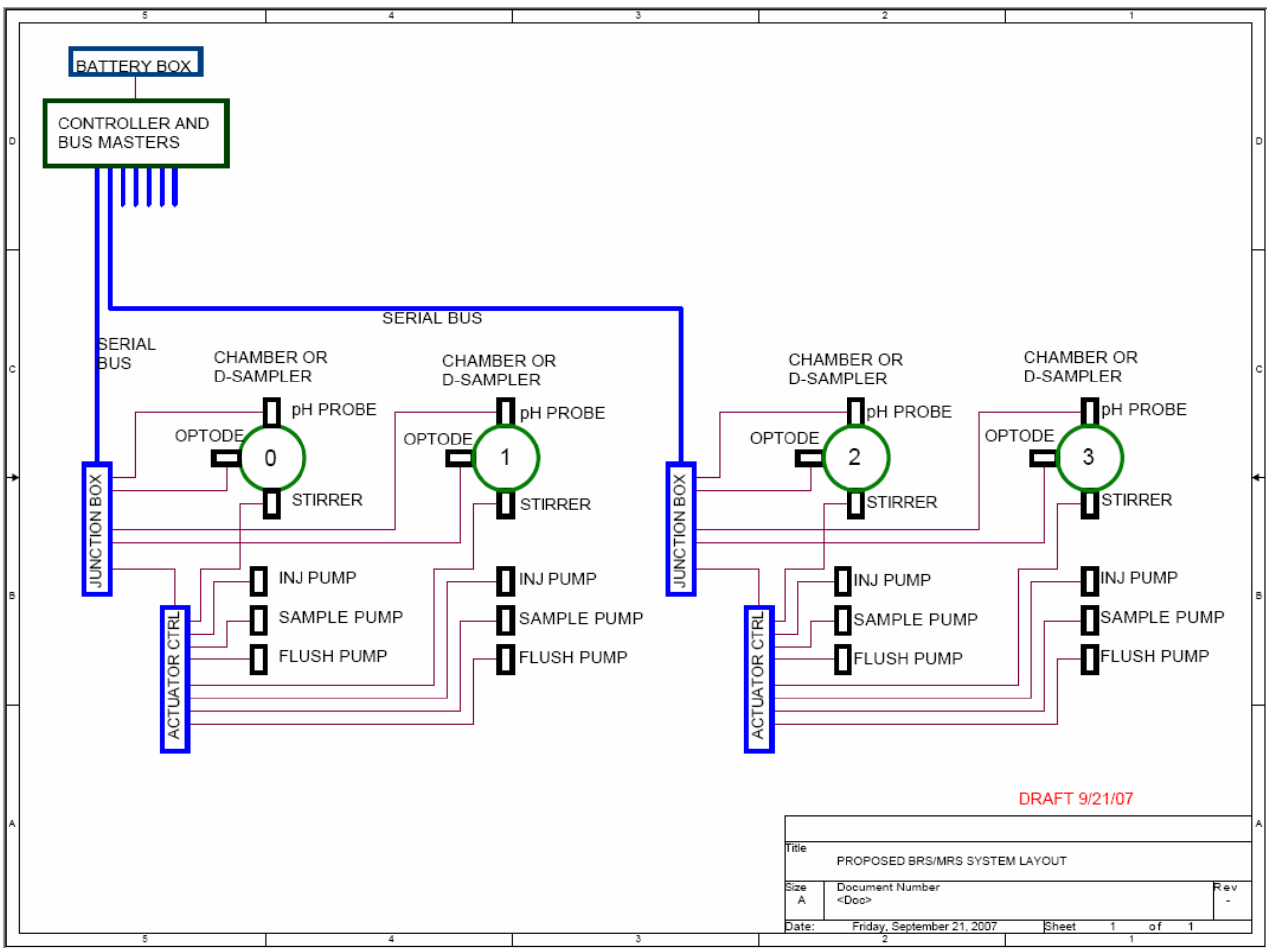
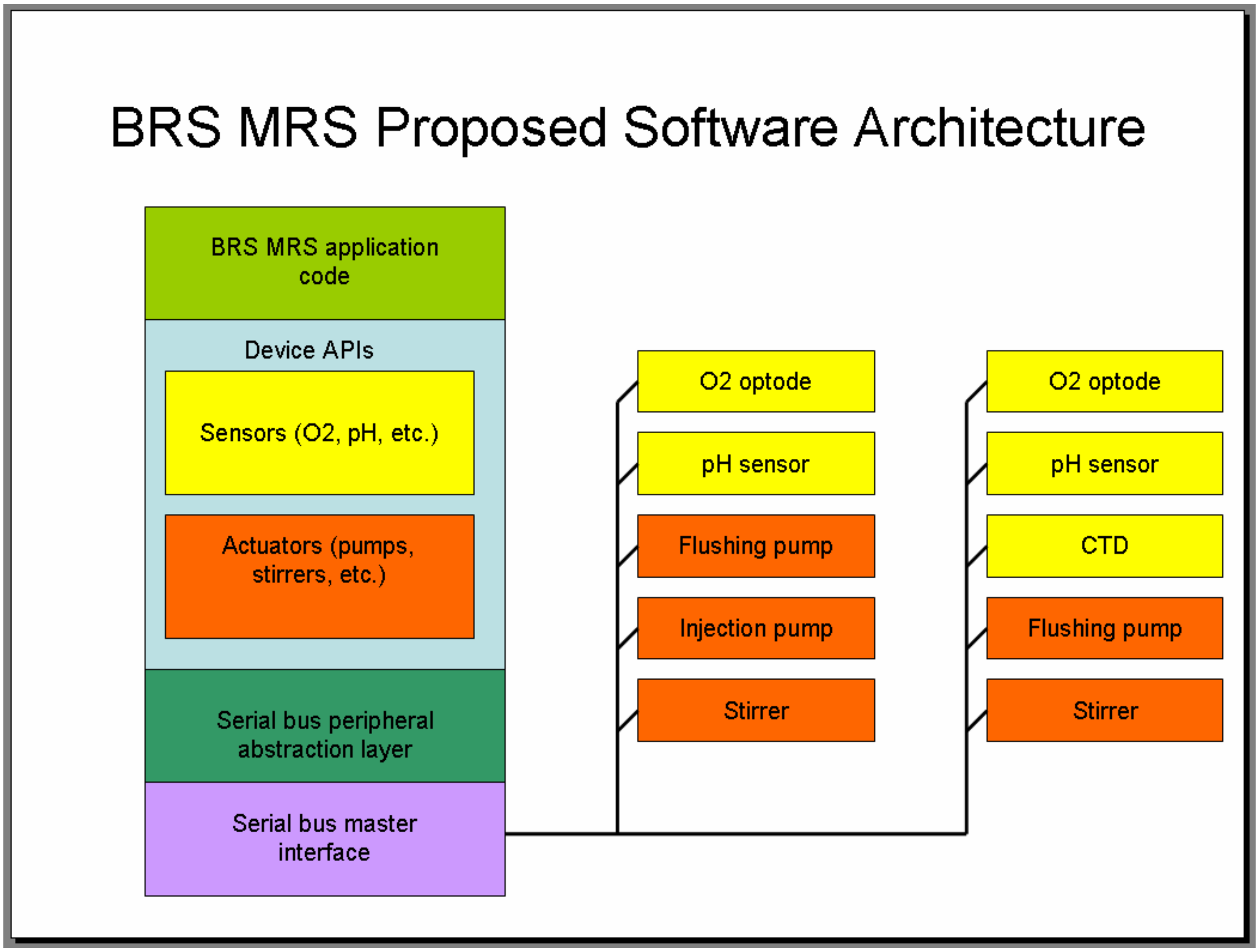


Figure 2. This block diagram illustrates the proposed software architecture of the upgraded BRS/MRS control system.



Modifications / Features Planned for MRS / BRS

BRS

- Increase the number of chambers to 5-10.
- Add the capability to withdraw samples during incubations.
- Use gas impermeable materials for chamber construction to reduce oxygen influx into chambers from wall material.
- Modify the controller hardware and software to accommodate the increased number of sensors, pumps, and stirrers.

MRS

- Increasing the capacity of the MRS 4 to 6 chambers.
- Add capability to read pH sensors and add prototype pH sensors to chambers.

- Add capability to inject chemical solutions to manipulate pH, as well as other parameters (previously planned for 900617 MRS 2007 but will be delayed to better utilize labor resources if this project is approved).
- Re-design the module framework to accommodate the two additional chambers.
- Modify the pressure housing to allow for an additional electrical penetrator.
- Modify the electronics to support the additional communications and power channels.
- Modify the wiring harness to accommodate the additional chambers.
- Modify software to accommodate additional samplers.

Estimated Timeline for Activities
2007-2008

- Scoping of control system hardware and software architecture (late 2007-early 2008)
- Design review of control system, chamber design (Feb-March 2008)
  This will result in a modular design for individual sensing units that will be useable in either respiration system.
- Modifications to expand chamber capacity on the MRS (March-April 2008)
- Prototype and revision of control system completed by April 30, 2008
- Development and integration of the MRS will be complete by April 2008
- Field trials of MRS by August-December 2008
- Transition of existing BRS to new control system by ~October 2008
- Design of expanded chamber system for BRS – mid-late 2008
- Fabrication of modular BRS chamber system – late 2009
  Incremental addition of chambers will be possible following the completion of the major controller upgrade and implementation.

2009-2010

- Field testing of expanded BRS (early 2009)
- Expansion to ~6-10 chamber and increased sampling capacity (mid 2009)
- Testing and refinement (early 2010).

Field testing and deployment of the MRS will occur in August-December 2008, using sea days requested under the Midwater Ecology Project (200108). Any field deployments of the upgraded BRS will occur in sea days requested in the Benthic Ecology Project (900703).

Data (availability outside project team, uniqueness)

Data from the BRS and MRS will be available in publications arising from its use.

The electronic and software upgrades to both respirometry systems will better enable MBARI to transfer this technology to the outside research community, should the publications that result from these systems create sufficient interest. Hypothetically, if another institution showed interest in duplicating one of these systems, MBARI could either supply them with the plans and software or build a replica system(s) under contract.

Significant changes from previous project proposal (continuing projects only)

None

c) Specific deliverables (new and continuing projects)

- Upgraded BRS & MRS
- Presentations at national and/or international meetings and publications in peer-reviewed journals based on results of field and laboratory use of the respiration systems

d) Project team (new and continuing projects)

Mike Risi (manager), Craig Okuda, Bob Herlein, Kim Reisenbichler, Kurt Buck, Bruce Robison, Jim Barry, Peter Brewer.

e) Project lab space (new and continuing projects)

We request the building B laboratory presently used for the BRS with the addition of the entire center table.

3) BUDGET JUSTIFICATION (new and continuing projects)

BRS

We are requesting funds to support partial upgrades of the benthic respiration system during 2008, to be followed by additional requests in 2009. This will spread the costs over 2 years. Major items include 2 oxygen optodes ($9856), materials for titanium oxygen optode adapters ($3.2K), injection/sampling pumps ($2K) and cables and connectors ($10K). Materials are also requested for chamber fabrication ($5K).

MRS

We are requesting funds to support the upgrade of the midwater respirometry system during 2008, to be followed by minimal additional request in 2009. The costs for 2008 are as follows: samplers, optodes and pH sensors ($23.5K), cables and connectors ($11.5K), hydraulic coupler and associated hardware ($2.3K), titanium optode adapters ($3.2K), electronics ($5.75K), new pressure housing ($5.75K) and “C” compiler/CAN protocol analyzer ($0.8K).

MRS/BRS Shared Spare Optode Assembly

We are requesting funds to purchase a single optode to be used as a spare and shared between the MRS and BRS, as needed ($4928). We will also need to manufacture and additional titanium optode adapter at an estimated cost of $1600.

Detailed Budget Request

Account	Sub-Account	Description	Request
Supplies	Equip. < $5K	HBOI Detritus Samplers, 2 ea. (MRS Upgrade)	$8,680
	Equip. < $5K	Aanderaa 3820 Optodes for MRS, 2 ea. (MRS Upgrade)	$9,856
	Equip. < $5K	pH sensors, 6 ea. (MRS Upgrade)	$5,000
	Equip. < $5K	Aanderaa 3820 Optodes for MRS, 2 ea. (BRS Upgrade)	$9,856
	Equip. < $5K	Aanderaa 3820 Optodes for MRS, 1 ea. (BRS/MRS Spare)	$4,928
-5330	**Total Equip<$5K**		$38,320
Supplies	General	4 port RS-232 serial PCMCIA Card (MRS/BRS)	$400
	General	"C' compiler and CAN protocol analyzer (BRS/MRS)	$800
	General	Electronics, PCBs, etc. (BRS/MRS)	$5,750
	General	Titanium Aanderaa adapters, 1 ea. (BRS/MRS Spare)	$1,600
	General	Cables and Connectors (MRS Upgrade)	$11,500
	General	Hydraulic decoupler parts and materials (MRS Upgrade)	$2,300
	General	Titanium Aanderaa adapters, 2 ea. (MRS Ugrade)	$3,200
	General	New pressure housing (MRS Upgrade)	$5,750
	General	Misc Supplies and components (MRS Upgrade)	$10,000
		Titanium Aanderaa adapters, 2 ea. (MRS Upgrade)	$3,200
	General	Injection and sampling pumps (BRS Upgrade)	$2,000
	General	Connectors (BRS Upgrade)	$10,000
	General	Supplies and Materials for chamber fabrication (BRS Upgrade)	$5,000
-5360	**Total Gen. Suppl.**		$61,500
Total			$99,820

4) MILESTONES (new and continuing projects)
REVISE FOR PHASE 2

	Milestone 1	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Milestone 6**	**Milestone 7**	**Total Resources**[2] for each resource category for all milestones listed here
Milestone Date	**Jan. 2^{nd}, 2008**	**Feb. 15^{th}, 2008**	**Mar. 30^{th}, 2008**	**Apr. 20^{th}, 2008**	**May 20^{th}, 2008**	**Aug. 11^{th}, 2008**	**Sep. 22^{nd}, 2008**	
Milestone Description	**Requirements Review**	**PDR**	**Proto-electronics complete**	**CDR**	**Revision, integration and lab testing complete**	**First MRS field trial w/ new configuration**	**BRS Prototype**	
EE								
SE	**5**	**23**	**20**	**14**	**20**	**3**	**2**	**77 (Risi) 10(Herlien)**
ME								
Project Management	**1**	**2**	**1**	**2**	**2**	**1**	**1**	**10 (Risi)**
Support Engineering								
Elect/Mech Engineer	**2**	**14**	**20**	**15**	**20**	**11**	**4**	**86 (Okuda)**
EE Tech			**10**		**4**			**14**
SE Tech								
ME Tech			**5**		**15**	**5**	**3**	**28**
Machine Shop				**7**	**8**	**4**	**4**	**23**

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

Proposed WBS for Project 900827 (Modification of in situ respirometers for ocean acidification studies)

		Jan - Mar 2008						Apr - Jun 2008						Jul - Sep 2008					
Task Description	**Days**	**Risi**	**Okuda**	**Herlien**	**E-Tech**	**M-Tech**	**M-Shop**	**Risi**	**Okuda**	**Herlien**	**E-Tech**	**M-Tech**	**M-Shop**	**Risi**	**Okuda**	**Herlien**	**E-Tech**	**M-Tech**	**M-Shop**
Reviews																			
Requirements Review and preperation	4.5	2	2	0.5															
Preliminary Design Review	4.5	2	2	0.5															
Critical Design Review	6.5							3	3	0.5									
Management																			
Project Management	10	3.5						3.5						3					
Technician Oversight	2								1						1				
Development																			
Software Development																			
Serial bus microcontroller master code	5	3						2											
Serial bus microcontroller peripheral code	10	8						2											
Serial bus controller master interface	5	3						2											
Serial bus controller peripheral abstraction layer	10	7						3											
Controller device APIs	15	9						6											
Application code	12	7						5											
BRS application code	1.5							0.5						1					
MRS application code	1.5	1						0.5											
OASIS modifications	8.5			5						3.5									
Electrical Development																			
Serial bus microcontroller master	8.5		4		2				2		0.5								
Serial bus microcontroller sensor	8		3		2				2		1								
Serial bus microcontroller actuator	8.5		4		2				2		0.5								
Controller	15		9		3				2		1								
MRS system cabling	5		1		1				2		1								
BRS system cabling	3								1						2				
Mechanical Development																			
Controller housing	9		2			1			3			1	2						
Sensor modification	5		1			1			2			1							
Junction box	7		1			1			1			2	2						
Actuator controller housing	6		1			1			2			1	1						
Flushing pump modification	12		2			1			3			3	1					1	1
Stirrer modification	7		1						2				2					1	1
Sampling/injection pump	11		1						2			2	2					2	2
MRS system frame	14		2						2			5	5						
BRS system frame	10														2			4	4
Testing	23							7	3					3	10				
Totals	**248**	**45.5**	**36**	**6**	**10**	**5**	**0**	**34.5**	**35**	**4**	**4**	**15**	**15**	**7**	**15**	**0**	**0**	**8**	**8**

Totals by resource	
Risi	**87**
Okuda	**86**
Herlien	**10**
E-Tech	**14**
M-Tech	**28**
Machine Shop	**23**

Note: Unless specified with BRS or MRS all task are common to both instruments.

9/22/2008

5) RISK MATRIX (development and infrastructure projects only)

Please carefully read Section 5.2.3 in the instructions for internal proposals for an explanation regarding the risk matrix. This table must be completed for **ALL** development and infrastructure proposals (new and continuing). The instructions can be found at http://mww.mbari.org/resources/2008_Proposal_Process/Internal-only_Instructions_2008.htm.

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