Project Number: 901006

Project Start: Jan. 1, **2010** **Project Duration (in years):** **2**

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

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

Project Manager[2]: Bill Ussler

Principal Investigator: Charlie Paull

Lead Scientist:

Lead Engineer: Alana Sherman

Project Title: Benthic Event Detectors (BEDs)

[1] Development and infrastructure projects must complete the risk matrix (see item #5 at the end of the proposal form).
[2] 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)

We propose developing a Benthic Event Detector (BED) to measure the down-canyon movement of the sediments within Monterey Canyon during mass transport events. This project will be structured as a hybrid feasibility-development project whose goal is to determine the feasibility of constructing a self-contained sensor system (the BED) that detects seafloor sediment motion, and to build a prototype unit ideally in the latter half of 2010, if feasibility is adequately demonstrated.

The BED will be equipped with a yet-to-be-determined suite of motion sensors (most likely tilt and/or acceleration) and a pressure transducer, and will be buried just below the sediment surface. This unique sensor will aid in evaluating the new hypothesis that sedimentary fill within submarine canyon floors may move downslope as large masses, not primarily in suspension in the water column above the seafloor or as bedload moving over the surface of the seafloor. If it is conclusively demonstrated that substantial subseafloor movements are occurring, this promises to overturn existing paradigms that explain how sediment moves down submarine canyons.

2) PROPOSAL

a) <u>New Projects</u>

Statement of the problem, why it is important

Multibeam mapping of Monterey Canyon has revealed the existence of crescent-shaped bedforms in the axial channel extending from the canyon head (~11 m) down to ~1900 m water depth. AUV multibeam mapping surveys of other submarine canyons along the California continental margin show that these features are characteristic of active submarine canyons. The occurrence of these bedforms has captured the attention of the marine geologic community and the origin of these features is already controversial.

Our recent efforts to determine the origin of these bedforms have included monitoring the movement of buried homer beacons, repeated AUV-multibeam mapping surveys, and ROV vibracoring in upper Monterey Canyon. Results obtained so far have clearly demonstrated that the bedforms are generated during brief, energetic sediment transport events that occur a few times each year which are capable of moving boulder-sized objects hundreds of meters down-canyon.

What actually happens in these sediment transport events is less clear. The initial assumption, which logically extended from the existing paradigm, was that the wave-like bedforms are produced by suspension and redeposition of sediments during high-energy turbidity events. In contrast, our data suggests that large sections of the canyon floor appear to move in a slump-like fashion during these events, somewhat analogous to movement of ice within a glacier. This new model challenges the turbidity current model and forces us to re-interpret old data and assumptions. At issue is whether the sediment transport events are turbidity currents that exhume material from the canyon floor and carry it either suspended in the water column, as bedload over the seafloor before it is redeposited further down canyon, or as down-canyon translations of large coherent segments of the seafloor. The depth to which the bottom movements penetrate is unknown, but sustained translation of the seafloor down-canyon is a potential mechanism for carving the canyon into its host rock. An instrument buried in the seafloor designed to record motion during the down-canyon sediment movement would aid in discriminating between the turbidity current, bedload, or coherent-slab transport models.

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

This project fits both the basic exploration and enabling persistent presence categories of the MBARI Strategic Plan. The current level of scientific interest and excitement makes this feasibility-development project timely. The sediment transport process being explored is important because it is clearly associated with the first-order movement of sediment from the shoreline into the deep-sea, which is critical for understanding sediment and carbon budgets along this portion of the continental margin. It also offers the possibility of understanding canyon carving processes and the origin of the canyon itself.

In addition to providing fundamental information for understanding the dynamics of the upper canyon, the BEDs offer to provide critical information to both the on-going Benthic Ecology Project (900703) led by Jim Barry and the Biodiversity Initiative (900901). While cycles of disturbance and recovery obviously exert a first order control on seafloor faunal assemblages, practical limitations have usually forced this variable to be downplayed, largely because it has been nearly impossible to properly constrain. Monterey Bay is already unique in that MBARI's long term commitment to understanding the canyon through monitoring and geological studies has provided a detailed understanding of the frequency, magnitude and extent of the canyon floor events, which are the dominate disturbance events in this area. The coupling of geologic knowledge, with our existing data about the distribution of benthic communities (e.g., VARS data) already has provided a surprising payoff in delineating the impact of mass-wasting disturbances on the chemosynthetic biological communities (CBC; Paull et al., 2009). The initial studies were possible because of the slow growth of the CBCs and the timescales of decades to centuries since the last disturbance. However, if we are to invest in detailed census taking of the existing communities, knowing when the community is disturbed and watching how it recovers will be critical. BEDs are a tool to alert us of benthic disturbance events and define "time zero" for the benthic succession cycle. However, distinguishing between the different hypotheses about the processes that occur during the events is also a critical dimension necessary for understanding the impact of these events. For example, the usual assumption associated with the turbidity current paradigm implies that the events we are observing will extend throughout long sections (e.g., 10's of km) of the canyon, however, if the movements involve thick sections of the canyon fill, the area effected during an individual event may be much more local (e.g., 1-2 km). We need to understand this in order to properly track the succession of organism following disturbances and to constrain the role of the canyon as a conduit for feeding deep-sea organisms. The BEDs will provide information and understanding critical for distinguishing among climate, anthropogenic-induced changes, and those that are caused by canyon events.

Approach to the problem

A schematic design for the BED was proposed last year in our Continental Margins and Canyon Dynamics proposal (200010). We were encouraged to re-submit this concept as a development proposal for support in 2010.

During the process of formulating the present proposal, it became apparent that although the initial design developed in 2009 may be a workable and appropriate design and that the component costs outlined last year are of the correct magnitude, there may be other, perhaps more suitable, approaches to the problem of detecting seafloor sediment motion. Thus, we would like to have this project begin by obtaining the engineering time to define and evaluate the options. We propose to begin by presenting the project engineering group with the specifications of what we would like to measure, without pre-supposing which one of the multiple implementation paths we will ultimately try to implement.

In 2010 we propose to break the project into two phases: a feasibility and design study, and a development project, thereby better formulating the overall design before actually building a deployable unit. A detailed outline of the structure of the project is listed below. It outlines how the project could be completed in just one year, but we are requesting this be a two-year project, to allow proper flexibility in the development phase.

Some preliminary modeling has already been undertaken to better define the kinds of motion that may occur during sediment transport and what kind of signals may result. This kind of information will be utilized to select sensor type and sensitivity. Two possible motions are sliding and rolling. Below are the results of a simulation, which shows in theory that these motions can be distinguished.

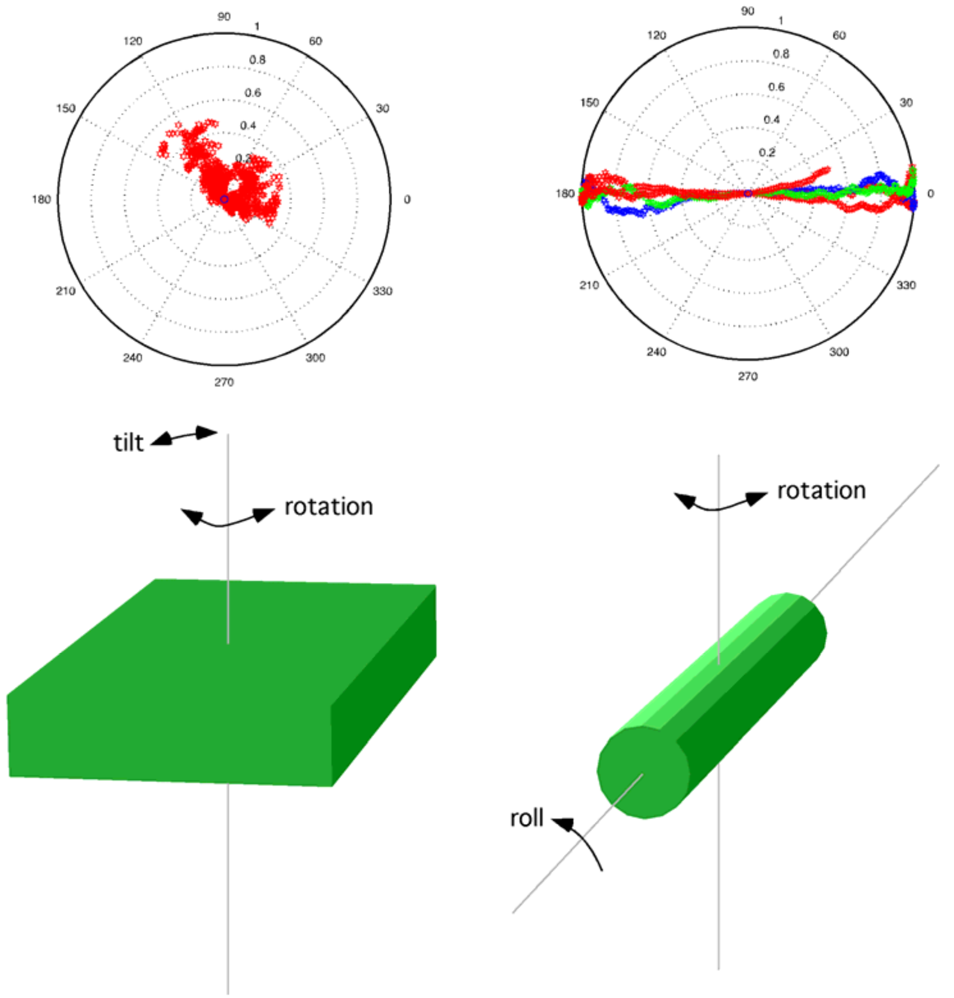

Figure 1: Simulations of two possible end-member particle motions during sediment transport events. The left-hand polar plot shows the expected distribution of a perpendicular pole (rotation axis) during slab-like displacement of sediment down canyon. The right-hand polar plot shows the expected distribution of the rotation axis perpendicular to the long-axis of a cylindrical object rolling down canyon. The initial pole is vertical and plots in the center of the polar plot (open blue circle). In the case of slab movement this pole wiggles around the rotation axis by tilting and rotating producing a random cloud of pole projections. In the case of rolling, a band of pole projections is generated by the rolling movement, and small random rotations around an orthogonal axis. In both simulations, rotation could be clockwise or counter-clockwise. These simulations were generated by a sequentially-additive Monte Carlo method that added independent estimates of random wiggle to each subsequent value of position. The random wiggle generated for the slab model and rotation around the rolling axis for the rolling model were normally distributed; whereas the rolling random wiggle was entirely random positive numbers. Data is plotted on a unit radius polar plot where the azimuth is the rotation and the radius is either the tilt or the amount of roll. Model steps were equally-spaced. 1000 model steps were run for the slab model and 750 steps were run for the rolling model. The colors in the rolling model represent projection into the upper hemisphere (all the red points) and the lower hemisphere (blue, then green points) when the cylinder is 'upside-down'.

We note that the concept behind developing BEDs is complementary to, yet distinct from the STED and McSTAR systems. The STED is primarily a water column event detector, and McSTAR is a passive listening device that will indicate the timing and potentially the magnitude of sediment debris flows, which may involve both the seafloor and the benthic water column. BED, STED, and McSTAR are complementary observing systems, and in concert may enable unique identification of sediment transport processes in the canyon; otherwise without one of these components, the data may be more ambiguous.

Publications (from other projects over the last 5 years)

See listing in the Continental Margins Processes Proposal (901023).

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

[Click here to enter text]

Significant changes from previous project proposal

[Click here to enter text]

Publications based on the results of this project only

[Click here to enter text]

c) New and Continuing Projects: Plans for 2010

Research Activities

The initial and primary effort in 2010 is to design an instrument (e.g., BED) to record the timing and sense of motions that occur during sediment transport events. We also hope to construct a prototype BED that can be deployed late in 2010. We suggest that a cruise of opportunity be used to provide the ROV time required for deployment of the prototype BED. Deployment depth would be less then 500 m, which would require less than one day of ship operations (one shallow water ROV dive).

Engineering/technology development

The structure of the project, goals, and milestones are listed below in the Milestones section.

Field programs (detail ship requirements/deployments)

Ship time to deploy a BED in upper Monterey Canyon will be coordinated with McSTAR deployments which are independently requested in the Continental Margins and Submarine Canyon Processes project (901023) in late 2010.

Specific deliverables

Deliverables include a functioning BED that can be deployed in 2010; a data interpretation scheme; and a method for integrating independent data derived from STED and McSTAR deployments.

Milestones

Structure of the Project - Major Goals and Milestones

As stated above, the project will be subdivided into two phases - a Feasibility Study and a Development Project. A detailed listing of important milestones and decision points are outlined below to provide a framework for assessing progress towards determining the feasibility. Engineering resources to conduct the feasibility phase of this project are requested for early in 2010. The development phase of this project may be initiated as soon as the 3rd quarter of 2010. Estimates of the hardware costs and engineering personnel resources for the development phase are provided in this proposal, subject to the final design and management approval. The time schedule outlined below assumes the project can be completed in one year. Depending on the outcome of the feasibility study and resources available for development, we suggest that the project time table could be relaxed by moving it into a second year.

Feasibility Study – 1st and 2nd quarter 2010

Concept Phase – Jan and Feb 2010

1. Define and model the physics that constrain sensor selection, including the sensitivity and resolution of the sensor, the sampling frequency and the suite of sensors that will provide a unique and interpretable dataset that resolves the motion of seafloor sediments in Monterey Canyon during gravity flow events.
2. Specify scientific and functional requirements.
3. Define design requirements.
4. Formulate design concept(s) - there may be more than one possible design concept.

5. Conduct a **High-level Concept Design Review –** present design concepts, assess how they meet the functional requirements, and select most appropriate design concept. Assess technical risks at this stage. This is an EXIT point for the project if feasibility is not demonstrated.

Design Phase – Mar to June 2010

6. Create basic functional block diagrams; select sensors; wiring diagrams; power, data, and telemetry budgets; and algorithms for data acquisition, power and data management, event detection, and communications. Design for packaging and mechanical components – particularly pressure case(s), communications system (i.e., an acoustic modem or pop-up float), and a full deployment plan.
7. Conduct a **Preliminary Design Review** – assess functionality and complexity of the system design. A decision to move forward to the detailed design and construction phase will be made at this time. Request additional resources if needed. This is an EXIT point in the project if the system is not feasible and does not meet the functional requirements.

<u>Development Project</u> – 3rd and 4th quarter 2010

8. Detailed Design – create complete electrical and mechanical prints, and software algorithms; finalized a Bill of Materials, and estimate engineering time requirements for construction and testing of the BED system. Establish a test plan and acceptance criteria for the system.

9. Conduct a **Critical Design Review –** freeze design.

Construction and Testing Phase – 3rd quarter 2010

10. Construction and Laboratory Testing Phase – acquire and build hardware; write computer code, test, and debug. Finalize as-built prints for electrical, hardware, and telemetry subsystems. Document computer code.

Implementation Phase – 4th quarter 2010

11. Deployment by end of 2010 – before winter storms; couple with the McSTAR experiment and possibly a STED deployment in upper Monterey Canyon. (Note: we currently have a STED that will probably be deployed along with McSTAR at some point next fall.)

Below are some of the expected technical risks other than typical problems such as leaky pressure cases, cold solder joints, battery polarity incorrect, etc.

1. Resolving motion – rates may be smaller than what can be measured by individual sensors. RISK MITIGATION – understand the physics of sediment motion, sensor resolution, and frequency of measurements.
2. Modem communications through sediment may be of poor quality or pop-up tag (if utilized) is lost or does not communicate successfully with shore base. RISK MITIGATION – test acoustic modem in situ; test pop-up float off-shore with actual receiver on-shore (using a cruise of opportunity).
3. BED may be lost down the canyon and not located. All data is lost. RISK MITIGATION – include a homing device in package; may not be practical.
4. No event occurs during deployment period. RISK MITIGATION – recover after 1 year, replace batteries and redeploy.
5. Signals may be ambiguous—cannot interpret the data. RISK MITIGATION – do your physics homework.

Budget justification

Feasibility Phase – a few items and supplies are requested for empirical testing of possible components and creating mockups. These include evaluation boards ($800), microcomputer and A/D board ($750), sensors for simulations ($1,500), batteries ($250), miscellaneous electrical and mechanical supplies ($150 and $300). Total request including tax and shipping is $4,160.

Development Phase – sensors ($15,000), interface boards ($1,800), microcomputer and A/D board ($1,000), modem or RF communications ($6,000), mechanical packaging ($5,000), Homer Pro ($8,000), miscellaneous supplies and hardware ($1,500). Total request including tax and shipping is $42,000.

Total budget for both phases is estimated to be $46,160.

Project team

Feasibility Phase – Because of her scientific background and systems level approach to engineering, Alana Sherman is suggested to be the Lead Engineer (240 hours), with assistance from Brett Hobson (80 hours) and Craig Okuda (80 hours) in defining communications and other aspects of the design. Larry Bird (120 hours) will assist with design and mockup construction, and John Ferreira (120 hours) and Tom Marion (120 hours) will assist with mockup assembly and testing. Time estimates include time for project reviews. Project design reviews will be open. Feasibility phase hours: 760.

Development Phase – Alan Sharman is suggested to continue as the Lead Engineer (240 hours) assisted by Paul McGill (120 hours), Brett Hobson (120 hours), Jon Erikson (192 hours), and Larry Bird (120 hours) in finalizing the design. Software development will most likely require software engineers familiar with embedded systems and hardware architecture. Mike Risi, Thom Maughan, and Bob Herlein (720 hours) have appropriate experience in these areas. Mechanical and electrical assembly will be accomplished by John Ferreira (240 hours) and Tom Marion (240 hours). Machinist time is estimated to be 160 hours. Time estimate includes time for project reviews, testing and documentation. Development phase hours: 2152.

Total project hours: 2912. 1.58 FTE engineering time at 100% allocation.

Project lab space

Adequate space exists in the Paull labs for the fabrication and testing of the BED prototype.

Data availability outside project team, uniqueness

To our knowledge there are no devices that exist which can measure the movement of submarine sediments down submarine canyons. Development of the BED concept would enable other investigators worldwide to deploy comparable devices to monitor and measure sediment movement down submarine canyons. With a dataset more comprehensive that what can be obtained from Monterey Canyon, a more robust understanding of submarine canyon processes will be obtained. What we learn in Monterey Canyon can be extrapolated to other submarine canyon systems in the world for both the development of second generation monitoring systems and for interpreting observations and data from the canyon systems.

Risk matrix (development and infrastructure projects only)

Initial technical risk for this project is high because of the uncertainties in how to design a BED to provide the kind of information we need to better resolve sediment motion in the seafloor. Provided a satisfactory feasibility study and preliminary design is completed, we believe the overall risks to be low, except for labor. The matrix below reflects our expected level of risk for the development phase of the project.

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

3) MILESTONES (new and continuing projects)

	Milestone 1	Milestone 2	Milestone 3	Milestone 4	Milestone 5	**Total Resources**[3] for each resource category for all milestones listed here
Milestone Date	**February 28**	**June 15**	**August 15**	**September 1**	**December 1**	
Milestone Description	**Concept Design Review**	**Preliminary Design Review**	**Critical Design Review**	**Construction and Testing**	**Implementation**	
EE	**120**	**120**	**280**	**80**		**600**
SE			**240**	**96**		**336**
ME	**160**	**120**	**240**	**192**		**712**
EE Tech	**40**	**80**	**40**	**200**		**360**
SE Tech						
ME Tech	**40**	**80**	**40**	**200**		**360**
Machine Shop				**160**		**160**

(See next page for personnel classification information.)

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

Personnel Classifications

Engineer - Mechanical Engineer (Reg)	**Engineer - Electrical Engineer** (Reg)	**Engineer - Software Engineer** (Reg)	**Engineer - Mechanical Tech** (Reg)	**Engineer - Electrical Tech** (Reg)	**Engineer - Software Tech** (Reg)	**Observ Support Technician** (Reg)	**Research – Software Engineer** (Reg)
Gene Massion	Mark Chaffey	Tom O'Reilly	John Ferreira	Jose Rosal	Karen S	Mike Kelley	Mike Godin
Jon Erickson	Ed Mellinger	Brian Kieft	Jim Schofield	Dick Littlefield		Erich Rienecker	Frederic Py
Farley Shane	Paul McGill	Rich Henthorn	Mike Parker	Tom Marion			
Brett Hobson	Alana Sherman	Rob McEwen		Jim Montgomery			
Doug Pargett	Scott Jenson	Brent Roman		Paul Coenen			
Andy Hamilton	Chad Kecy	John Graybeal					
Larry Bird	Craig Okuda	Kevin Gomes					
Bill Kirkwood	Kevin Sullivan	Danelle Cline					
Jim Birch (2/3)		Bob Herlien					
Mark Brown (1/2)		Mike Risi					
		Wayne Radochonski					
		Mike McCann					
		Thom Maughan					
		Brian Schlining					
		Rich Schramm					
		Duane Edgington(2/3)					
		Kent Headley (2/3)					