Development of a Self Triggering Submarine Canyon Event Detector

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Abstract- Instruments to detect the occurrence of energetic sediment transport events within submarine canyons are being developed. Submarine canyons are known to act as conduits for transporting sediment from the continents into the deep sea. Because the sediment primarily moves in discrete energetic events, determining the occurrence of events and the quantity of sediment involved in these transports has been difficult. Instruments placed at sites known to experience transport events are frequently lost, along with their data. In an effort to address this problem, the Monterey Bay Aquarium Research Institute (MBARI) has developed a Self Triggering Event Detector (STED). This presentation will deal specifically with the design, development, testing, and initial deployments of the proto-type STED system.

The STEDs are placed in the axis of the Monterey Canyon at locations known to experience frequent sediment transport events. A combination of MBARI (Paull et al, 2003) [1] and USGS (Xu et al, 2004) [2] experiments demonstrate that the maximum currents on the floor of the canyon are less than 60 cm/sec under normal conditions. However, during sediment transport events, current velocities of over 200 cm/sec are sustained for several minutes. When a STED platform experiences currents in excess of 200 cm/sec, one meter above the sea bed, a positive buoyant science package is released to the surface. Included in this science package is an ARGOS Pop-off satellite transmitter that will time stamp the event and can be adapted to provide essential scientific data.

Elements of the STED system include: a benthic platform, current detecting/triggering mechanism, Argos satellite transmitter, Homer Pro beacon, and instrument suite. The base is a robust structure constructed of heavy gauge steel which rests on the seafloor. An aluminum tower one meter in height is attached to the base and supports the triggering/release mechanism. The triggering/release mechanism rotates and functions as does a weather vane, always pointing into the prevailing current. When a current velocity exceeds the 200 cm/sec threshold, a trigger plate, forced to face into the current by the vane assembly, triggers the release, permitting the positive buoyant instrument suite to float upwards through the water column to the surface.

Upon reaching the surface the ARGOS transmitter establishes satellite contact and down loads the acquired data. The unique identification of each ARGOS transmitter establishes the time and location in the canyon where an event/s has occurred. The Homer Pro beacons will allow these sites to be surveyed by ROV after an event has been detected. Requirements include: ease of manufacture (expendable), deployable and serviceable by ROV, remain functional for up to three years, survive currents up to the 200 cm/sec release threshold, and reliably release and deliver the instrument package to the surface. A goal of this project is to deploy several on these systems within the Monterey Canyon. To accomplish this it is necessary to design a system that is simple, affordable, and relatively easy to manufacture. These systems will be deployed by ROV, driving weight constrains of 91 kg in air and 45 kg in sea water. In the event of a release and the survival of the platform, the system can be rearmed by ROV intervention.

To validate the system, significant testing was conducted in the MBARI 1,500.000 liter test tank. Two STED devices were deployed in depths of 290 and 520 m on May 30, 2006. On June 19, 2006 a release occurred at the 550 m site. Investigation revealed an event had taken place resulting in the transport of this platform 500 m down canyon.

I. INTRODUCTION *(a brief history)*

In 2001 MBARI initiated a project entitled Canyon Dynamics. The objective was ***"To understand the physical processes of submarine canyons as conduits for transporting materials from continents to the deep sea"*** Dr. Charles Paull. The intention was to address this topic both by using conventional techniques and by developing new technologies to address this question. A cabled observatory was to be established in the upper Monterey Canyon. Instrumented platforms were deployed within the axis of the Monterey Canyon at depths of 290 and 520 meters, separated by ~10 kilometers of channel. These Remote Instrument Nodes (RINs) (Fig. 1) were to be interconnected with a fiber optic/power cable, through the use of ROV based cable deployment (Bird 2002) [3]. This would establish a network that could measure the currents, suspended sediments concentrations, salinity, and temperature at these sites.

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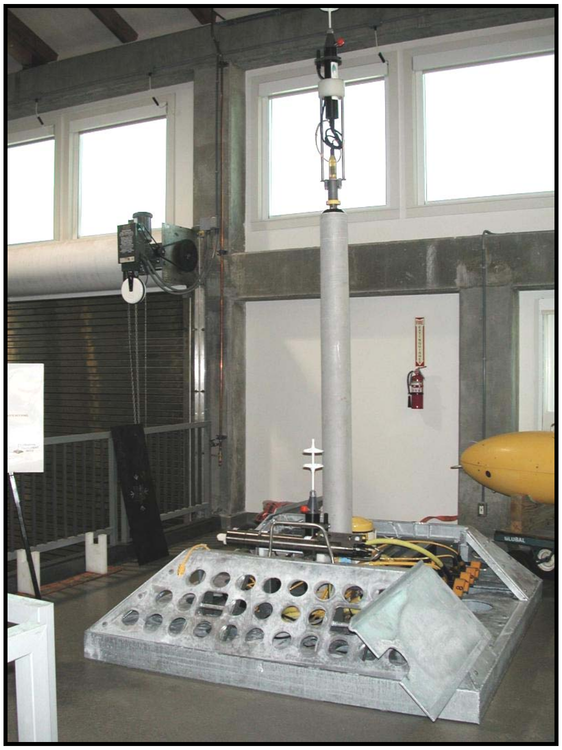

Figure 1. RIN platform outfitted with instruments before deployment (compare with figure 2).

Unfortunately a mere thee weeks after these RIN's, were deployed, (weighing over 1,400 kg each and designed to withstand a 500 cm/sec current), a major sediment transport event occurred. During this event one RIN was lost. The other severely damaged and moved 120 m down canyon (Fig 2).

Figure 2. RIN after transport event buried frame in more than 70 cm of sediment and moved frame ~120 m down the canyon's axis (compare with figure 1). Empty battery case is bent around base of mast.

In 2002 in a continued effort to understand the physical processes at work within the canyon a series of platforms dubbed simple RINs, (uncabled), were deployed in the canyon. The instrument package on these simple RINs contained a Nobska current meter equipped with a CTD that sat upon a 1.5 m mast that extended from a base frame similar in size and geometry to the original RIN. These instruments were routinely changed out via ROV intervention.

Valuable data was gleaned in this effort; however the caveat was that if a major event occurred, the instruments were usually lost, along with their data set. If the instruments were recovered no major event had taken place. Eventually all these all these simple RIN's were lost. While efforts to establish a cabled observatory within the axis of the upper canyon were abandoned, a great deal had been learned. The belief that sediment transport events were infrequent and required a trigger event was reevaluated. Sediment transport events are indeed frequent, with no perceptible trigger required.

II. Self Triggering Event Detector

In 2006 the challenge of obtaining data from within an obviously active canyon system was addressed in a wholly different manor. Instead of trying to resist the forces at work within the canyon, a device could be designed that identifies and harnesses the energy created in sediment transport. A device that detects the signature of an event, and releases a positively buoyant, (recoverable), science package to the surface (Fig. 3). Thus began MBARI's current effort to investigate the processes at work within the Monterey Submarine Canyon.

III. Concept

The concept is to design a simple, relatively low cost, and ROV deployable system that reliably detects currents of 200 cm/sec and releases a positive buoyant/recoverable science package to the surface. ROVs are used to deploy the STEDs to assure they are placed directly within the axis of the canyon. Regular ROV access exists within the Monterey Canyon because MBARI operates the ROV *Ventana* as a day boat from Moss Landing, California. The science package contains an ARGOS satellite Pop Off transmitter and can be adapted to ultimately carry other instruments. If this concept proves valid, ultimately as many as thirty STED devices could be deployed along the length of the upper Monterey Canyon. This would establish a network that determines the frequency, location, size, and, timeframe of major sediment transport events within the Monterey Canyon and elsewhere.

IV. Design Requirements

A. Reliability

Reliability is essential. The expense of manufacturing a unique system and deploying via ROV is substantial. To validate the system extensive testing took place in the MBARI 1,500,000 liter test tank.

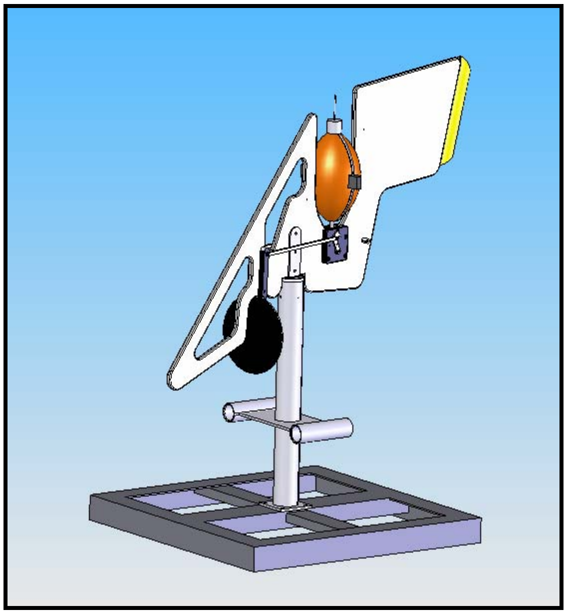

Figure 3. Three dimensional model of the STED device (generated by Solidworks). Mast is 1 m high.

B. Expendable

In the event of a major sediment transport the entire STED, except for the released positive buoyant science package, is likely to be lost. By keeping the system as simple as possible and relatively inexpensive, lost units can be replaced as needed. To accomplish this, the system is strictly mechanical. This eliminates expensive pressure housings, current meters, and, electronics, that might be lost along with their data.

C. Omni Directional

Although major sediment transport events will move down slope through the canyon's axial channel, the precise direction of the flow at any point in the channel is hard to predict in detail. Thus, the STED's design needs to function regardless of the direction of the current.

C. Weight Constraints/Operation Requirements

The STED system is designed to be deployed by ROV; in part to assure accurate placement within the axial channel the canyon. However, the ROV payload capabilities restrict maximum weights of 91 kg in air and 45 kg in seawater. A maximum height of 2 m and width of 1 m is also required.

D. Long Term Functionality/Survivability/Materials

The ability to remain functional on the bottom for a minimum of three years is expected. The manufacture and material of each element requires careful consideration to achieve this goal

E. Re-Armable via ROV Intervention

In the event that a science float is released from the STED and the rest of STED platform survives, a replacement science package can be reengaged into the triggering/release mechanism.

F. Readily Configurable

As requirements change the science package can be easily be reconfigured to carry other sensors without a major redesign of the system.

V. Design/Modeling

The parametric modeling program Solidworks was employed for the entire design (Figs.3, 4, & 5). Each element of the system was designed within a 3D environment. These parts are assembled into a complete 3D model of the device. This model can be analyzed and readily modified to address constraints and system requirements. The entire assembly was designed and evaluated for function, weight, and, fit before manufacturing began.

VI. Base/Tower

The base platform is a robust steel frame 1 m square, 4 cm in height, and weighing 57 kg, (Fig. 3). This represents 65 % of the weight of the entire system, resulting in a low center of gravity. The tower is made of aluminum (6061 T-6) and is 11.5 cm in diameter and 1 m in length. The aluminum tower and fasteners used to attach it to the steel frame are isolated to prevent contact of these dissimilar metals.

VII. Vane Assembly

Compliance to current direction was accomplished by designing a vane that functions as does a weather vane, (Fig. 4). The vane assembly consists of the vane, vane stem, and, stem bushing. The vane is constructed of 10 mm epoxy G-10 (Garolite) composite. This material is very strong, rigid, and, has attractive characteristics in seawater. The vane stem is made from titanium (6al4v). The stem bushing is ultra high molecular weight polyethylene (UHMW PE). The vane stem is retained within the bushing with a titanium lock collar. The titanium stem within the UHMW PE bushings makes for a very smooth, easily rotating assembly. In a velocity, as little as 50 cm/sec, the vane will reliably report into the prevailing current. The total surface area of the vane is 1.290 m^2. The vane forces a trigger disk with an area of .073 m^2 to face perpendicular to the current. At the desired release velocity of 200 cm/sec, 16.4 kg of force is exerted upon the trigger disk (Fig. 5). The trigger disk pivots, on an arm, about a shaft and transmits this force to the release mechanism thru the use of a simple linkage. Placement of the trigger disc at the front of the assembly assures the minimum disturbance to the current. The nose that protrudes ahead of the trigger disc acts a guard helping prevent accidental release. Also, a great deal of debris such as clumps of kelp and water logged wood slowly migrate down canyon. This nose will prevent the trigger disc from becoming fouled by directing this material up and over the vane.

VIII. Release Mechanism

The release mechanism, (Fig. 5), is composed of triggers, trigger block, trigger shaft, trigger bar, and release springs. The 16.4 kg of force generated on the trigger disc by the 200 cm /sec current velocity is resisted by two titanium (6al4v) extension springs.

As the velocity of the current approaches the 200 cm/sec threshold, the rotational movement of the trigger plate is transformed into linear movement of the linkage. This linear movement forces the triggers to rotate about the trigger shaft and disengage from the trigger bar, (Fig. 5), and release the science package. A small cam on the triggers creates a very discreet release point. The release mechanism is symmetrical, with linkage, triggers and, springs on both sides of the vane.

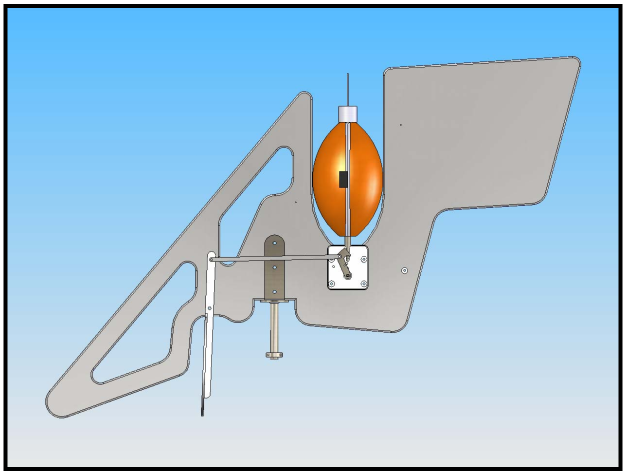

Figure 4. Vane Assembly

To assure long term reliability and corrosion resistance the triggers, trigger shaft, and, trigger bar are manufactured of grade 3, (commercially pure), titanium. The trigger block is constructed of UHMW PE. Should the system need to be rearmed using an ROV, a grab on sides of the science package allows the vehicles manipulator to reinsert a science flotation package down into the trigger block. The triggers latch over the trigger bar, rearming the system.

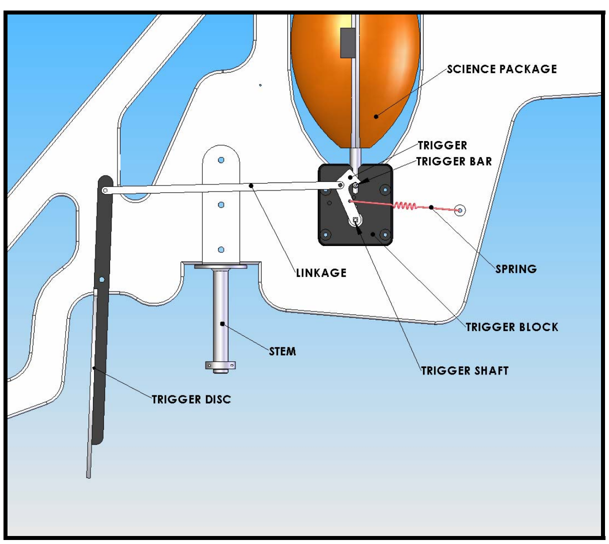

Figure 5 Release Mechanism

IX. Science Package

A. Flotation

The flotation associated with science package consists of a .015 m^3 foot ball float of 2,000 m rated syntactic foam (Fig. 6). This float produces 6.4 kg of positive buoyancy. This particular float was selected simply because they are also used by MBARI ROVs as flotation for umbilicals. The flotation could actually be any foam of an appropriate shape and depth rating. Sandwiched between the two float halves are the trigger bar assembly, ROV manipulator grab, and the ARGOS satellite transmitter. The manipulator grab is a very stout piece of 100 durometer rubber. As the instrument suite aboard the science package evolves, the flotation package can easily be modified to accommodate larger payloads, without major redesign

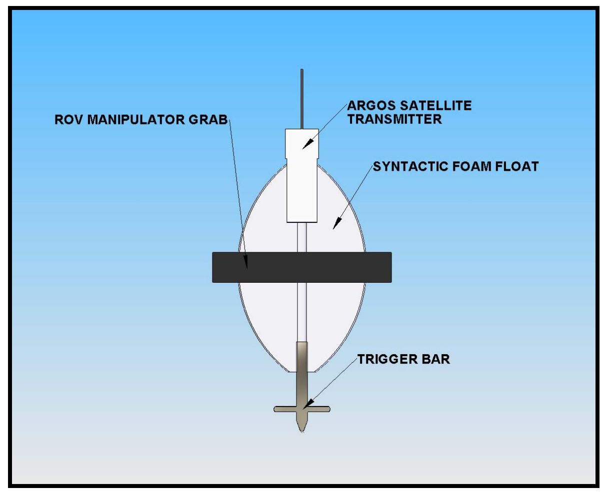

Figure 6. Science Package in cross section

B. Wireless Transmitter

A wireless transmitter was needed to notify the project team when an event was detected in the canyon. Candidate systems were cellular telephone, HF, VHF and UHF line-of sight radio, and satellite-based systems operated by ORBCOMM, Globalstar, Iridium and Argos. While the line-of-sight radio may have worked for our proof of concept deployment site in the upper Monterey Canyon, we hope to use this technology in areas that are over the horizon from shore-based facilities and therefore focused our attention on the satellite-based systems.

To minimize development time and expense on the proof-of-concept systems we selected an Argos satellite-based system that one of the team members had used for animal tracking experiments [4]. The PAT Mk10 (Fig. 7) is a pop-off archival tag developed by Wildlife Computers Inc. The tag is designed to collect temperature, depth and light level data while attached to an animal, then automatically release and telemeter the stored data back to the researchers through the Argos Satellite network [5]. The 75 gram tag stores data on 16 Megabytes of memory for at least one year activates a burn-wire release system and is able to transmit approximately 10,000 32 byte messages. For our initial STED deployments we disabled the burn-wire and sensor logging and used the depth sensor to detect when the tag had released from the STED platform. Once at the surface the device transmitted its unique Argos ID number through the Argos network to a centralized email account at MBARI. An email list-server then relayed this notification to all the members of the project team.

Figure 7. PAT Mk 10 ARGOS transmitter

X. Testing

Extensive testing took place in the MBARI 1,500,000 liter test tank (Fig. 8). A thruster, driven by a hydraulic motor, was employed for testing. Producing a maximum of 300 cm/sec at 1.5 meters, a diffuser was mounted in front of the thruster to assure a laminar flow. A Nobska current meter was mounted directly in front of the trigger disk and cabled to the surface. This provided a very accurate gauge of the current velocity affecting the trigger disc. The procedure was to place the armed STED in front of the thruster and slowly bring up the current velocity until a release occurred. The system proved easy to fine tune merely by adjusting the tension of the release springs. Testing proved that the device reliably tripped at the desired velocity plus or minus 10 cm/sec.

Figure 8. STED being lowered into MBARI Test Tank

XI. Deployments

On May 28, two STED devices were deployed in the upper Monterey Canyon. The sites were at depths of 290 m and 520 m within the canyon axis and were chosen as sites that are believed to be very active. The STED device was mounted aboard the ROV *Ventana* (Fig. 8). The vehicle carefully maneuvered into the center of the axial channel. Using the vehicle's Schilling Titan III manipulator the STED device was placed upon the seabed (Fig. 9). Three more of these systems are in manufacture and are scheduled for deployment in December 2006.

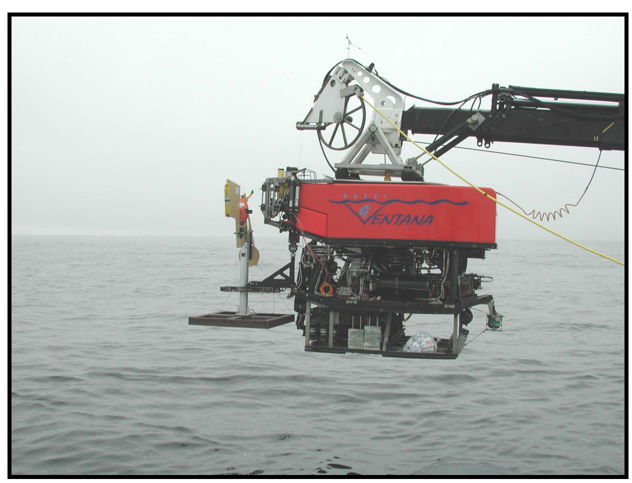

Figure 9 STED being deployed by ROV *Ventana*

XII Initial Success

On June 19, 2006, at approximately 9:00AM Pacific Daylight time, STED # 2 initially located at 520 m in depth released. Subsequent interrogation of the Homer Pro beacon from the surface revealed the STED platform had been transported ~500 m down canyon

Figure 10 STED deployed in 350 m, Upper Monterey Canyon

XIII. Conclusions

In consideration of the extensive testing, June 19th release, and subsequent proof of an event, we are very encouraged. These devices demonstrate a potential for the some very interesting investigation of activity within submarine canyons. If initial deployments prove reliable and a network of STED devices is established, perhaps a better understanding of submarine canyon processes can be realized.

XIV. Acknowledgements

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