Instrumentation for Investigating Submarine Canyons

The Development of a Self-Triggering Event Detector to Investigate Sediment Transport Events

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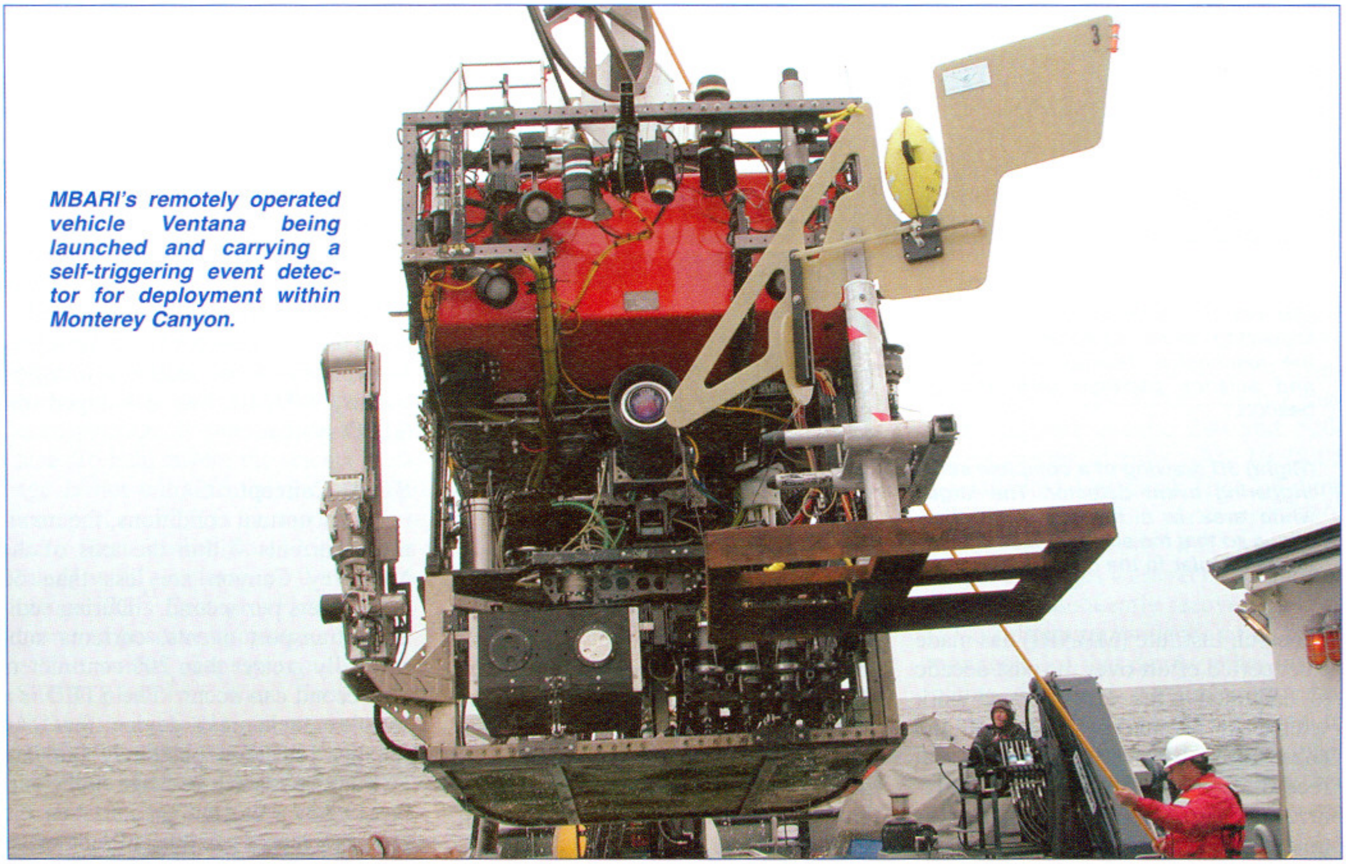
Self-triggering event detectors (STEDs) comprise a novel system to detect the occurrence of energetic sediment transport events within hostile submarine canyon environments. STEDs are mechanical devices deployed within the axis of submarine canyons and are calibrated to detect the onset of energetic gravity flow events that episodically occur in this environment. When such an event takes place, the STED will release a buoyant instrument package to the surface. On the surface, a satellite radio transmitter contained within the instrument package reports the event through the Argos satellite system. An array of STEDs will provide data to calculate the velocity at which a sediment gravity flow passes through the canyon and the channel length affected by the event. STEDs were developed because traditional oceanographic instrumentation is commonly damaged by these sediment transport events, and typical sampling intervals fail to characterize these events.

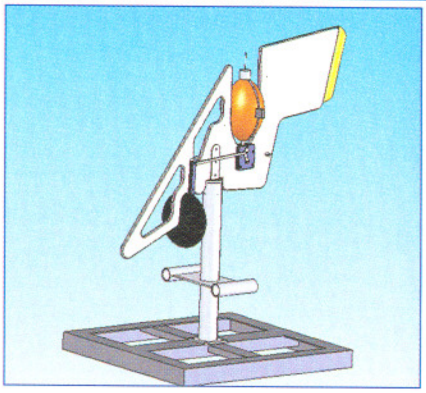
Canyon Dynamics

Submarine canyons are primary conduits for transporting sediments from the continents to the deep sea. The Monterey Bay Aquarium



MBARI's remotely operated vehicle Ventana being launched and carrying a self-triggering event detector for deployment within Monterey Canyon.

(Above) The vane section of a self-triggering event detector, including the mechanical release mechanism and science package with pop-up beacon.



(Right) 3D drawing of a complete self-triggering event detector. The large white area is a rotating vane that aligns so that the smaller black disc is perpendicular to the current.

Research Institute (MBARI) has made a concerted effort over the past decade to understand the processes at work within the Monterey Canyon off the coast of California. The geological record clearly shows episodic gravity-driven events have moved huge volumes of sediment down the slope and through the channel of the Monterey Canyon into the deep sea. These events are believed to occur in a range of styles, with some carrying nearly solid masses of material (e.g., debris flows) and others flowing as turbid suspension (e.g., turbidity flows),[1,2] somewhat analogous to mountain avalanches. Most of what is known about episodic sediment transport events on the continental margins comes from the study of the deposits they leave. Few direct measurements have been made that characterize the conditions within the actual event.[3,4]

Taking basic measurements to document the occurrence of sediment transport events, their frequency and the quantity of material they convey is challenging. At first thought, using traditional methods for investigating this phenomenon might appear to be routine. All that needs to be done is to deploy instruments within the axis of a submarine canyon that can measure currents, suspended sediment concentrations, conductivity and temperature, and then recover these instruments. Unfortunately, instruments deployed within the upper Monterey Canyon are frequently damaged or lost when an event occurs. For example, in 2002, an instrumented platform (approximately 1,500 kilograms) designed to withstand a 500-centimeter per second current was lost along with its entire instrument suite in an event that occurred at a depth of 530 meters. Also, the modest sampling intervals for an extended deployment of traditional battery-powered instruments, typically 15 minutes or more, fail to provide adequate resolution to properly measure the passage of these events. In a continuing effort to investigate and understand the dynamics of the Monterey Canyon and these sediment transport events, MBARI has developed the STED system.

STED Concept

Under normal conditions, the maximum currents within the axis of the Monterey Canyon are less than 60 centimeters per second.[3,4] During sediment transport events, currents substantially greater than 200 centimeters per second can occur.[4] The STED is a simple mechanical device that can reliably release a positively buoyant instrument/science package to the surface when a current greater than the preset threshold of 200 centimeters per second is encountered. The package includes an Argos satellite radio that transmits notification of the release.

The STED platforms must be viewed as expendable, as their loss during energetic sediment transport events is expected. However, they must also be reliable for their entire three-year design life. To assure long-term reliability in an expendable instrument, a simple, economical mechanism that does not require batteries, pressure cases or sophisticated electronics is employed

STEDs are designed to orient themselves to face into the prevailing current in a manner similar to a weathervane. The STED platform consists of a robust steel base that supports a one-meter-tall aluminum tower. Mounted on the tower is a vane assembly that can freely rotate and turn into the current. A trigger/release mechanism—which consists of the trigger disc, mounting arm, linkage, trigger, release springs and positive buoyant science package—is integrated into the vane assembly. The vane (with an area of approximately 2.6 square meters) forces the trigger disc (with an area of .073 square meters) to face perpendicular to the current. At a 200-centimeter per second release threshold, 16.8 kilograms of fluid drag force is exerted on the trigger disk. This force is resisted by a pair of titanium extension springs mounted in tandem on either side of the vane. The trigger disc is attached to a mounting arm that pivots about a bearing point. The rotational movement of the trigger disc is transformed into linear movement via linkages, also mounted on either side of the vane. The linkages mount to the triggers, which engage the trigger bar on the buoyant science package. When the target current velocity is reached, the triggers pivot forward and disengage the trigger bar on the science package. The positively buoyant science package is released to the surface. To help ensure the science package is not entrained in the sediment transport event, it is encased in a syntactic foam football float (2,000 meter-rated) with a volume of 0.013 cubic meters. This float provides 6.4 kilograms of positive buoyancy.

The initial deployments of the STED platforms were done using MBARI's remotely operated vehicle (ROV) Ventana, which operates regularly out of Moss Landing. The ROV payload is limited to 91 kilograms in air and 45 kilograms in sea water. The steel base is one meter square and weighs 57 kilograms. This accounts for 65 percent of the weight of the STED platforms, resulting in a low center of gravity. STEDs can also be deployed from a surface ship using an acoustic release on a wire line.

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Materials selected for the other components of the system were based on weight, corrosion resistance and the planned three-year service life. These include aluminum 6061 T-6 for the tower, epoxy composite G-10 (Garolite) for the vane and trigger disc, commercially pure (Grade 3) titanium for all release mechanism elements and ultra-high molecular weight polyethylene for all bearing surfaces.

Phone Home

An over-the-horizon radio telemetry system is included in the science package to notify shoreside researchers when an event occurs. Determination of the extent and speed of an event is possible through the knowledge of the time each STED is triggered. Therefore, a depth sensor and accurate clock are needed in the science package. For the prototype units described here, a commercially available device intended to record the behavior and distribution of marine animals was employed. This device transmits acquired data at a preset time through the Argos satellite network. Mk10-PAT pop-up archival tags, manufactured by Wildlife Computers (Redmond, Washington), were programmed to record depth every three seconds. Water temperature, light intensity and battery voltage are also logged. A tag starts logging as soon as a depth change of greater than 10 meters occurs. When a wet/dry (conductivity) sensor indicates the tag is back on the surface, an Argos platform transmitter terminal radio begins broadcasting messages to orbiting satellites. CLS America (Largo, Maryland) processes the Argos radio transmissions and sends an e-mail that is forwarded to all project team members. In addition to relaying a compressed data set, the Argos satellite system can determine the approximate position of the tag. This is used along with a reward sign to recover the tag. The tag must be recovered before the high-resolution depth profile can be reviewed. This profile is used to determine the exact time the STED platform released the science package and tag. Future deployments will employ a system that can immediately relay the exact time of the STED release through the satellite network.

Testing

Performance of the STED design was first evaluated in the MBARI 1.5 million-liter test tank. A hydraulically driven propeller thruster fitted with turbulence-reducing vanes was directed at the trigger disc on the vane assembly. A Nobska (Woods Hole, Massachusetts) acoustic current meter was mounted immediately in front of the trigger disc, and the current meter was cabled to a laptop computer on the deck of the test tank to provide real-time velocity measurements of the current on the trigger disc. The test procedure slowly increased the current velocity until a release occurred. The system was easy to fine tune by merely adjusting the tension of the two titanium 6AL4V springs on the release mechanism. Subsequent testing proved the system released reliably at the target velocity of 200±10 centimeters per second. The calibration of multiple units was accomplished using a similar procedure.

To further test the system, two STEDs were deployed in upper Monterey Canyon on May 28, 2006. They were deployed in the axial channel at sites believed to experience regular transport events: 290 and 520-meter water depths. At 16:28:05 Coordinated Universal Time on June 18, 2006, the STED platform in 520-meter water depth was triggered, Argos messages were received and the tag was subsequently recovered.

Corroborating evidence of an event was recorded that day by other instruments deployed deeper within the canyon. Subsequent ROV dives to investigate both STED deployment sites were unable to locate either STED. However, a signal from an acoustic beacon originally on the base

> ***"The recently deployed STED array may provide valuable new data to aid in the understanding of the physical processes at work within submarine canyons."***

of the 520-meter STED was detected, indicating that the STED had moved over 500 meters down the canyon from its initial deployment site. ROV inspection of this location beacon showed that it was buried within a sediment debris flow.

From May 8 to 11, 2007, an array of five STEDs was deployed at water depths of 290, 520, 770, 1,030 and 1,384 meters. The instruments are spread over a more than 34-kilometer-long sinuous segment of the active channel of the Monterey Canyon.

Conclusions

Although it is early in the development of the STED system, MBARI researchers are encouraged by the preliminary results. Considering the extensive testing and the successful June 18 release last year, it is likely that this platform will function as designed. The recently deployed STED array may provide valuable new data to aid in the understanding of the physical processes at work within submarine canyons.

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