The Benthic Rover: The Other MARS Rover

Alana Sherman, MBARI

The Benthic Rover is a bottom-crawling, autonomous underwater vehicle capable of making continuous time-series measurements of biogeochemical processes in the deep ocean to depths of up to 6000 m for periods of up to six months. The deep ocean ecosystem covers two-thirds of the earth's surface yet its inaccessibility makes it poorly understood and grossly under-sampled. The deep ocean is a hostile environment, where a vehicle needs to withstand an extreme environment of high pressure, corrosive salt water, and low temperature. The Benthic Rover instruments and control system were developed at the Monterey Bay Aquarium Research Institute (MBARI). The vehicle was designed for long-term deployment as a cost-effective method of collecting numerous measurements that capture changes that occur seasonally or episodically. The specific scientific interest for this project is understanding the coupling between pelagic (water column) derived food supply and benthic (seafloor) community utilization of this organic carbon influx. The understanding of how carbon is cycled from the atmosphere through the water column to the benthic community is even more crucial now, as the ocean has become the biggest sink for increased anthropogenic carbon in the atmosphere.

The mechanical configuration of the Rover is driven by three requirements: it must withstand depths of 6000 m, it must transit across very soft sediment, and it must be capable of floating to the surface when commanded at the end of its mission. To meet the depth and endurance requirement, all one-atmosphere housings are made of titanium. Electrical equipment that can withstand ambient pressure, such as wiring and motors, are contained in lighter oil-filled housings supplied by four separate positive-pressure oil compensation systems. The vehicle is 2.6 m long, 1.7 m wide, 1.5 m tall, and weighs 1136 kg in air. To keep from sinking into the soft sediment of the ocean floor, floatation is mounted on the vehicle such that it weighs only 68 kg in water. The vehicle drives on two wide tracks with a combined surface contact area of about one square meter; this provides good traction while minimizing the disturbance to benthic sediments. The vehicle is constructed entirely out of titanium and plastic, two materials that will withstand six months in seawater without corroding. A 113 kg steel drop-weight is suspended below the Rover's center of gravity using a series of lever-arms that are retained by a redundant pair of release actuators. The Rover is ballasted to weigh 68 kg in water with the drop weight present, and to be 45 kg buoyant when the drop weight is released.

The Rover is equipped with instruments developed to study sediment community activity at multiple sites. Two respirometer chambers on the front of the vehicle measure sediment community oxygen consumption (SCOC). A respirometer is a sealed chamber with an oxygen sensor that records how much oxygen is consumed by the organisms contained in the chamber. The respirometer chambers on the Benthic Rover are acrylic cylinders 30 cm in diameter and 21 cm in length. On the lid of the chamber are three hydraulically actuated valves. Inside of the chamber is an optode (Aanderaa, 3830) that optically measures dissolved oxygen in water. The chambers are inserted into the sediment by a brushless-motor actuated lead screw. Once the chamber is inserted into the sediment, the valves on the lid are closed thus sealing off the volume. Respirometery experiments last between 24 and 72 hours depending on the activity level of the community. Additional instrumentation includes a fluorometry system to detect phytopigment fluorescence from chlorophyll on the sediment surface. Three cameras on the Rover provide images of the sediment being measured, along with a wide-angle view of the immediate surroundings during transects.

A typical mission starts onboard a research vessel, when the Benthic Rover is deployed by crane into the water and freefalls to the ocean bottom. While waiting for disturbed sediment to settle, the Rover monitors the direction of the prevailing current in order to move into or across current to avoid disturbance of measurement sites. The vehicle moves forward 10 m to a new measurement site, where it again waits to allow disturbed sediments to settle downcurrent and away from the measurement site. During the transit, a forward-looking survey camera captures images of the sediment. After movement stops and sediment has settled, two other cameras capture close-up images of the study site, and an imaging fluorometer records the quantity and distribution of chlorophyll on the sediment. Next, two benthic respirometer chambers are inserted into the sediment. The oxygen concentration within the chamber is measured for up to three days. After that time the chambers are raised and cleaned by water jets. The Rover then moves 10 m to a new study site and begins a new measurement cycle, repeating the sequence up to 50 times. At the end of the mission an acoustic signal is sent from a surface ship instructing the Rover to release its drop weight and resurface.

The Benthic Rover can be deployed autonomously for up to six months or it can be tethered to an ocean observatory. The Benthic Rover has completed 20 deployments in the Monterey Bay and at the deep-ocean time-series site Station M (depth 4000m) augmenting ongoing ecological studies. The Benthic Rover was connected to the Monterey Accelerated Research System (MARS) cabled observatory in 2009 on two separate missions for a total of three months at 980 m depth.

This presentation will cover the results from these deployments, as well as lessons learned while trying to develop a robust deep sea rover.