**MONTEREY BAY AQUARIUM RESEARCH INTITUTE**
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# ROV Based Tool Sleds For The Placement of Fiber Optic Cable Between Benthic Instrument Nodes

***Abstract*- In 2001 MBARI committed to developing the necessary technology to deploy fiber optic/power cable from ROV based tool sleds, an important element of the MBARI Ocean Observation System (MOOS). The original effort involed the design and building of a cable laying tool sled for the ROV Ventana (2000 meter vehicle). This effort was in support of the MBARI Canyon Dynamics experiment. The goal of this experiment to understand the physical processes of submarine canyons as conduits for transporting materials from the continent to the deep-sea. Engineering's task was to develop the tools necessary to accomplish this goal. The key elements are instrumented platforms referred to as Benthic Instrument Nodes (BINs) deployed in the axis of the Monterey Bay Canyon at depths of 250 and 500 meters, located 10 kilometers apart. These BINs were connected with a fiber optic/power cable and established a network that can measure the currents, suspended sediment concentrations, salinity, and temperature at these sites. Building on this effort and in support of the MOOS Science Experiment (MSE), a fiber optic cable laying tool sled was developed for the ROV Tiburon (4,000-meter vehicle). The goal of MSE is to study deep seafloor processes within and adjacent to lower Monterey Bay Canyon. At the study site near Shepard Meander, one BIN will be deployed in the axial channel of lower Monterey Bay Canyon, and another will be deployed on the adjacent seafloor outside the canyon. These interdisciplinary BINs will be connected to power and communications through a MOOS mooring. A satellite link from the mooring to shore will be used to monitor system function as well as the deep-sea conditions during the experiment. This technology will act as building blocks for MOOS, Monterey Accessible Research System (MARS), and future cabled observatory efforts.**

**Design elements include; integration with the ROV's Ventana and Tiburon, meet operational weight constraints, the ability to (pick up, drop, and reacquire the cable spool), deploy up to 5 kilometers of cable, support the vehicle's Schilling Titan III and Kraft Raptor manipulators, variable ballast systems, monitor/control cable payout speed as a function of distance along track. Currently these tool sleds are complete and ready for service. Testing has taken place at various sites in the Monterey Bay. The ROV Ventana has successfully deployed and recovered 2,000 meters of cable in depths of 1,000 meters. The ROV Tiburon has successfully deployed 2,000 meters of cable in depths of 4,000 meters.**

## I. INTRODUCTION

This paper will deal specifically with the design, build, testing, and deployment of these ROV based tool sleds constructed for the placement of cable on the seabed and interconnections with the BIN platforms. Challenges faced engineering these tool sleds and the components developed to accomplish this. Topics covered will include the fiber optic/power cable, core sled, peripherals, testing, and accomplishments.

## II. FIBER OPTIC/POWER CABLE

### A. Construction.

South Bay Cable (SBC) manufactured the custom fiber optic/power cable. The construction is a polyurethane outer jacket of high visibility orange, a kevlar braid strength member, five copper single conductors insulated in polypropylene, and four single mode (SMF-28) fiber optics in a gel filled stainless steel tube. Interstices are water blocked. The maximum tensile working load is 500 pounds (227 kg). The outside diameter is .300" (7.6 mm) with a minimum bend radius of 12" (305 mm). The weight in air is .174 pounds per meter (.0788 kg/meter). The weight in water is .072 pounds per meter (.0327 kg/meter). The first 100 meters to be laid within the axis of the canyon will be armored with two layers of hardened GIPS steel resulting in a diameter of .450" (11.5 mm). The goal in the development cable was to meet the power, communications, and survivability requirements with least weight possible.

### B. Interconnects

Ocean Design Incorporated's (ODI) Mark II ROV wet-mate hybrid connector was chosen because of the extreme nature of this application and ODI's experience with optical interconnects. The MKII's titanium body assures corrosion resistance for the 5-year life of the experiment. Care was given to isolate the titanium body from less noble materials, thus minimizing electrolysis. Connector details include a 10,000-psi pressure rating, 5 amps/circuit, and 1000 vdc working voltage, 125-micron single mode fibers, and a working temperature range of -10 to +50 degrees Celsius.

## III. CABLE LAYING/NAVIGATION

The cable laying procedure is to launch the vehicle at a BIN platform site with up to 5 kilometers of cable on the spool. The vehicle dives to the BIN and performs the interconnect. Doppler Velocity Log (DVL) bottom lock and WinFrog navigation coordinates of the location are established. The vehicle then proceeds along the cable routes premapped waypoints. The vehicle will follow the bottom a few meters off the seabed maintaining visually the bottom and the cable as it is deployed. The maximum deploy speed is 1 knot (1.85 km) per hour. Deploying approximately 10% more cable length versus distance traveled avoids tensioning the cable and forming spans. This is accomplished using control software that displays the amount of cable deployed versus the actual distance traveled across the bottom. Pay out speeds will be adjusted manually to match the speed of the vehicle. Upon reaching the BIN, the cable spool is dropped, as an anchor, holding the excess cable. Using the ROV's manipulator, the connector is removed from a dock within the cable spool body. A 20 meter service loop of cable on the exterior of the cable spool allows the vehicle to maneuver to the BIN and perform the interconnect.

## IV. CORE SLED

### A. Design.

The design of the core sled required the integration of the ROV with a large diameter cable spool capable of holding 5 kilometers of cable. The top frame of the sled duplicates the ROV's footprint. The cable sleds stand 42" (1.06 m) tall, an open sleigh like configuration was chosen which allows the sled to straddle the cable spool and cable as it is deployed. The 6" (152 mm) width of the ski like feet permits the vehicle to sit down on the bottom as required to perform interconnects. The sled design allowed for maximum freedom and versatility as peripheral mechanisms were developed. The only weld-on peripheral is an outboard manipulator mount. Its location relative to the bottom of the sled and to starboard is the same as all other sleds. The sled and all peripheral devices were fully designed in the parametric modeling program SolidWorks.

### B. Materials

The sled is constructed entirely from aluminum 6061 T-6. Gas Tungsten Arc Welding was employed to deliver the highest quality welds. All joints were fully gusseted with special attention given to the high stresses associated with the outboard manipulator mount. The entire sled was solution heat treated and returned to the T-6 condition to assure both long service life and maximum levels of safety supporting the ROV's core vehicle weight of 6,000 pounds (2,722 kg). From this point no further welding will take place on the sled, as all peripheral devices will be mechanically fastened.

## V. PERIPHERALS

### A. Payout Mechanism

This mechanism consists of the cable spool, the main drive motor, the overboarding sheave (cable tensioner), pinch wheels, and tension motor. A low speed high torque motor, powers the cable spool. Power is transmitted from the motor to the cable spool via 12 tooth, 5 DP spur gear. The overboarding sheave is a conventional 16" (40.6 cm) Sherman and Reilly 73 series block that is directly coupled to an identical motor. The pinch wheels mate against the over boarding sheave applying pressure to the cable. Through the use of a hydraulic proportioning/relieving valve a constant pull of 20 pounds (9 kg) is applied to the cable regardless of deploy speed. Any disparity in speed between the cable spool and tensioner is made up for in slip, on the overboarding sheave. Payout speed is controlled manually.

### B. Drop/Reacquire Mechanism

As mentioned earlier the cable spool will be dropped at the completion of the cable run. A further design requirement is the ability to reacquire the cable spool. Should a problem develop with the vehicle, the support vessel, or if weather deteriorates during the cable lay, the cable spool can be dropped at any point. When the problem is corrected or when weather improves the cable spool can be reacquired and the cable run completed. The mechanism consists of the cable spool, grab sub frame, grab yokes, grab bushings, stabs, and stab cylinders. The sub frame bolts to the core frame in four places. The grab yokes are Y shaped structures designed to mate with the grab bushings. The grab bushings are located on the out board ends of the cable spool shaft. The stabs are moved linearly by the hydraulic cylinders under the grab bushings capturing the cable spool in the yokes. Retracting the stabs allows the cable spool to fall away from the sled, maneuvering the yokes onto the grab bushings and advancing the stabs reacquires the cable spool.

### C. Cable Spool

The cable spool requires it be manufactured economically enough that it can be left on the bottom for several years, yet at the same time be robust enough to carry and deploy 5 km of .300" (7.6 cm) cable. The components of the cable spool are the aluminum body weldement, delrin bushings, drive gear, and stainless steel shaft. The drum diameter is 20" (50.8 cm) with a width of 30" (76.2 cm), the flanges are 38" (96.5 cm). The drum and flanges are ¼" (6mm) aluminum 6061 T-6. The weight of the entire cable spool assembly is 60 pounds (27.2 kg). The spool turns about the shaft on the bushings that are pressed into the center tube of the cable spool weldement. The 96 tooth, DP 5 spur gear is bolted directly to the port face of the cable spool and mates with the spur gear on the main drive motor.

### D. Variable Ballast

The ROV Ventana and ROV Tiburon have variable ballast systems. These systems allow for the deployment of 2 kilometers of our current cable. Beyond 2 kilometers modules of syntactic foam are released to maintain roughly neutral buoyancy. These modules offer 28 pounds (13 kg) positive buoyancy each. One module is released for each kilometer of cable deployed beyond the first 2 kilometers.

## VI. TESTING

Initial testing began in the MBARI 400,000-gallon (1,500,000-L) test tank. The ROV with the cable laying tool sled performed interconnects with instrumented BIN platforms. Trials at sea began in depths of 500 meters deploying 400 meters of cable. These tests allowed the systems to be fine tuned and tests progressed to 1,000 meters depth and cable lays of 2,000 meters. In the most recent test of the ROV Tiburon cable laying tool sled, a cable lay was accomplished from a depth of 3,850 meters within the axis of the lower Monterey Bay Canyon, to a depth of 1,800 meters along a 3 kilometer track.

## VII. CONCLUSION

Over a three years period MBARI has developed two fully functional cable deploy systems. These systems have been proven in testing and actual cable lays. This technology will support on going MBARI cabled observatory experiments. Future efforts will support MOOS, MARS, and future projects.