POLAR S.INC

"SINC OR SWIM"

SUBMERSIBLES INCORPERATED

STUDENTS WITH INVENTIVE MINDS

Fairbanks, Alaska

Ursus Maritimus

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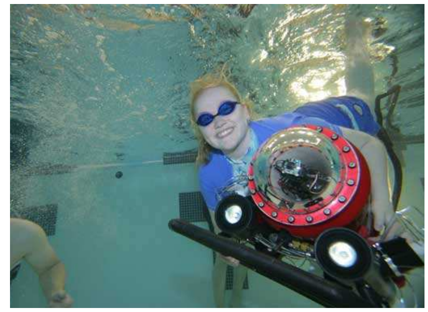
ABSTRACT

Polar Submersibles Incorporated, a robotics team consisting of six college and high school students from interior Alaska, manufactured an underwater Remotely Operated Vehicle (ROV) for the purpose of competing in the 4th annual national MATE ROV competition. The competition, held at the NASA Neutral Buoyancy Laboratory in Houston, Texas on June 17th-19th; 2005; features regional winners from across the nation and Canada demonstrating the strength and agility of their vehicles. The ROV, which was designed and constructed by Polar Sinc, consists of a single streamline cylindrical housing, Innovation FIRST electronic controls, a single high-resolution color video camera and other electronics. The ROV was constructed with a four thruster propulsion system, configured to allow the robot to move in any desired direction within the water column. One unique feature of the Polar Sinc vehicle is its capability to communicate with its operators via a semi-tethered, wireless, system. The semi-tethered feature utilizes a free floating communications buoy transmitting audio, video and radio to the remote based control booth. The robot has been designed to be esthetically pleasing, but also versatile, functional, and competitive. Polar Sinc has received generous support from local businesses, educational institutions, and other organizations. The ROV, named Ursus Maritimus, was designed to be upgradeable and yield itself to many further applications beyond the competition, such as scientific and professional uses.



Kluane holding on!

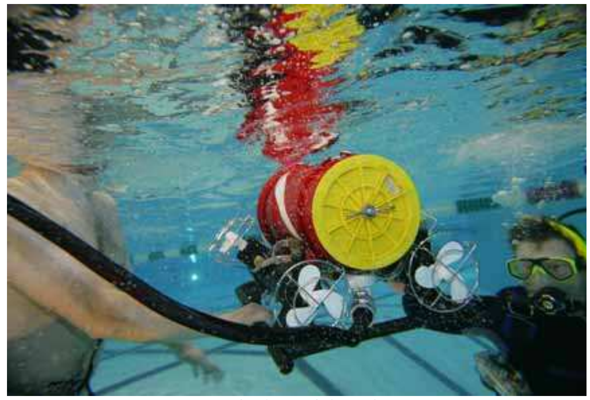
Watching the ROV perform

Touching the robot

The ROV Discovers Local Marine Life

DESIGN RATIONAL

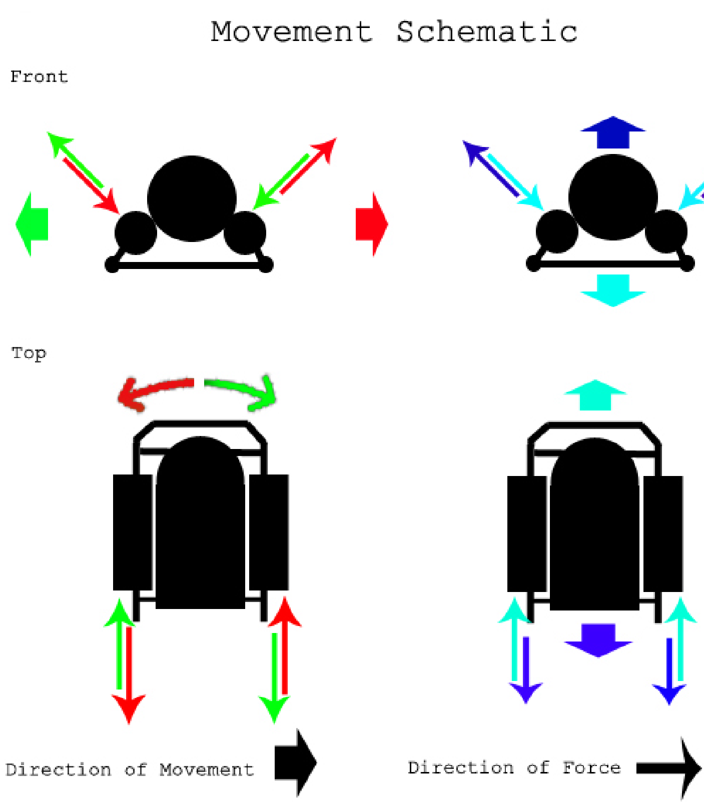
Main Housing:


An aft view of the robot

Polar Sinc decided on a one-piece 20.32cm diameter PVC fuselage with a 50cm length. Much like an airplane fuselage, the main housing was designed as such for three reasons: Firstly, this type of design provided large amounts of displacement therefore creating positive buoyancy without the addition of extra bulky floatation attachments. Secondly, with one large compartment, all the necessary electronics and wiring were conveniently housed together. This created efficient wire management and decreased the need for multiple sealed containers and complex routing of wires. Lastly, with the use of a single housing, the electronics and wiring were concealed, which was aesthetically appealing and offered a streamline profile. A tubular design provided all of these aspects as well as yielding strength and only two open ends; the front of which was sealed with a custom made acrylic dome and the rear with a high pressure test cap capable of withstanding pressure equivalent to a 12.192 meter depth.

Skids:

Skids on the underside of the ROV provided protection against impact to the dome, as well as a means by which to attach payload devices. These skids were constructed out of 1.91cm PVC tubing and traveled the length as well as breadth of the vehicle. To help maintain appropriate ballast lead was housed within the hollow cavities of this pipe.



Thruster Nacelle:

Attached underneath the main housing each at a 45-degree angle are two nacelles. Each nacelle contained one rear thruster, one vertical thruster, a high intensity light, and two compartments which house variable lead weights. These nacelles were created with 7.62cm diameter ABS piping.

Propulsion:

The team concurred upon four Sevylor 12V 7amp-trolling motors, which would provide all propulsion and movement needed by the vehicle.

Because of the amperage limits imposed by the competition, Polar Sinc considered it imperative to minimize the amount of motors necessary, without sacrificing performance. The use of only four motors also gives rise to longer run time, spatial conservation, while maximizing cost effectiveness. Two rear thrusters provide forward, reverse, as well as turning capabilities. Vertical thrusters were fixed in a vertrans configuration, enabling vertical and crabbing capability, which allows the vehicle to strafe side to side.

Visual Aspects:
For observation, the vehicle is equipped with a color, CCD, micro video pinhole camera, which produced an analog signal. The pinhole camera has a 70-degree viewing angle, which allowed for an impressive viewing field, considering its size. The small footprint of only 3.81cm x 3.81cm is essential to the mounting of this camera within the limited size requirements. This camera captures video at 460 lines of resolution and has a 1-lux rating. Giving it the ability to view in almost complete darkness. In order to adapt as the human eye adapts to varying light levels, this camera has a stepless automatic electronic shutter. This dilating shutter allows the vehicle to operate in bright, as well as low lighting conditions.

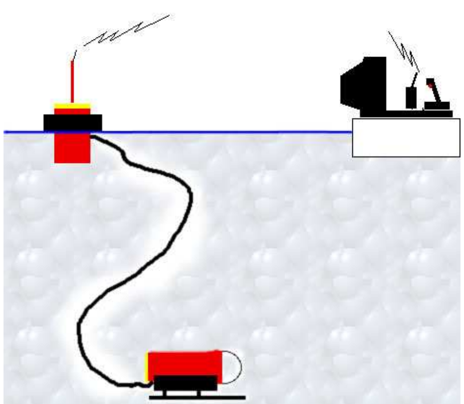
Hitec Servo

The pinhole camera is attached to servo made by Hitec. By coupling the viewing angle with the tilt function, the camera has the ability to see a 180-degree vertical viewing field.

To enhance color and bring illumination to dark places, the ROV has been equipped with two halogen 20watt submersible lights. These lights are powered by the system battery and may be controlled independently by the controller.


The pinhole camera

Semi-tethered Ability:
After much research, the team determined that the direct tether length was an unfortunate and unnecessary limiting factor to the robot's operational range. Therefore, to increase the operational range, yet maintain a 12V battery source a semi-tethered system using an intermediate buoy to wirelessly communicate with the shore based operator was conceived and developed. The necessity of a tether from the ROV to the surface because of inability of underwater wireless transmission, logically lead to the construction of a 15.24meter tether.


Semi-Tethered Diagram

On the surface, a buoy is attached to the terminating end of the tether. The buoy is a sealed, positively buoyant, container, which houses a 12V Absorbed Glass Mats (AGM) battery. Because all electrolytes are absorbed into the glass mats, these batteries are immune to any possibility of spills and damage from vibrations or inpact, therefore maximizing safety around water. Also housed inside the buoy are two separate transmitters a 900Mhz data radio transmitter for control of the robot and a 2.4Ghz video transmitter to transmit the analog video signal from the onboard remote camera.

The semi-tethered configuration allows us to deploy the robot into the water and control it anywhere within a 213.3-meter range. Application of this system can prove invaluable in future scientific research where the researcher does not want to interfere with subjects under investigation. In addition, for military operations or activities limiting personal involvement the wireless, semi-tethered feature offers quality control while protecting the operator. A similar semi-tethered system would be required during any Europa exploration mission, because of the obvious impracticality of running a tether back to earth.

Controls:

It was decided to use the Innovation FIRST controller system because of previous experience in other robotics competitions. This system allows programmable operation, tethered as well as radio operation and the ability to interface with multiple potentiometers and switches as needed.

Controller Interface:

The controller interface is a versatile and compact computer that can be programmed using "C" and provides multiple control options for the user to implement. For vehicle movement and activation of devices, two joysticks are attached to the controller interface, which are capable of operating every aspect of the robot. This controller can communicate either with the robot tethered or via a 900Mhz wireless transmission.

Robot Interface:

The robot interface, onboard the vehicle, receives the commands from the controller interface via direct link or wireless communication whichever is chosen prior to launch. After each command is received, the robot distributes commands to their appropriate device, be it a headlight or thruster.

At the Helm

Victors:

Used to regulate the power to each thruster, the Victor 884 speed controller is capable of providing variable voltage from 3-100%. These victors interrupt the direct power to the thrusters and are controlled via Pulse Width Modulation (PWM) cables attached to the robot interface.

Spikes:

All other electronic devices, including halogen lights and the camera, are switched by individual spike H-bridge relays. The robot interface, through PWM cables, controls these relays as directed be the operator on the surface. Each spike is equipped with an onboard 20amp fuse, which protects the device to which it controls.

Circuit Protection:

To provide over current protection to the entire electrical system, a 25amp breaker was installed to ensure safe operation within the competition rules. Additionally, power for each individual device must travel through a breaker board, which has varied auto-resetable overcurrent protection.

Payload Devices:

Rather than building complex mission devices, the team opted for simple detachable payload tools designed around each individual task. These payload tools were fixed and relied upon the dexterity and skill of operator to maneuver the ROV into the correct position.

Pipeline Valve:

For completion of the valve task, Polar Sinc attached a rubber coated hook, which could be used by the robot to close the valve in the appropriate manner necessary.

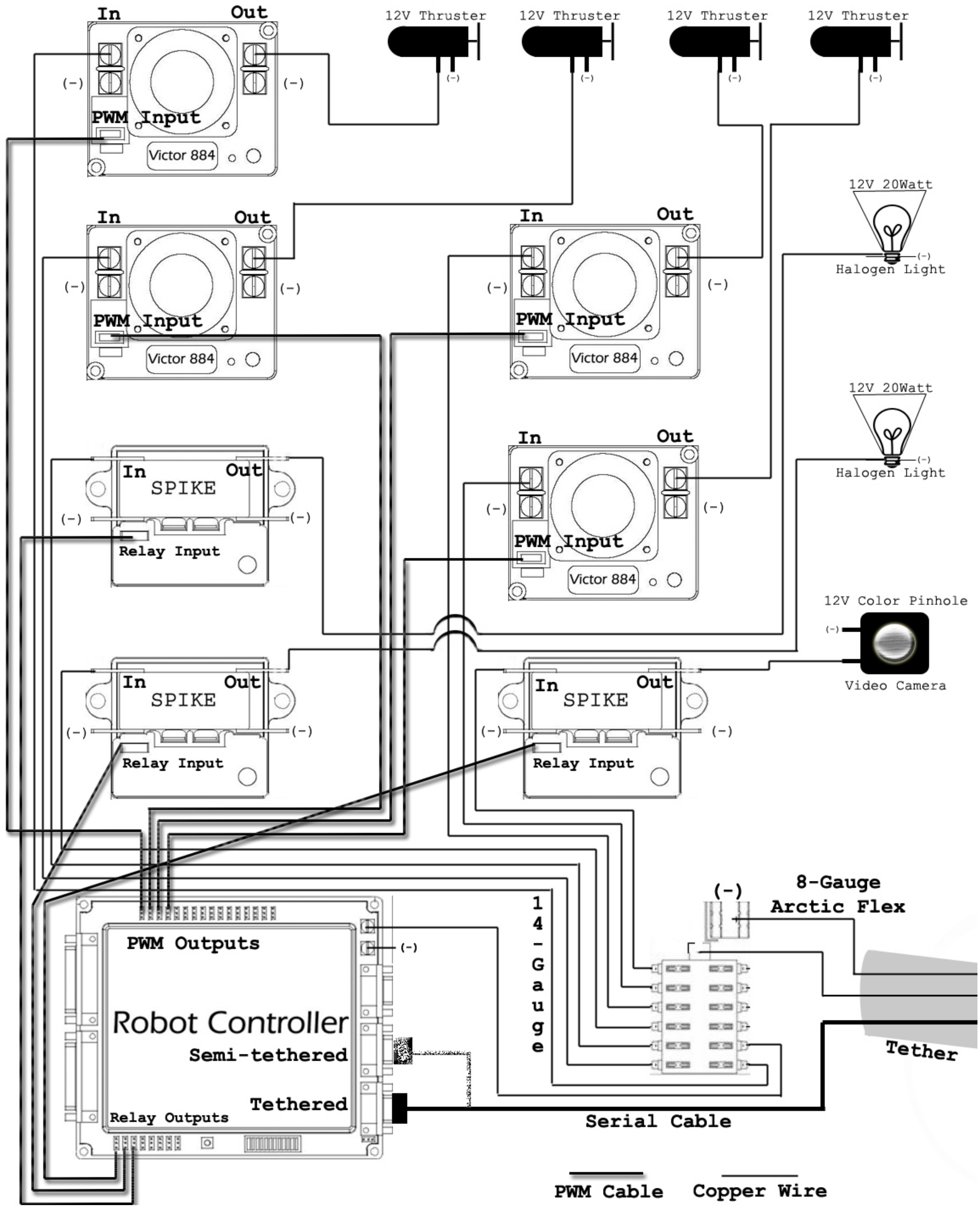
Communications Probe:

For the second mission task, the team decided upon using a similar mission device to the first. However, instead the hook's orientation will be modified such that the communication probe can be removed by turning the ROV abruptly to one side once insertion has taken place.

Hubble Module:

In the third mission, the device constructed for the robot was a simple spring-loaded system that required only skillful driving and minimal moving parts. It is designed to release the module only after the full forward power is applied.

ELECTRICAL SCHEMATIC



A CHALLENGE THE TEAM FACED

Although sealing the robot from water was one of the most ongoing challenges. The most unique challenge that Polar Submersibles team faced was interference between the video and control transmitters. As a part of the semi-tethered system, the robot was required to transmit video as well as commands. The team had already acquired a 900Mhz video transmitter and after acquisition of the Innovation FIRST 900Mhz control system an interference problem between the two transmitters became apparent. For many of the initial water tests, the vehicle utilized a fully tethered system and therefore the problem was not evident. Once semi-tethered tests were conducted, the ROV and monitor revealed some alarming symptoms. The video camera image intermittently flickered and could not maintain a solid picture. In addition, the Innovation FIRST controller monitor indicated a “No Data/Radio” problem and the servo controlling the camera tilt convulsed in sequence with the video loss.

900Mhz Video Receiver

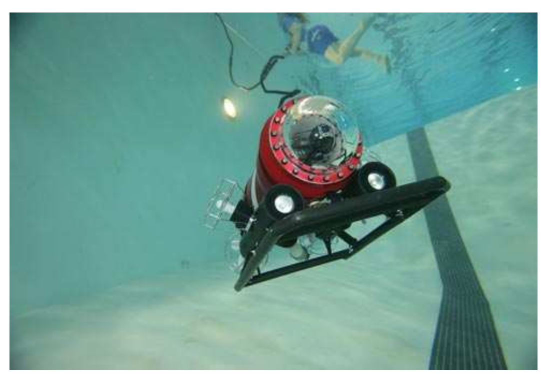
900Mhz controls transmitter

To troubleshoot this problem, the video transmitter/receiver system was tested independently of the controller and showed no interference likewise the computer controllers operated flawlessly once the video transmitter was shut off. It was therefore concluded that there was wireless transmission interference. Initially, it was assumed that the proximity of these transmitters was causing the interference, but after separating the two transmitters, the symptoms persisted. After, a series of channel alterations were performed to both the video and controller bases without significant effect.

Chill’n on the bottom

It was concluded that the problem was a 900Mhz vs. 900Mhz interference problem. To confirm the conclusions Northern Lights Video and TV Service was contacted. Their expert advice confirmed the diagnosis and recommended a new video transmitter that would operate at a frequency of 2.4Ghz. The team purchased a new video transmitter and receiver system from Supercircuits.com. Upon arrival, the team was pleased to see that new system worked flawlessly in conjunction with the vehicle controls.

Problem solved!



Free floating

EXPLANATION OF TROUBLESHOOTING TECHNIQUES

Most of the Polar Submersibles team has participated in previous robotics competitions, however the added difficulty of creating an underwater robot proved to be troublesome during construction and testing.

When the glass (or ROV) is half empty

After initial trials, a minor leak was observed which initiated an investigation of the end cap. After a thorough examination of the test plug, it was concluded that the end cap requires precision installation to seal properly. The o-ring seal had to be seated securely between either ends of the test plug.

The use of inexpensive Sevylor trolling motors, which were design for only about 45cm of submersion proved to give way to leaking under increased pressure. Moisture was detected inside of the tubing connecting the motors to the main fuselage. The exact whereabouts of these leaks were not easily ascertained; therefore, the team implemented an air pressure test to determine the exact location of leakage. Pressure testing consisted of pumping air into the sealed housing with the aid of an air compressor. With a pressure of approximately .345bar applying a water soap solution to all locations in question precisely identified leaks. By tightening and application of additional sealant, various leaks were controlled. Certain thrusters continued to leak and required additional attention including the installation of double-lipped elastomeric seals on the main shaft as well as silicone tape around main casing gaskets.

As a precaution, a leak detector was constructed and installed, that was linked to the Innovation FIRST controller, which would indicate a leak by flashing four red LEDs. This detector worked well and warned the team of several potential water problems well in advance of major soaking.

Overall, water protection required significant time and resources throughout our construction process in order to eliminate leaks. With the aid of pressure testing, as well as the water detection device, any future leakage can be efficiently detected and solved.

FUTURE IMPROVEMENTS

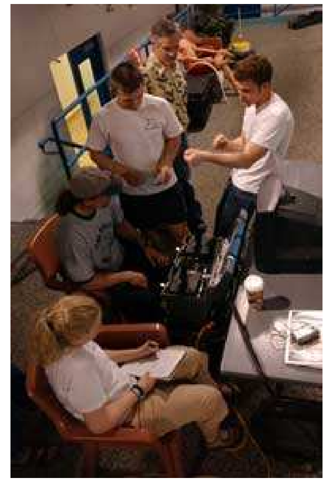
As they say: "Necessity is the mother of invention" and improvements can always present themselves at any stage of the design. The team at Polar Submersibles felt that the thrusters, while adequate for the MATE competition, would need to be upgraded.

Planning improvements

Thrusters having a watertight construction will be required for operating at greater depths. In the future, the ROV will be used in lakes, rivers and possibly in the ocean. In anticipation of these uses, a second camera would be useful, as well as a hydrophone, which would increase our overall data collection abilities. A rear-mounted dome was also considered as a possible upgrade in order to increase the vehicles visibility. Throughout testing, the durability of the skids was brought into question and in the future would be strengthened to ensure the robot's protection against impact or collision. Another important upgrade, which will be necessary for exploration at greater depths, is to increase the tether voltage. This will significantly reduce the line loss thus maintaining adequate power for thruster control. Although the vehicle's current state is competitive, it has been recognized that future improvements could undoubtedly improve the robot's performance.

A SKILL GAINED

The underwater maneuvering of our ROV was undoubtedly a new skill which required time, practice, and concentration to master. Drift is a major issue in regards to underwater navigation. Operators were required to compensate for drift by pulsing motors, and therefore creating an opposite force vector, canceling out undesired movement.



Teaching a sponsor how to drive.

The robot was designed to be slightly positively buoyant and therefore required thrust to maintain a constant depth. Drivers compensated constantly by firing the vertical thrusters downwards forcing the robot to maintain a level plane or by adjusting the trim to all thrusters to maintain a slow and steady push downward.

Vincent underwater with the ROV

Because the operator must only rely upon the video monitor and cannot feel motion change, it is imperative that the operator maintains vigilant spatial awareness. With the tilting ability of the camera, the driver can look above and below the ROV and therefore ascertain where the vehicle is within the water column. However, only with practice does the operator become fluent and develop the eye-hand coordination necessary to skillfully carry out the mission objectives.

ROV APPLICATIONS

British Petroleum (BP) has funded a deep-sea research operation and these studies are executed with the aid of an ROV. In this research scavenger traps must be set in order to collect specimens, which can be later studied. The robot is responsible to set and retrieve these traps by placing a spike, which has a ring attached to the top. For more information and video footage of the robot installing one such trap, visit the Serpent website at (http://www.noc.soton.ac.uk/GDD /serpent/trap.html). The vehicle must place the spike into the ground just as we must place the communication probe into the junction box. More information about this ROV and its activities as written about in the New York Stock Exchange Magazine is available at (http://www.noc.soton .ac.uk/GDD/serpent/files/NYSE %20 Article.pdf).

A scavenger trap

POLAR SUBMERSIBLES BUDGET

Category	Subtotal
Propulsion	$ 325.00
Optical	$ 200.00
Electronics	$ 2,400.00
Chassis	$ 200.00
Travel Expenses	$ 4,000.00
Promotional	$ 200.00
Miscellaneous,Connectors, ect...	$ 200.00
Total	$ 7,525.00

Conversing with the robot

Donated Items	Estimated Cost	Donor
(2x) 60AH AGM Batteries	$ 160.00	Alaska Battery Supply
Depth Gauge	$ 35.00	Test the Waters Adventure Sports
Submersible Compass	$ 25.00	Test the Waters Adventure Sports
Professional Paint Job	$ 100.00	College Collision and Refinish
8" PVC Tubing	$ 75.00	Vertex Insulation
Battery Connectors	$ 25.00	Alaska Battery Supply
Gasket Material	$ 15.00	Alaska Rubber
Total	$ 435.00	

ACKNOWLEDGEMENTS

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- We would like to thank Charlie Jeannet and Katherine Weibel for spending endless hours assisting with the design and construction of the robot.
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- Thanks Scott Lemley for arranging pool time for us to drive our ROV and practice.
- West Coast and Polar Regions Undersea Research Center for their generous support and encouragement.

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