Cape Henlopen High School

Technical Report

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ROV Name: The Valiant Viking

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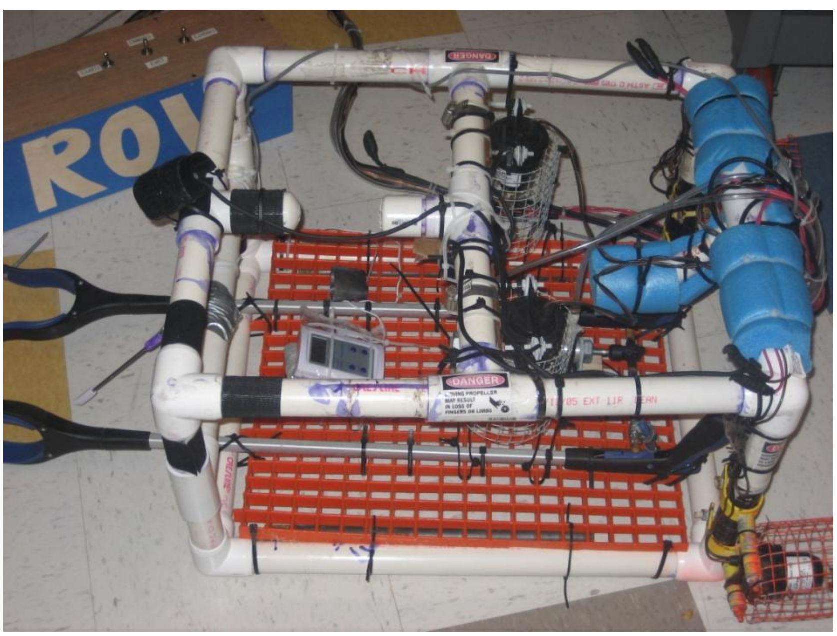
Abstract

A remote operated vehicle (ROV) is a tethered robot used for performing tasks in environments that would be dangerous for humans. Our ROV was built to navigate around the site of the abandoned HUGO research device and around the area of the Loihi Seamount. Our ROV can move up, down, forward, and backwards, and turn to the right or left. It is equipped with two highly manipulative arms on its front, one clamps vertically and one clamps horizontally, and both are operated by a pneumatic piston and air tank. The arms are used in all four Tasks, because of its great versatility (See Our Mission). There are two underwater cameras on our ROV. The primary camera is mounted on the front and is used for forward motion and control of the claws; the secondary camera is mounted near the center of the ROV, facing downward, and is used for monitoring the temperature readout and other auxiliary functions. Our entire robot is operated from a control panel that includes motor switches and a pneumatic switch. Building this ROV has taught us many lessons and the competition experience has given us some insight as to how real engineers work.

Figure 1: Our complete, intact vehicle photo.



Cape Henlopen High School

Expense Sheet

Cape Henlopen High School			Period:		
Instructor: William Geppert			From: 2/2/2010		
			To: 5/14/2010		
Date	Deposit or Expense	Description	Notes	Amount	Balance
2/2/2010	Deposit	Cape Henlopen School District		$2,000.00	$2,000.00
2/2/2010	Expense	Vinyl Lettering, J R U Bolts	ACE	$7.54	$1,992.46
2/2/2010	Expense	Buzzers	Radioshack	$12.47	$1,979.99
2/16/2010	Expense	Angle Gage, 2 PVC Caps, 3 Black Jacks	Home Depot	$12.21	$1,967.78
3/3/2010	Expense	HP Hosepipe adapter, ABS Sheeting	Home Depot	$96.05	$1,871.73
3/5/2010	Expense	Eveready 6 Volt Utility, 5 20/2 Bell Wire Twisted	Lowes	$5.17	$1,866.56
3/5/2010	Expense	Bulb, Tennis Balls, Fish Line, Mouse Trap	Walmart	$7.87	$1,858.69
3/5/2010	Expense	6 ct Ping Pong Balls, 2 Dt. Pepsi, 3 MT Dew, 3 Sprite	Food Lion	$15.49	$1,843.20
3/11/2010	Expense	Everready HD 6 Volt	Lowes	$11.61	$1,831.59
3/11/2010	Expense	50 ft Audio Cable, 50 ft Blue/White/Red Insulated wrapping wire	Radioshack	$35.68	$1,795.91
		Electret microphone element with leads, 1/8" MonoPhone Plug			
3/17/2010	Expense	9 Volt 2-pack battery, C-Battery 4-pack, Swivel, 2-inch Y, 3/ 4 adapter	Home Depot	$58.30	$1,737.61
		13-1/2 " PVC elbows, 3/4" Tee, 3-1&1/4" elbow, electric tape			
		3-1/2" PVC cap, 4-1/2" PVC tee, 2-3/4" 45°PVC, 1/4 lb solder			
4/12/2010	Expense	12- 3 way PVC connector for 1/2 in. pipe	ACF Greenhouses	$25.26	$1,712.35
4/16/2010	Deposit	CHEF Grant		$500.00	$2,122.35

4/21/2010	Expense	Hotel: Springhill Suites Norfolk, Old Dominion University	Marriot	$474.21	$1,738.14
4/26/2010	Expense	Hawaiian Shirts for Competition	Shirts of Hawaii	$236.92	$1,501.22
4/26/2010	Expense	Zinc Washer	Home Depot	$4.97	$1,496.25
4/ 26/2010	Expense	Swivel: 2 @ 4.41, 3/4" adapter: 2 @.32, 3/4 PVC elbow	Home Depot	$11.16	$1,485.09
		3/4 PVC Cap, 1 PVC Cap, 1/2" PVC Cap			
5/6/2010	Expense	Electric tape, Phone Jack, Phone Plug, Mini Amplifier	Radioshack	$25.26	$1,459.83
5/6/2010	Expense	Mineral Oil	Rite Aid	$4.99	$1,454.84
5/6/2010	Expense	Black Foam Poster Board	Michaels	$15.99	$1,438.85
5/11/2010	Expense	Wire Rope Clip 6@.58c, PSI Press 5@ 1.67	Lowes	$11.83	$1,427.02
5/11/2010	Expense	Audio Cable	Radioshack	$9.89	$1,417.13
5/14/2010	Expense	Poster	Parcel Plus	$88.59	$1,328.54
5/14/2010	Expense	Dinner	Olive Garden	$177.10	$1,151.44
			Total Deposit	$2500.00	Net Budget:
			Total Expenses	$1348.56	$1151.44

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Budget Summary

Our total cost this year was $1348.56. The task of staying on budget has been increasingly difficult. However, our team raised $2500 from various sources.

1. Cape Henlopen High School, District: $2000
2. CHEF Grant: $500

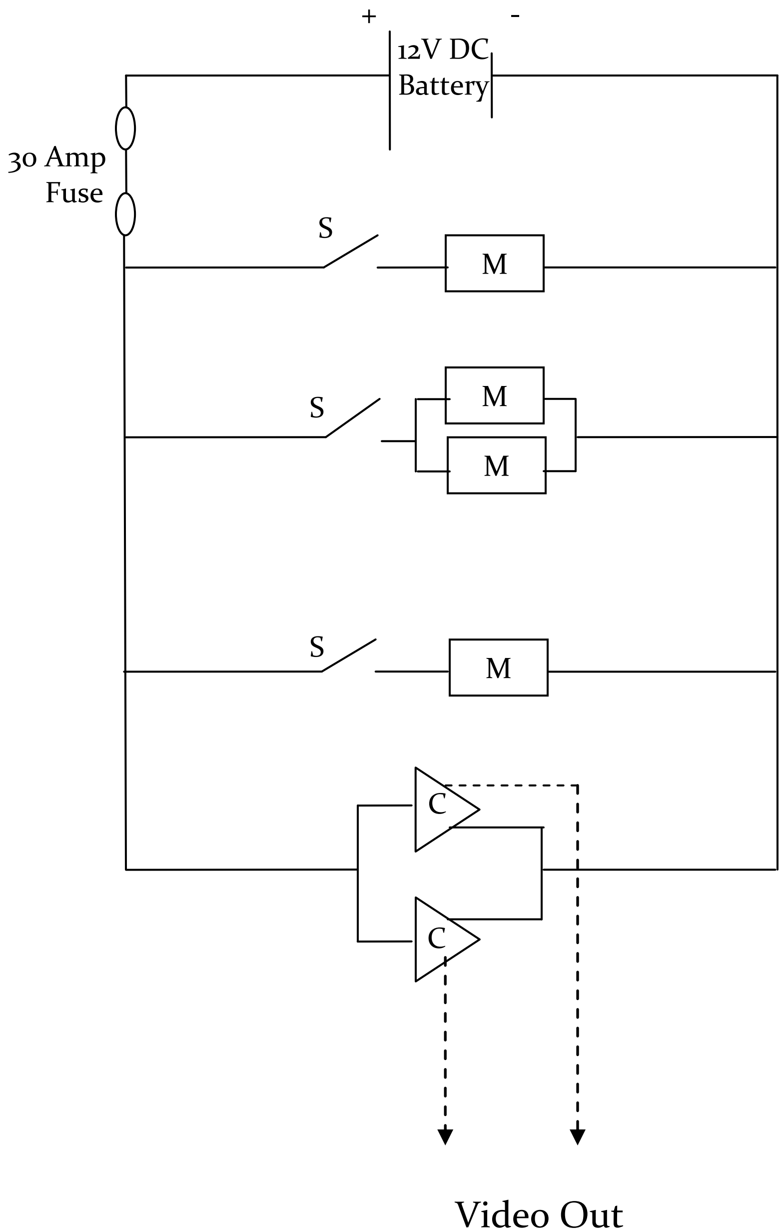
Because our ROV was mainly building off of last year's model, we were able to save money on a few of the larger items within our device. For example, using the bilge pump motors from last year's ROV saved us about $50.00 per motor, for a grand total saving of $200.

<u>Donated Items:</u>

1. Cameras @ $400.00/camera
2. PVC Piping (partially) @ $100.00 total

While preparing for the international competition our ROV team faced the major challenge of acquiring the funds for the trip, primarily to transport the team members and the robot. We approached this monetary problem by first asking the school and its government for scholarships, grants, etc. In addition, we spread the news of the team's win at the regional competition, and the request for funds, we put an article in the newspaper, and we appeared on the radio, in order to inform the general public and private organizations in hopes to get private donations. Another unrelated problem was that we had to maximize our expenditure by searching for the cheapest package of airplane flights, hotel rooms, and shipping charges.

Electrical Schematic



Key:

S: Switch

M: Motor

C: Camera

Mechanical Drawing

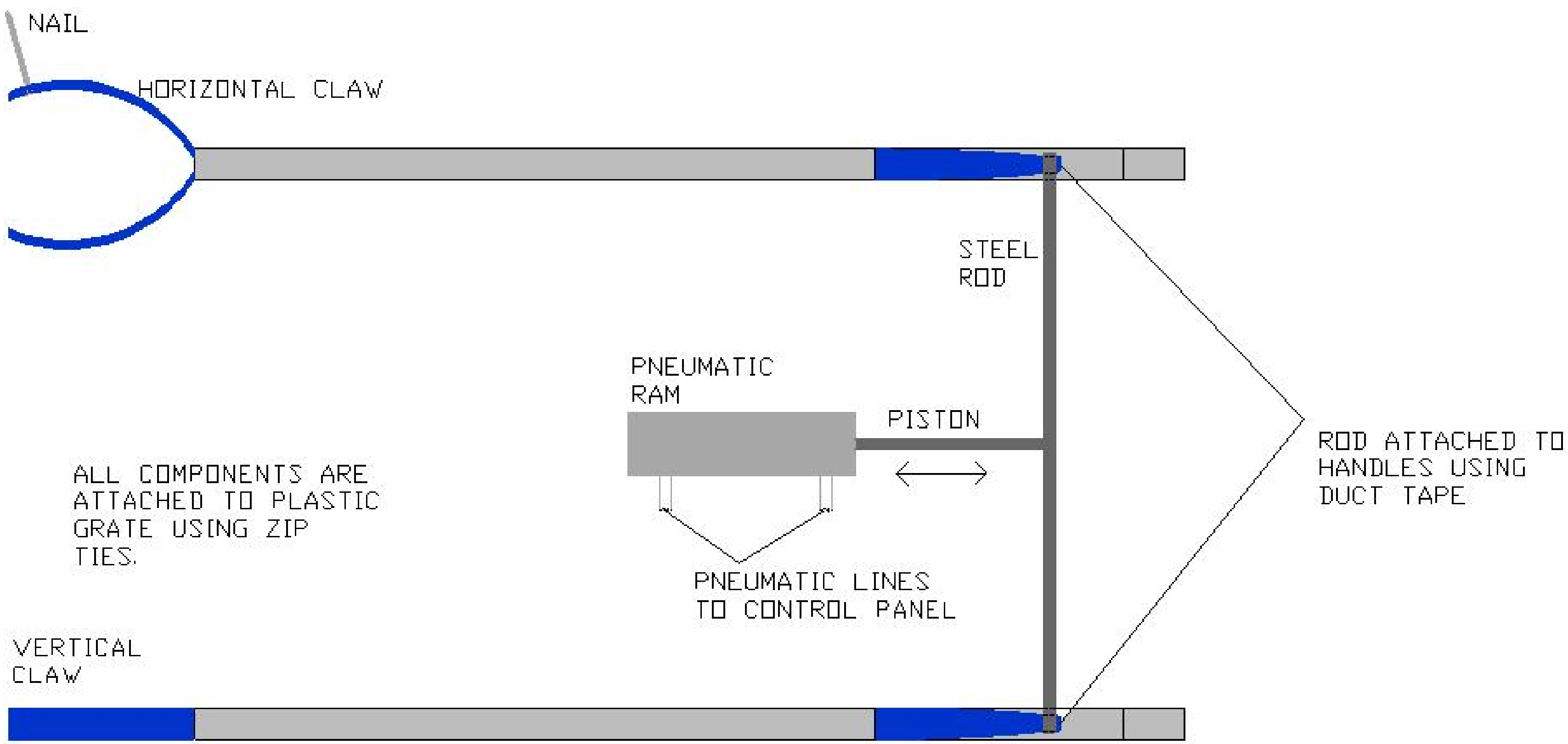


Figure 2: An overhead- view drawing of our pneumatic ram and claw system.

Design Rationale

Structure and Buoyancy

We built our ROV out of PVC Pipe and we used a cube for the basic shape so that we were able to distribute the weight of the materials on the ROV and maintain neutral buoyancy. On the base of the ROV we used a plastic grate to keep the arms sturdy and to provide a flat surface for our payload components. For instance, we zip tied the pneumatic ram to the grate for stability. The PVC frame is small enough that it fits into the cave in Task 2, but large enough that we have ample room for components and the downward-facing motors. Finally, using a trial-and error approach, we made the ROV neutrally buoyant using pool noodles (tubes) and small weights. To do this, we placed the ROV into a pool, (after all other modifications), and noted its pitch and overall buoyancy. To fix the problem, we repeatedly added the noodles and weights until the ROV was neutrally buoyant and level, securing the pieces to the frame using zip ties.

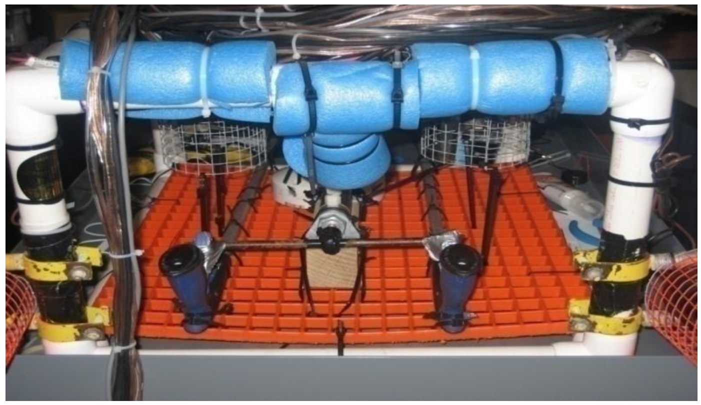


Figure 3: Rear view of our ROV:
Blue Noodle for Buoyancy
Zip-Ties to secure the pieces together.

Payload Tools and Sensors

Our ROV is designed to best accomplish the four tasks for which it has been assigned. The first task was to resurrect Hugo. Each task has a specific tool for a specific purpose, however, many tools are able to accomplish a variety of tasks. For example, the claws are used to insert the HRH connector into the port on the HUGO junction box and also collect ventral spire samples. In the second task, we have to enter a cave and remove three

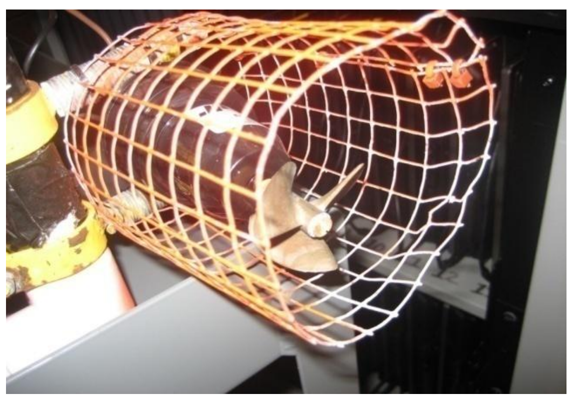


Figure 4: Safety Measure: Protection to Cover the Propeller

samples of the crustacean. To accomplish all of these things, we have four motors: two are 3785 Lph bilge pump motors, mounted at the rear, and two are 4732 Lph bilge pump motors for vertical motion. Together, these cave. Each of the rear-facing motors is controlled independently, while the two vertical motors are controlled simultaneously; this allows for both a wide range of motion and a stable robot.

Two cameras are mounted on the ROV. They are both commercially produced devices, specially designed for underwater use. They require only 2 lumens in order to function adequately. One of them is mounted on the front of the robot facing forward and is used to move the robot forward while operating the claws. The other camera is mounted near the middle of the robot, facing downward, and is used to see the bottom of the robot and the digital temperature probe readout. The cameras are connected to two video lines culminating in a switch, near the control panel, that controls which camera is activated for use on our television screen at the particular time. Cameras are imperative tools because they allow excellent visibility while completing all of the tasks.

Figure 5: One of our two waterproof underwater cameras.

The ROV has two claws which operate by a pneumatics system. The claws are commercially produced trash-removers, with a handle at one end of the arm. This arm is squeezed in to close the claw. These claws are mounted, parallel to each other, on the bottom grate of the ROV, using several zip-ties. For optimal control , one is mounted horizontally while the other is mounted vertically. The horizontal claw which includes an outward-facing nail, is used when precision is necessary, as in the removal of the pin and the HUGO Junction Box Cap in Task One. The handles of the claws are attached, using duct

Figure 6: Air Tank for the operation of our ROV's arms.

tape, to a rear-facing steel rod; the rod is attached to a pneumatic piston also mounted on the grate. The piston is controlled via two air lines running along the tether. The lines culminate in a control joystick mounted on the control panel. The joystick receives air from another air line running to our 38 L compressed air tank. The tank contains approximately 552 kPa of pressure, but two regulators, one mounted on the tank and one mounted on the supply line near the control panel, together lower the pressure to the system's operating pressure of 136 kPa. The system is an open system, meaning that any air released through use is not retained but is instead let out from the system. The claws are very versatile tools and are used many times throughout our missions; we accomplish many of the tasks using them.

When the control joystick is pushed to 'close,' high pressure air is allowed into the line running to the back of the piston container so that the piston moves out and the claw handles are pushed, thus closing the claws. When the joystick is pushed to 'open,' air is forced into the other air line, pushing the piston back and pulling the claw handle back to its original position; the handles are also spring loaded, so that as soon as force on the rod is decreased, the claws will open. We chose to use a pneumatic system because it was very simple and fairly easy to work with. A hydraulic system, our main alternative, would have been more costly and required a hydraulic pump during use.

There are two additional components of our payload that are mounted to our ROV. First, we have a temperature probe mounted on the front of the robot. In the third task, we are required to measure the temperature of the venting fluid at three different locations on the chimney. The actual probe is attached to the robot using duct tape. This allows it to be flexible enough to take a horizontal position or an angled position based on forced applied by the robot's motion, so as to fit in one of the varied chimney vent positions. The digital temperature readout screen is located on the bottom grate of the ROV in easy view of the secondary camera so that we can see the temperature at the probe tip immediately. To make the probe readout device water proof, we wrapped it in plastic wrap and sealed the remaining openings using hot glue and silicone sealant. Next is our hydrophone. We have constructed a hydrophone, from scratch, in order to locate, acoustically, the source of the sound in Task 1. The microphone element is in a film container, mounted on the front of the robot. Its speaker wire runs along the tether to an amplifier/speaker on the control panel, where a battery pack provides power for the hydrophone. Consequently, we can listen to the sounds being produced underwater using our noise-cancelling headphone, thus finding the source of the sound.

Finally, there are two components of our ROV system that are not actually mounted to it. First, we have a metal basket that we use to collect the crustacean samples, to hold our filled agar collector-tube, and to hold the vent spire sample before returning to the surface. There are both weights and buoyant pool tubes mounted to it so that it sinks quite slowly; and we use the barbed wire handle to pick it up and move it. Keeping with our goal to operate a wholly simplistic ROV, all the objects are simply dropped in the basket from above. Also, to collect the agar sample, we created a simple device. We cut the tip off of a 250 mL graduated cylinder, allowing just enough room for the correct amount of agar to occupy; put a one-way valve on the base using silicon, and attached solder so as to make it sink. We can pick up the device using our claws and push it into the agar sample before pulling it away, filled, and placing it in our wire basket.

Tether

A tether is very important to our robot because it provides electrical power and gives us control. Our tether is 19.812 meters long, allowing for a maximum operating distance of 15.24 meters long. There are several cables running through our tether. First, there are electrical cables running to each of the motors, which are controlled on the control panel. Next, there are two video cables that run to each of the cameras mounted on the robot. Our pneumatic air line runs the full length of the tether as well, to provide air pressure to the pneumatic ram. Finally, there is a single audio cable that connects the hydrophone to the amplifier mounted on the control panel.

Figure 7: 19.812 meter tether, connected to the control board.

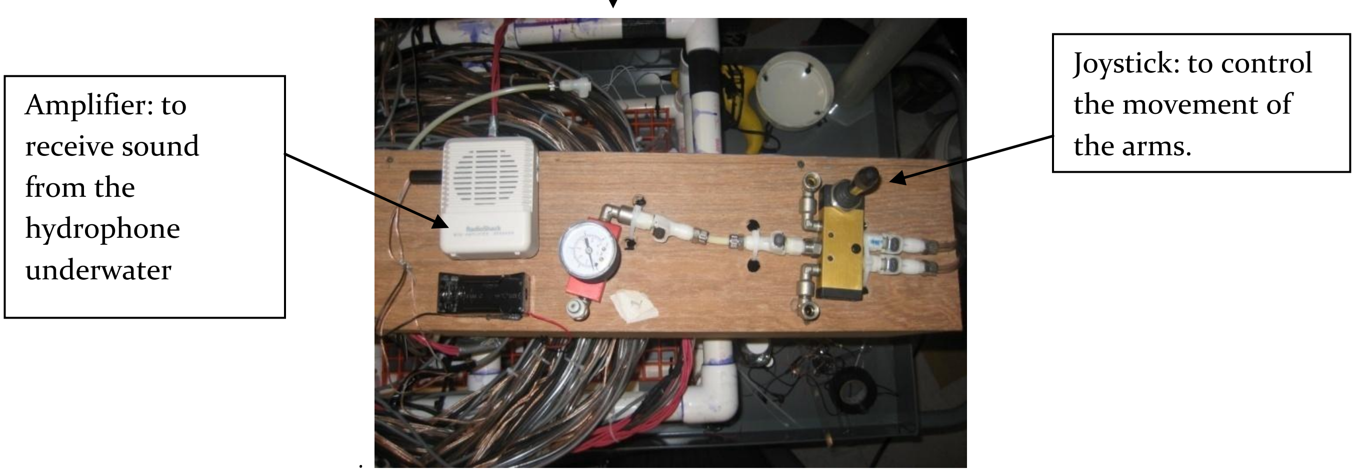
Safety Features

Our ROV had multiple safety features implemented into its design. The first safety feature was the use of mesh wiring around our motors to prevent any objects or body parts from being caught or damaged. We also included a series of water proof warning labels near the motors and on the control panel, to alert people that the motors can be dangerous and to be cautious of the power line. Another safety feature we incorporated into our design was insulated wiring to prevent short circuiting. On the tether there is also a 30 amp fuse integrated into it. The purpose of this fuse is to regulate the flow of power and prevent the robot from shorting out.

Control System

Our control panel is the key to the operation of the ROV. On the left side of the panel, we have three non-momentary switches. The two outer switches are attached to the right and the left motors, while the middle switch is attached to the motors responsible for vertical travel. In the center of our control panel, we have the amplification system for our underwater hydrophone. On the right side, we have a joystick which controls airflow in and out of the pneumatic system on the robot. We employed the use of a hardware only approach because we have experience with the use of this kind of control system. In a way, we had to sacrifice some maneuverability for the sake of simplicity and experience. However, we are happy with this choice because it has resulted in a design that is simple and easy to repair if necessary.

Figure 8: Control Panel for the operation of the arms



Lessons Learned

During this project, our team has learned how to work together. We have collaborated for our entire project, working off each other's ideas. This teamwork has given each of us a taste of how engineers work together to accomplish their goals. Also, this lesson has led us to respect each other's opinions because we have seen that each person's ideas are worth considering.

In addition, we learned about working with underwater electricity, a difficult and dangerous task. We learned a great deal about wiring and electrical connections. Several students were very impressed with the new understanding they gained from constructing our hydrophone and the connections that were associated with it. Additionally, we learned how to solder, a great ability to have, especially for tasks associated with robotics.

Future Improvements

In the future, we would like to have lateral movement added to our ROV. Currently, the robot is not able to move directly to the side: it can only turn. This, in turn, has an effect on the speed and maneuverability at which the robot can accomplish its tasks. Also, the ability to see both camera displays at once would be invaluable. Currently we have two cords from each camera, and we alternate between the two displays by switching the TV's video plug. If we were able to plug both in at once, this would save time, as would getting a two way Audio-Video Switcher.

Teamwork

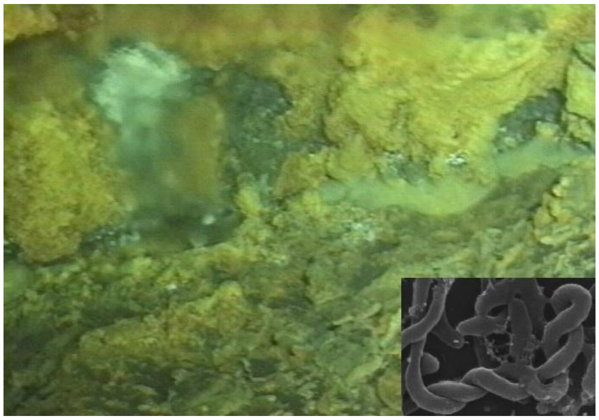
The success of our ROV is largely responsible for exceptional teamwork. Without active contributions from everyone, the construction, organization, and operation of the ROV would be near impossible. Jasmin Patel and Tanya Munyikwa were largely responsible for the organization of our project. They kept the budget in line and helped provide important information relating to the competition. Tanya and Jasmin also contributed to solving technical problems relating to the ROV. Joe Esposito, Andrew Ricker, Paul Jang, Chris Hubley, and Kyle Joseph were responsible for making sure the ROV was able to complete the tasks in a quick and efficient manner. Jasmin Patel and Kyle Joseph also worked together to operate the ROV during the competition. Andrew, Paul, and Joe were also responsible for the creation of our electrical schematic and helped relay technical information. Kyle and Joe also served to create the mechanical schematic of the pneumatic arm sub-system. All team members contributed to

The Loihi Seamount

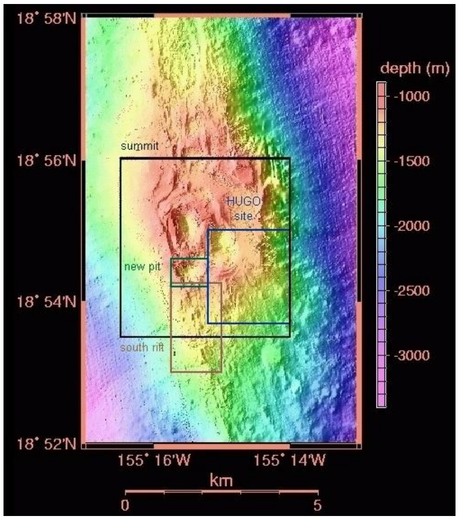
Figure 10

Figure 9

Hydrothermal vent with the newly discovered organisms.



Elevation map of Loihi Seamount



The Loihi seamount is an underwater volcano in the Hawaiian Hotspot area. This volcano rises about three-thousand meters above the seafloor. Until the 1970's, Loihi was thought to be an old seamount volcano, but after an expedition to study the earthquakes being generated in the location, it was found out to be an active volcano. In 1996, Loihi erupted, the first seamount eruption in recorded history. Since then the University of Hawaii has been studying Loihi's seismic activity. In October 1997, the Hawaii Undersea Geo-Observatory deployed a hydrophone to record the noises created by the volcano. This didn't last too long, since shortly after being deployed, a connecting wire from the island to the junction box which regulated the power for the hydrophone, filled up with seawater. In January 1998, the remote operated vehicle, Pisces V, was sent off to fix the problems. It was able to fix the failed connection and install a new hydrophone. In April of 1998, HUGO's cable was again damaged. It wasn't until November 2002, that HUGO was brought up to the surface, and then improved with stronger cables and stronger plating to prevent the HUGO from becoming inoperable again. In 1999 The National Science Foundation supported an expedition to Loihi's hydrothermal vents in order to take samples. They were able to find jelly-like organisms surrounding a vent that reached about 160 degrees Celsius. These organisms could contain countless benefits for mankind, and only through these kinds of expeditions and the use of ROV's, can we discover these benefits and new organisms.

Our work was similar to that of the ROV that back in January of 1998 helped HUGO. We had to repower the junction box, and reinstall the hydrophone in a site with volcanic activity. The rest of the tasks were basically other functions that the Hawaii Undersea Geo-Observatory would have: measuring different temperatures of hydrothermal vents to determine volcanic activity. Another goal our ROV was tasked with was obtaining a sample of agar. Just like the National Science Foundation, we had to obtain a sample of a jelly-like substance underwater. This shows the versatility and real-life applications of the work we have completed, and our robot.

Challenges Faced

In building our ROV, we experienced several challenges. Most significantly, we had to deal with a considerable time constraint coupled with busy schedules. Nearly all of the members of our team were involved with sports and other extracurricular activities, and so it was difficult for us to consistently find adequate time to meet. To cope with this problem, we chose to have several periodic meetings in which our main purpose was to set up a schedule for the coming weeks. This helped each team member to be able to make a sound commitment to working on our ROV and to manage their personal schedules, well, so as to be able to come. The result was that we had at least half of our team at every single practice session, meaning that we were able to be productive and make progress.

Another major challenge that we faced was Task 4 of the missions: collecting the sample of agar. We had some difficulty with holding on to the agar after we had displaced some of it. To solve this technical problem, we used a trial-and-error process. One of our team members had the ingenious idea to use a graduated cylinder turned upside down, so we cut a great deal of the actual cylinder off so that it would fit in the agar holder. Then we tested the device. While observing the test, we realized that the device would need a relief port to expel the water already in the cylinder, when the agar replaced it. To do this we decided that a small hole in the base (top) of the cylinder would work. Once again, through testing, we realized that another modification was necessary to prevent the agar from simply slipping out again. Considering and experimenting with several options, we finally chose to make a silicone seal around the hole we had drilled. We loosened part of the silicone seal with a knife, thereby creating a one-way valve. The resulting device works quite well: when moving downward through the water and into the agar, the silicone seal is flapped upward by the force of the moving water, and this allows the agar to easily fill up the cylinder. When we remove the agar cylinder, the seal is pushed downward by the force of the moving water so that the hole is sealed and almost no agar escapes. We used an effective problem solving technique to solve our technical problem, and the effects were observably great.

Troubleshooting Techniques

While we were designing and testing our ROV, there were many problems that we came across that required troubleshooting. However we used multiple techniques to help us solve the problem more efficiently:

a. Identify and isolate the faulty component
b. Repair or replace the part
c. Test to determine if the problem is solved
d. If the problem is not solved, try again or locate another defective component

An example of how we used our troubleshooting techniques was when we re-wired the robot. Our original wiring was unorganized and it would occasionally not function properly, so we decided to start from scratch and replace it. After securing and waterproofing the connections on the ROV, as well as making organized connections to the control panel, we tested our robot underwater. We are very happy with the results: all of the controls function properly and the tether is now easier to handle with the more organized wiring.

Reflections

This ROV has been an opportunity for us to experience a real engineering task. One of the most rewarding aspects of this experience was the being able to work as a team on a real life project. We were able to gain some background knowledge on an actual project and work towards and achieve multiple goals. There were some problems along the way but we worked together to solve the problems which also allowed us to gain a better understanding of our ROV. The best part was being able to see that all our hard work and dedicated time paid off in the end.

References

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Acknowledgements

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