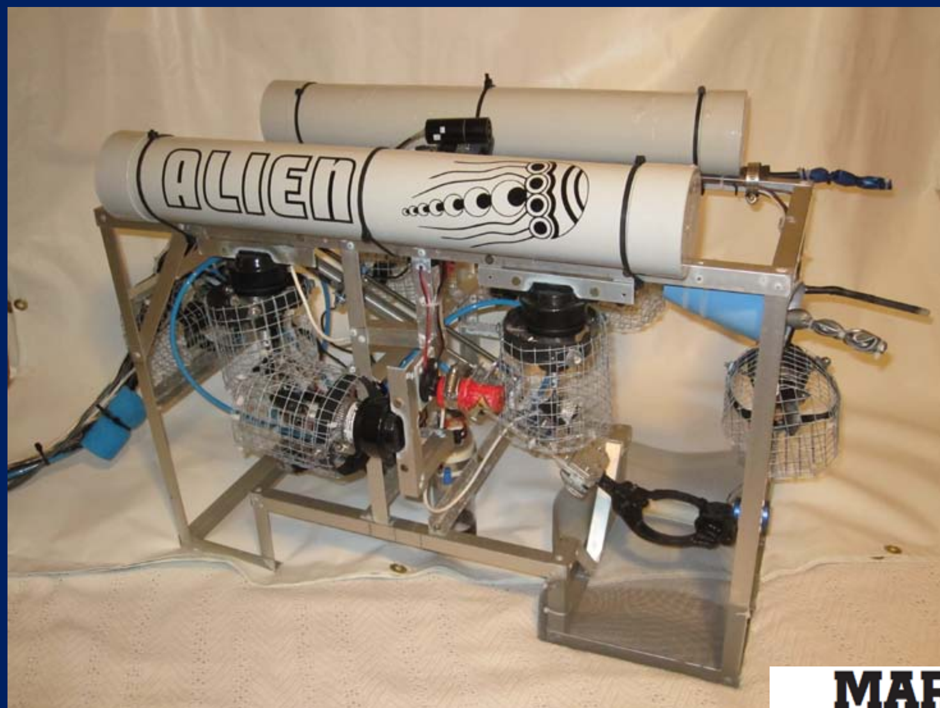
# Technical Report




MARINERS ALIEN

Submitted by the

## Aptos High School
## Under Water Robotics Team

**Aptos, California**

April 24, 2010

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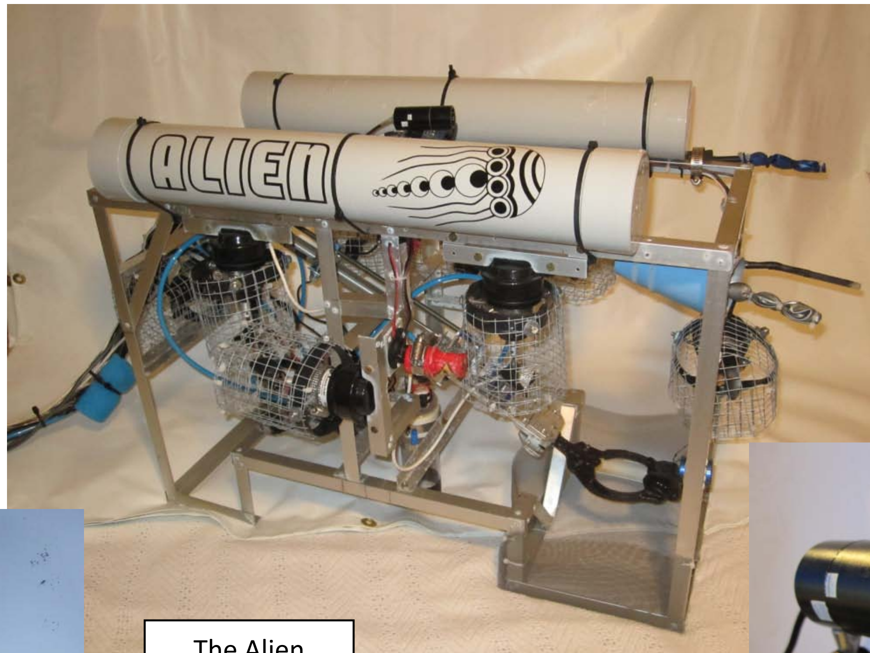
# Abstract

The Hawaiian Islands have been a hotspot of volcanic activity for centuries. However, scientists have recently discovered a new, very active member of this chain in the Loihi Seamount. This seamount has extraordinary amounts of biologic and geologic activity occurring, and has been the focus of much international attention. As a result of this, our ROV, *The Alien,* was created to perform a variety of tasks, including: sampling marine life, taking measurements on hydrothermal vents, and helping to repair HUGO, the undersea volcano observatory. The two primary design elements of our ROV are maneuverability and a retractable mechanical arm and claw. To ensure maximum visibility underwater, we installed three cameras located in strategic positions to facilitate our mission. To propel our ROV we used eight bilge pumps with modified propellers for increased speed and maneuverability. We took advantage of an Xbox 360 game controller and wired it through a specific circuit board that allows it to control our ROV. To sample bacterial mats, we have a cylindrical "cookie-cutter" with a one-way valve that cuts out and holds sections of bacteria. The most challenging, yet effective, part of our ROV is our mechanical claw. It makes use of solenoid controlled pneumatic actuators to both activate the "grabbing" mechanism, and to extend and retract the claw so that we can drop items into an internal storage basket. We plan to demonstrate that our design is the most effective and efficient at accomplishing the tasks of the competition.


# Vital Statistics of The Alien

- Length: 82cm
- Height: 55cm
- Width: 54cm
- Weight: 11.3kg
- 8 Propulsion Motors
    - Four 3.2 amp motors for moving up and down
    - Two 3.2 amp motors for forward and backward movement/ turning
    - Two 3.2 amp motors for strafing/ turning
    - All motors have wire shrouds to protect blades and body parts
- Horizontal Speed: 0.6 m/sec
- Vertical Speed: 0.75 m/sec.

# Photographs of "The Alien"




The Alien

Pneumatic Claw

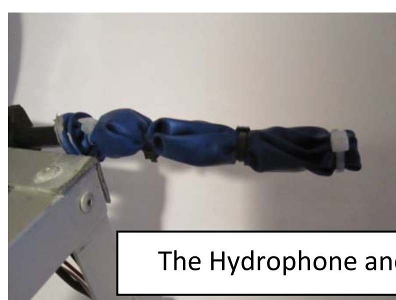
One of three Cameras

Motor in Protective Cage

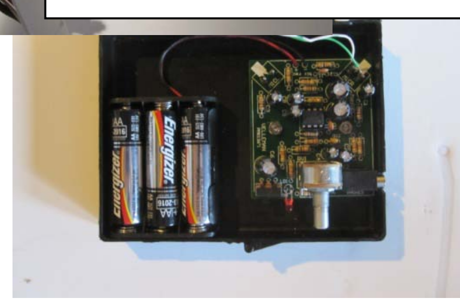
Temperature Probe

Bacterial Mat Collector

Software System and Joy Stick



The Hydrophone and Receiver



Aptos High School
Joe Manildi - Instructor

# Budget/Expense Sheet

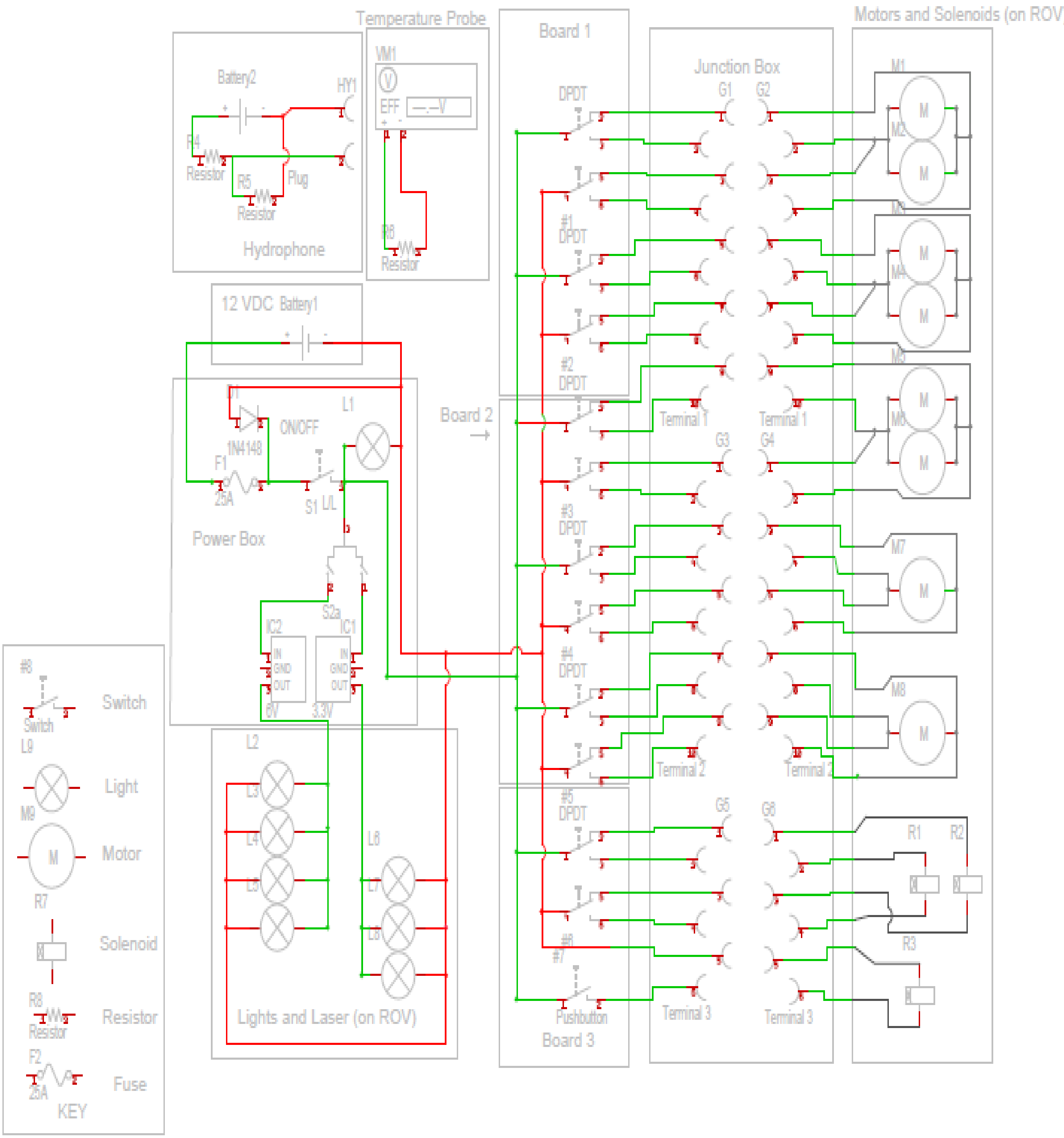
Expenses — 2010 MATE ROV Competition - Expense Report

| Date | Supplier | Description | Category | Amount | Sub Totals | Balance | Notes |
|---|---|---|---|---|---|---|---|
| 11/9/2009 | | Cameras | Camera | $0.00 | $0.00 | $0.00 | utilized from last years ROV |
| | | | | | | | |
| 1/30/2010 | Radio Shack | Heat Shrink Wire | Electrical | $4.36 | | -$4.36 | |
| 2/5/10 | SC Electronics | Voltage regulator, 5V | Electrical | $7.47 | | -$11.83 | |
| 2/13/2010 | Home Depot | Cat 5 Wire, Speaker Wire, Outlet box | Electrical | $177.04 | | -$188.87 | |
| 1/4/2010 | Home Depot | Electrical Supplies, Wire, Junc. Box | Electrical | $188.76 | | -$377.63 | |
| 4/12/2010 | OSH` | Strain reliefe fittings for junction box | Electrical | $12.29 | | -$389.92 | |
| 4/18/2010 | Paypal - Chris Harriman | Relay Boards for controls | Electrical | $195.81 | | -$585.73 | |
| 4/26/2010 | Digikey | Power Diode | Electrical | $21.43 | | -$607.16 | |
| 5/4/2010 | Red Lobster - gift | Thank you to Chris Harriman | Electrical | $50.00 | | -$657.16 | |
| 5/19/2010 | Tether Store | Tether casing | Electrical | $30.00 | | -$687.16 | |
| 4/9/2010 | Chris Harriman | Relay Board | Software | $190.00 | | -$877.16 | |
| | | | Total Electrical | | $877.16 | | |
| 12/13/09 | Ace Hardware | J-bolts, Plastic spray paint | Mission props | $7.63 | | -$884.79 | |
| 12/28/09 | OSH | PVC fittings | Mission props | $2.71 | | -$887.50 | |
| 12/11/09 | Home Depot | PVC fittings | Mission props | $41.12 | | -$928.62 | |
| 3/15/10 | Big 5 | Fishing lures, grubs | Mission props | $8.72 | | -$937.34 | |
| 12/10/10 | Aptos Hardware | PVC fittings | Mission props | $21.37 | | -$958.71 | |
| 12/14/09 | OSH | Lexan sheets | Mission props | $24.56 | | -$983.27 | |
| 1/2/10 | Radioshack | Buzzer and 9V batteries | Mission props | $24.77 | | -$1,008.04 | |
| 12/13/09 | Home Depot | PVC fittings | Mission props | $33.06 | | -$1,041.10 | |
| | | | Total Mission Props | | $163.94 | | |
| 12/18/2009 | 99 Cent Store | Tank Cleaner | Mission Specific Device | $2.18 | | -$1,043.28 | |
| 1/9/2010 | Ace Hardware | Gasket Kit, 8 LED Flashlights | Mission Specific Device | $23.18 | | -$1,066.46 | |
| 3/2/10 | Allied Electronics | Voltage regulator, 3.3V | Mission Specific Device | $13.98 | | -$1,080.44 | |
| 1/24/2010 | Amazon | Red Laser Pointers | Mission Specific Device | $23.64 | | -$1,104.08 | |
| 1/15/10 | Grainger | Temperature sensor and readout | Mission Specific Device | $27.16 | | -$1,131.24 | |
| 4/12/10 | Radioshack | Microphone Components | Mission Specific Device | $21.22 | | -$1,152.46 | |
| 4/12/10 | Santa Cruz Electronics | Stero microphone kit, stereo plugs | Mission Specific Device | $17.71 | | -$1,170.17 | |
| 4/23/10 | Electronics | Hydrophone | Mission Specific Device | $159.00 | | -$1,329.17 | |
| | | | Total Mission Devices | | $288.07 | | |
| 2/20/10 | Radioshack | Push button switches | Pneumatics | $6.10 | | -$1,335.27 | |
| 1/2/10 | Ace Hardware | Pneumatic fittings | Pneumatics | $13.62 | | -$1,348.89 | |
| 1/15/10 | OSH | Pneumatic tubing, fittings | Pneumatics | $41.36 | | -$1,390.25 | |
| 4/6/10 | Ace Hardware | Linear Bearing Mount hardware | Pneumatics | $15.19 | | -$1,405.44 | |
| 1/27/10 | Grainger | Pneumatic cylinder | Pneumatics | $35.86 | | -$1,441.30 | |
| 1/16/2010 | Home Depot | Pnuematics Supplies, Claw component | Pneumatics | $67.36 | | -$1,508.66 | |
| 3/5/10 | Applied Industrial | Pneumatic cylinder spare, fittings | Pneumatics | $48.21 | | -$1,556.87 | |
| 1/8/10 | Sizto Tech Corp, Palo Alto | Pneumatic valves and actuators | Pneumatics | $89.31 | | -$1,646.18 | |
| 1/10/2010 | Simon Cassar | Pneumatic Tubing/Fittings | Pneumatics | $0.00 | | -$1,646.18 | Donation |
| | | | Total Pneumatics | | $317.01 | | |
| 1/14/2010 | R/C Dude Hobbies | Propellers | Propulsion | $15.90 | | -$1,662.08 | |
| 12/10/09 | Dan Atwell | Bilge pump motors (4) | Propulsion | $40.00 | | -$1,702.08 | |
| 12/10/09 | West Marine | Bilge pump motors (8) | Propulsion | $0.00 | | -$1,702.08 | Utilized from last years ROV |
| | | | Total Propulsion | | $55.90 | | |
| 1/16/2010 | Home Depot | Tape, Epoxy, PVC Supplies, Tailpiece | Structure | $28.75 | | -$1,730.83 | |
| 3/7/10 | Ace Hardware | Cable ties, Paint | Structure | $21.51 | | -$1,752.34 | |
| 3/23/10 | Ewing Irrigation | 3" PVC Drain line and end caps | Structure | $19.02 | | -$1,771.36 | |
| 3/5/10 | Home Depot | Soldering iron, solder, Aluminum | Structure | $102.05 | | -$1,873.41 | |
| | | | Total Structure | | $171.33 | | |
| 4/23/2010 | Beverly's/Palace Arts | Supplies for Display Board | Display Board | $164.34 | | -$2,037.75 | |
| | | | Total Display Board | | $164.34 | | |
| **Total Expenses** | | | | | | **-$2,037.75** | |

Income

| Date | | Description | | Amount | | Balance | Notes |
|---|---|---|---|---|---|---|---|
| 3/26/2010 | | Fundraiser - School Club Carnival | | $130.00 | | -$1,907.75 | |
| 5/3/2010 | | AHS - Booster Club Matching Commitment | | $500.00 | | -$1,407.75 | |
| 4/10/2010 | | Fundraiser - MPC Pool Practice | | $130.00 | | -$1,277.75 | |
| 4/24/2010 | | Fundraiser - MPC Competition Day | | $275.00 | | -$1,002.75 | |
| 4/30/2010 | | Fundraiser - School Club Carnival | | $323.00 | | -$679.75 | |
| 5/15/2010 | | AHS - Boosters Club Grant | | $1,000.00 | | $320.25 | Above break even cost! |
| **Total Income** | | | | | | **$2,358.00** | |
| | | | | | | | |
| **Net ROV Income/Expenses** | | | | | | **$320.25** | |

# Electrical Schematic



# Design Rationale

**Structure**: Why Aluminum?

One of the major differences in this year's ROV is the frame. In years past, we, and most other teams have used wet PVC frames. However, this year we went with a frame made purely out of riveted aluminum angle, ¾ inches in size. The whole ROV ended up looking much cleaner and aesthetically pleasing, but choosing aluminum over PVC frame was also done for practical reasons. Aluminum angle has numerous advantages over PVC: it is lighter, cheaper, stronger, and easier to work with which allowed us to customize many aspects of our ROV.


The Basic Aluminum Frame

Inch for inch, aluminum angle is actually lighter than a PVC pipe of comparable size. In addition, aluminum angle has no internal volume, so while a wet PVC frame gains significant mass from filling up with water, aluminum angle has no such weight gain when underwater.

Aluminum is also cheaper than PVC. While the angle itself is more expensive than the pipe, the aluminum requires no special fittings to be attached together; cheap rivets do the job. PVC, in contrast, needs expensive fittings to be assembled, often running a dollar or more apiece. When all the costs are added up, an aluminum frame is significantly cheaper than one made of PVC.

PVC has a tendency to flex, or even crack under a heavy load: aluminum does not have this disadvantage, especially when used in a well thought out design. Riveted aluminum joints are much stronger than PVC joints, flex less, and can be more precisely built.

Finally, aluminum angle is easier to form and work into custom angles and shapes. Once bent, aluminum holds its shape, and it can be attached to other pieces all along its length. As a result, a frame built out aluminum is more precisely built, with specific angles and shapes, than a PVC frame could ever be.

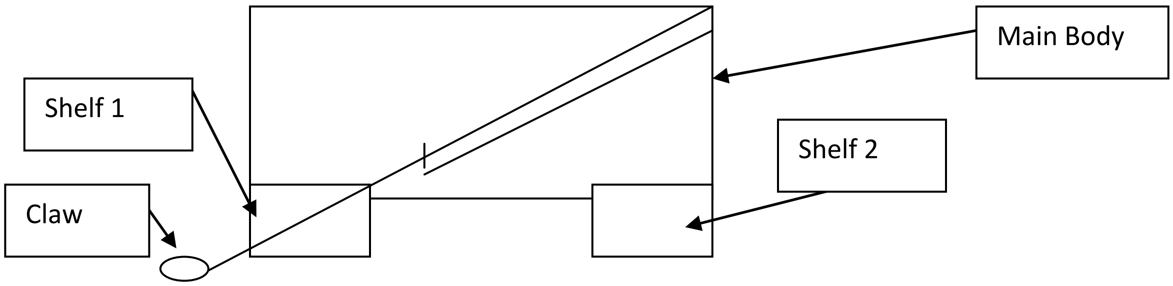
**Structure:** Our focus on weight reduction!

Our weight reduction programs included:

- Making the frame out of aluminum instead of PVC piping, because with PVC piping you have to carry around all the extra weight of the water that fills in the pipe.
- Cutting lightening holes in the aluminum to make the frame lighter and more aerodynamic
- Replacing many heavy, steel parts with alternatives made of light aluminum metal.
- Rebuilding our motor shrouds out of lighter, thinner metal to cut down on weight.
- Using a light, flexible Festo pneumatic tubing.

**Structure**: Why the Shape?

Our frame is generally a rectangular shape. This is because our eight propulsion motors are arranged in the same shape, and we needed a frame to support and hold the motors in their correct positions, as well as enclose all of the ROV's components.




*Line diagram of the ROV structure*

The main body of the ROV has been made so that all of the motors can be properly spaced out, and to allow room for all of the mission specific devices. The largest component of the ROV is the pneumatic claw extension cylinder, which spans the majority of the main body length. The main body is long and tall enough to enclose the cylinder in its entirety, and hold it at the correct angle for proper claw operation. The first shelf serves as the collection basket for the claw. It is lined with netting, and is positioned directly below the claw when it is in the contracted position, so it can drop and store objects in the first shelf. The second shelf also serves an important purpose: it is the area where the pneumatic solenoids are mounted. The solenoids are extremely important, forming the heart of the pneumatic systems. They need to be well protected, and mounted in a stable position. This second shelf fulfills these requirements, keeping the solenoids safe.

In addition to serving their own individual purposes, both shelves work together to serve a few additional purposes: the shelves balance each other out, stabilizing the entire ROV, and they also elevate the main body above the ground when the ROV is sitting underwater. This second aspect is particularly important for the operation of one of the ROV's core devices. The underwater agar coring and sucking device, or "UACSD," is used in the fourth task to cut and lift a sample of the agar to the surface. In order to function correctly the device, which is mounted on the bottom of the ROV, must be able to contact the bottom of the pool with a large enough area cleared around it so that no part of the frame bumps into any potential hazards around the agar. This explains the size of the concavity between the shelves on the bottom of the ROV. In short the shelves act as mounting and storage points for important components, and act as "feet" so the UACSD may function properly.

**Electrical**

Our final electrical system was designed to eliminate our past failures and attempt to make our new system as fail proof and easy to use as possible. Our box includes a 25 amp fuse that is very easy to replace. We included our own fuse so that we did not have to rely on MATEs

Connor Wiring the Electrical System

fuse. We installed an on/off switch so that we are able to control whether our ROV get power separate from just connecting the terminals. After the on/off switch the power is split to into three separate directions: power to the relay boards, power to the lights and lasers, and electricity to our power indicator light. To help us differentiate whether our battery connection has faulty power and our fuse is blown, or if our actual power cables are having problems we built in an LED light that will light up if there is power running past the point of the fuse and on/off switch. The power also goes into a secondary box that has switches that can independently turn on the lights and lasers. The power to the lights and lasers are dropped to 6 volts and 3 volts respectively by two separate voltage regulator chips. The last connection, and probably the most important to our mission success, goes into the relay boards which distribute power to the motors. Also incorporated in our box is a series of easy release power terminals. This allows us to easily disconnect our relay boards and connect our toggle switch board instead if we experience problems at a moment's notice. This is a failsafe for our software, since we have not thoroughly tested it for bugs and it may break. All of this is laid out in a spacious box that is easy to get into to eliminate a packed box that is hard to find out where a broken connection may be. Our electrical is also as simple as possible, unlike last years, so that we may work on it easier.

**<u>Mission Specific Devices</u>**

- **Temperature Sensor**

To complete the hydrothermal vent task, we needed to construct a temperature sensor. We had many ideas to accomplish this task, from using a kitchen thermometer to waterproofing an electrical thermometer. However, these ideas, when tested, took a long time to stabilize at the correct temperature. We eventually found a solution that worked: a thermistor waterproofed inside of a hollow BIC pen. A thermistor senses temperature changes through changes in resistance. As temperature goes up resistance goes down. It may sound crude, but we have found it to be extremely effective, giving a resistance output instantaneously. All we have to do is check the resistance against a graph we made that shows the relation between resistance and temperature. We made this graph by testing water temperature with a kitchen thermometer, and then plotting that temperature (converted to Celsius) against the resistance given in the same water. Please see our calibration curve in the Appendix. This setup allows us to complete the temperature vs. depth chart swiftly and accurately.

- **Hydrophone**

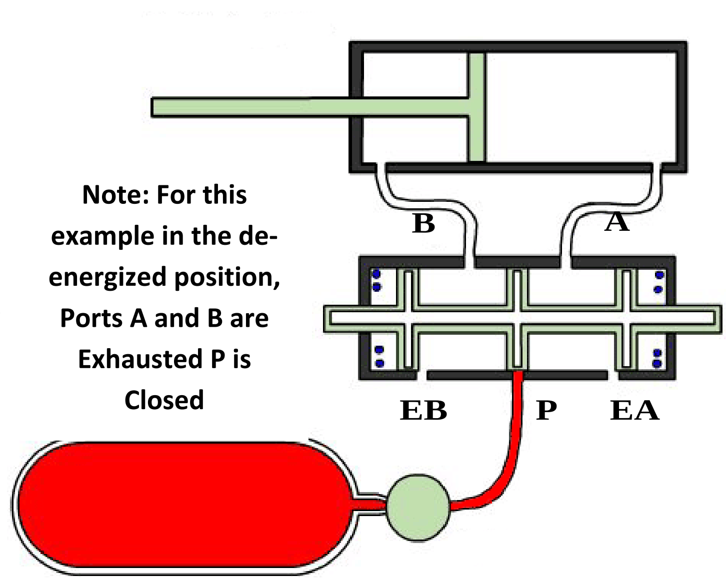
The reason our team decided to put a hydrophone on our underwater robot was because we need to be able to hear "the rumbling of a volcano" underwater, and the only way to hear under the water is with a hydrophone. We needed to find a way to make a cost efficient hydrophone, so we searched the internet. We found directions on how to make a hydrophone that also gave us the part numbers for Radio Shack. We built a hydrophone following these directions, however we were unable to hear with it under water at all, and it seemed the microphone had been over heated. So, we remade the hydrophone without soldering and only used micro wire connectors. This did not work either, and we later found out that we were using the wrong kind of jack (mono); what we needed was an audio jack. We discovered another problem; the hydrophone was not loud enough, so we soldered together an amplifier circuit kit that we found at the local electronics store. This allowed us to hear in the water, but we could only hear the motors. In the end, we found that using a balloon to encase the microphones worked much better than the film case and mineral oil we used in the first model for waterproofing.

- **Underwater Agar Coring Sucking Device (UACSD)**

Deceptively simple, the task of retrieving a sample of agar is perhaps the most difficult task, and the right tool for the job makes all the difference between success and failure. At first, we were stumped about what kind of tool would be able to take an exact amount, hold onto it, and bring it up to the surface. Eventually we decided that a "cookie cutter" type device would be ideal. After much debate and extensive testing, we decided on the UACSD. The device is quite simple: it consists of a just under 5cm diameter plastic tube with a thin hollow plastic tube mounted on the side and a one way valve mounted on top of the larger tube. This device is mounted vertically directly below the main body of the ROV, extending down as a far as the two shelves on the ends of the ROV. In order to take a core sample of the agar, the ROV is maneuvered above the agar, and then the ROV is driven down to plunge the UACSD into the agar. The UACSD cuts a core sample with a volume of approximately 130ml by the time it reaches the bottom of the container. During the "coring", the one-way flapper valve is opening and releasing the water inside the tube displaced by the agar core. Simultaneously, the hollow tube mounted on the side of the corer is allowing water to come in between the outside of the corer and the remaining agar, breaking any seal with the non-cored agar that would have made the corer also retrieve any extra agar other that the core sample. The ROV is then driven upwards, and the agar core sample stays inside the tube because the now closed one-way valve is creating a vacuum, preventing it from coming out. The ROV brings the core sample up and out of the cup, leaving behind the extra agar. The ROV is then driven to the surface with the agar core secure, and once out of the water, the air allows the agar core to slip out of the tube and be measured. The UACSD allows us to quickly and easily retrieve an agar core sample of the correct volume.

## Pneumatics

In last year's ROV competition, we utilized a linear actuator for our claw. However, we used an electrically powered, worm-gear actuator. This actuator ended up being very slow and very weak for our applications. Also, because it was electrically powered, we had to water proof the actuator, which was a giant pain. In light of the troubles we went through last year, this year we have decided to use pneumatic actuators to power our claw and to extend and retract it from the frame. We have two actuators, a 25.4 cm linear actuator and a 2.54 cm linear actuator. They are each connected to a solenoid valve so that we can activate them from our control board. We have a 5/2 valve connected to the small actuator that controls the opening and closing of the claw. It has a single actuating, spring return cylinder with the spring keeping the claw open normally and with the actuation closing the claw when needed. The switch keeps the claw held closed until the air pressure is released.




Pictorial Drawing of a 5/3 Valve and Double Acting Cylinder

The long actuator is used for extending and retracting the entire claw mechanism so that the claw can go out of the confines of the frame to grab or manipulate items and then retract back in to drop items off in a basket. This actuator uses a 5/3, two solenoid actuator and double acting cylinder. Because this valve allows for three positions, we can extend, retract, and hold the actuator in any position in between. This is because pressure is applied to both the extension and retraction ports when neither solenoid is energized. As a result of all of this, we can electronically control pneumatic actuators from the surface that can open, close and extend or retract our claw.

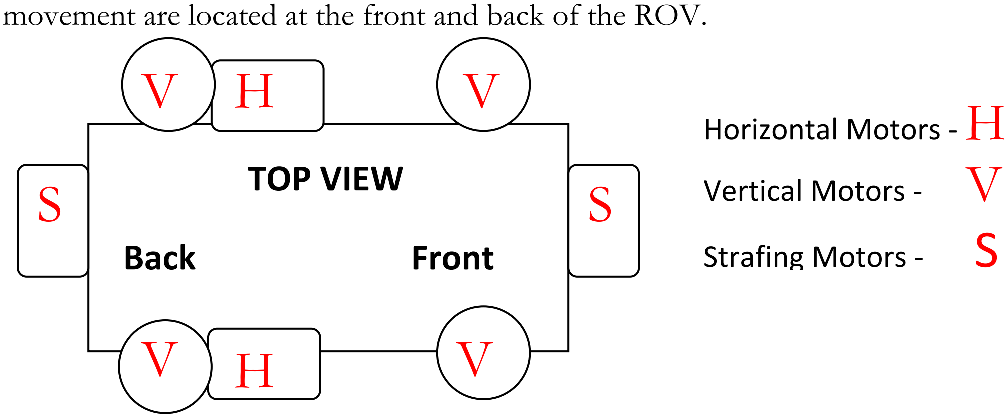
**Claw**

For our ROV we wanted to design a claw that could do as many tasks as possible. To do this, we started off with a simple, two-pronged, horizontal grabber that opens and closes when a rod is pushed and pulled due to a series of gears. The task for us was how to remotely push and pull this rod. To do this, we attached a small, 1.3 cm throw pneumatic actuator with electric regulator valves so that we can operate the pneumatics through our control board. Some of the mission tasks involve picking up items and bringing them to the surface. In order to make the least possible number of trips to the surface, we wanted to be able to grab the items and then drop them in some sort of storage container so that we could make one big trip with all the items in it. To do this, we designed our claw so that it would extend outside of the confines of the ROV, and then retract within it to drop off items in a basket. We did this by mounting the claw on the end of a 25.4 cm pneumatic actuator, which will extend and retract the claw, and is controlled in the same way as the smaller one.

A problem with this design was that the rod the claw was attached to would spin around freely, so the claw was never in the right orientation. To fix this, we added a stabilizing rod that was connected to the claw and the base of the actuator, thus stopping any spin of the claw. We then conducted a Failure Mode Effects Analysis (FEMA), where we concluded that the friction of the stabilizing rod against the aluminum hole it slid through might eventually cause us problems. To resolve this possible issue, we added a low-friction bushing onto the rod so as to prevent any such friction induced problem.

**Propulsion**

Our ROV has a total of eight motors. We utilized nautical bilge pumps because they are waterproof and very effective. To maximize thrust, we extended the propeller shafts to 12 cm. We made custom made aluminum sheaths to connect the propellers to the shafts. We are utilizing eight 3,785 LPH pumps for our horizontal and vertical movements. For safety, we designed and installed wire shrouds around all of the propellers. We used four pumps for vertical movement. They are positioned near the corners of our vehicle so that they can provide equal balance around the center of gravity. Two additional pumps are employed for forward and backward movement and to assist in turning capabilities. They are equidistant from the center of gravity to keep our ROV moving in a straight line. Our last two pumps, which are applied for strafing movement are located at the front and back of the ROV.



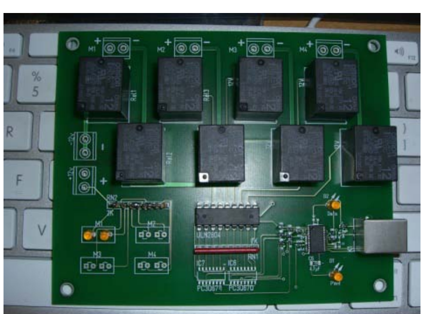
**Cameras**

The *Alien* is equipped with two 12 volt color security cameras and one 7.5 volt black and white security camera. All three cameras have been waterproofed by filling the camera enclosure with an epoxy solution. Our black and white camera is mounted on our pneumatic arm, providing detailed visual for tasks requiring the claw. Being black and white gives this camera high resolution, which allows great visibility with our detailed tasks. One of our color cameras is mounted on top of our ROV and provides a forward looking overview of the task area. We utilize this camera to give us perspective and direction. Our other color camera is positioned down to assist us with collection of the agar solution and also to provide us with sea floor positioning. Each camera has a specific task. By utilizing all three cameras together, we have excellent visibility of our entire work area.

Mounting the Motors and Cameras

**Controller and Software Description**

This year when building our ROV, we set out with a plan in mind to improve our control design from previous years we had competed. The clunky control boxes we were familiar with using were too difficult to control because of the size of the control box itself and the difficulty of flipping and holding the switches. At the beginning of this year, we began to look into the possibility of using a video game controller for our ROV, and initiated a search of the internet. We discovered a program called Microsoft Robotics Studio, and it seemed the perfect fit. However, it soon became apparent that time would be a major issue if we were to go through with this plan. There was no way we would be able to set up a system and implement it before the competition. However, we happened to know an engineer who works on robotics for a living down in Arizona. He helped us design a board for our ROV and assisted us in writing a program to use that board. The board consists of electronic relays, two per motor, and USB to serial chips. The boards are connected to a laptop running the program, and thus we are able to run our entire ROV through an Xbox controller. We created a flowchart showing how the software program works and have included it in the Appendix. Thanks to our engineer mentor, Mr. Chris Harriman, we were able to accomplish our goal of designing a better control system.



**Relay boards**

**Relay boards wired in control box**

**Safety**

While building our ROV, one thing that was constantly implemented into every system was a sense of safety. There are numerous safety features as a result. All of the motors have steel mesh cages, to prevent any loose or wandering fingers from accidentally contacting a spinning propeller. Our ROVS frame was also built with safety in mind: all sharp or potentially dangerous edges have been ground down and smoothed, to prevent any risk of cuts. The electrical systems are perhaps the most safety centered, with the large amount of work that went into them. There are numerous safety features implemented in the electrical systems: there is a fuse first thing from the battery, all of the wiring is clean and neat, no wires or contacts are exposed, and all wiring on the ROV is neatly hidden within the aluminum angle.

# Challenge Faced

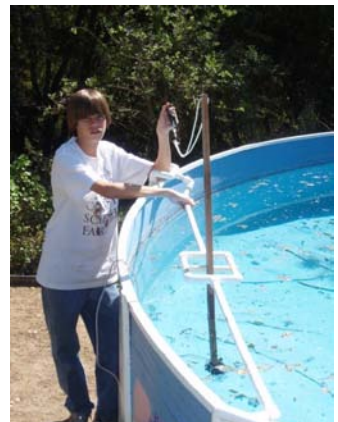
One challenge we faced this year in our ROV project was getting our video to work. We faced numerous problems while working on this challenge, many of which were difficult to overcome. Our initial plan was to reuse cameras from last year, but we soon discovered that only one of the cameras was still working. Last year we were forced to run our cameras off a higher voltage than they were intended for, and as a result most were dead this year. Fortunately, another team from our school left their ROV to us, (all but one member of the team graduated) and as such we were able to use two of their cameras. We were glad to get this problem out of our way, but soon discovered yet another problem. The cameras off of their ROV utilized only about half the length of our tether, which meant that if we were going to use them, we would only have half the tether to work with. This seemed like a major problem to us, but was solved by splicing the cables from broken cameras into the working ones. We figured nothing was wrong with the cables, so why not use them? However, several weeks later we finally put the ROV in the water and two of the cameras stopped working. We were dumbfounded; we thought they would work fine. When we checked them out, we realized that we had not thought of waterproofing the splices. We were only concerned with extending the cable, and waterproofing slipped by us. Not only that, but how were we supposed to pot a cable in epoxy? We came to the conclusion that we should pot them in a BIC pen tube. This seemed to work fine, and in fact did very well for a week or two (new record!). But as we discovered there was yet another problem to deal with. We soon found out the hard way that the cameras from last year's Senior Team were not waterproofed correctly. Instead of filling the inside of the camera with epoxy, they instead sealed any holes that were visible with superglue, hardly a waterproof solution. We realized this when one of the cameras became foggy on the screen and another stopped working. When we went to check the issue we saw there were water droplets on the inside of the cameras' lenses. Ultimately, we were forced to change out these cameras with properly waterproofed ones. All in all, the cameras were one of the biggest challenges we faced this year in our ROV project, and we will take precautions next year to ensure we won't encounter the same problems.

Making Poolside Adjustments

# Troubleshooting Techniques

**Propeller Testing**

In all of the previous years that Aptos High School has participated in the MATE ROV Competition, all teams have used the same propeller: a medium sized plastic boat propeller. However, this year we wanted to see just how effective this type of propeller really was, and if the there was a better option. We bought a small sampling of air propellers to test the difference in thrust (if any) between the different types. We used a thrust measuring rig, with a motor mounted on a wooden beam, dipped into a pool of water. An electronic force meter was attached to the opposite side to measure the resulting thrust. With a standard 12 volt battery, and the standard boat propeller in question, we achieved a respectable 0.75 Kg of thrust. Up next, we tested the air propellers: we had no idea what to expect. The result was quite spectacular, with the propeller VERY visibly bending back a full 90°- and thus providing a virtually immeasurable amount of thrust. We concluded that our team should stick with the boat propellers, and that air propellers have no place underwater, they are much too thin and flexible to provide a useful amount of thrust.



Nathaniel measuring propeller thrust

**Wire Gauge Testing**

All throughout the building process of this years' ROV, there was very little disagreement between our team members about what design was best, or how we should build something. If there was any disagreement, it was simply discussed, and we would come to a design that would satisfy everyone, often within seconds. However, there was one area in which there was a more extreme disagreement: how heavy a gauge of wire should be used in our tether to power our ROV's motors. In previous years, one team used thin Cat 5 wire to power their motors- while the other used significantly thicker 16 gauge wire. However, little to no difference in speed was ever noticed between the two ROV's, probably because the differing variables: weight drag, amount of motors, etc. It was argued that although the 16 gauge wire would have less resistance, the amount of power gained would be negligible, and would not make up for its significantly heavier weight. In order to come to definite conclusion, a test was carried out: a 12 volt battery was connected to motors mounted in a thrust testing stand, using 30 foot lengths of either 16 gauge wire, or Cat 5 wire. The results were quite clear:

| Wire | Cat 5 (24awg) | 16awg |
|---|---|---|
| **Voltage at Battery** | 12.5v | 12.5v |
| **Voltage at Motor** | 5.0v | 11.6v |
| **Thrust** | 0.33Kg | 0.75Kg |

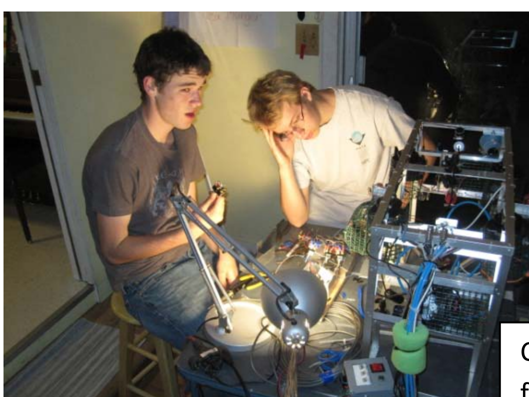
Since DC motor power ideally scales directly in relation to input voltage, less voltage should mean less power. This idea is obviously shown in our test results, so we know that they are accurate. The difference is quite extreme: in a 30 foot length, 16 gauge wire provides about 172% more voltage and power to a motor at 12 volts, versus Cat 5 wire. Due to this extreme difference, we decided to go with thicker gauge wire, even at the cost of more weight. The power gain was significant enough to make this sacrifice.

# Future Improvements

We have had a lot of fun and have experienced much success building this year's ROV, but we still wish we had more time to change a few things. Firstly, we would have liked to make a longer tether, this would allow more flexibility, and the ability to explore further and deeper. Our current tether is ample for the current mission tasks, but it would have been nicer to have a longer one. A digital electronic speed control is another improvement we would have liked to have implemented, but could not in the interest of time. This would have increased our maneuverability and preciseness of control significantly, especially with our digital Xbox controller. The UACSD agar corer would also have benefitted from a better valve, so if we had the time we would have removed the home made flapper valve and replaced it with a better sealing manufactured check valve.

# Lesson Learned

A major lesson we learned this year was that it is vital to test components of our ROV as we build them, even before the entire ROV is put together. This way, we know beforehand that each piece of the ROV works individually, and all that we have to do is put them all together. This became apparent to us as we first began pool testing, and found ourselves spending more time fixing components that we assumed would work than actually getting pool practice time. At first, it appeared as though the lesson learned was "when building something, assume it will break," but we realized that everything that was working were parts that we had tested while building them, and as such we had already worked out any bugs with the system. For instance, we spent a long time working on our pneumatic claw, and every time we thought we were done, we would test the claw and ultimately add something new that would make our claw work even better. Once we completed and tested the final claw, we mounted it on our ROV and haven't had to fix or repair it ever since. However, other parts of the ROV (such as our hydrophone) were found to not be working at almost every pool practice. After having so many problems with our ROV, we have learned that checking individual pieces of our ROV before putting them together is an extremely important part of preparing for the competition.



Connor and Isaac experience the frustration of late night repairs!

# The Loihi Seamount

Three thousand meters (9583 feet) above the floor of the Pacific Ocean rests the Loihi seamount, the most recently active volcano in the Hawaiian-Emperor seamount chain. Earthquake swarms in 1952, and later in 1996, first brought significant attention to this region.

**<u>Formation of a Seamount</u>**

Loihi is a seamount, or an underwater mountain that doesn't reach the ocean surface. A typical seamount can range anywhere from 1000-4000 meters above the sea floor, and are a result of thousands, if not hundreds of thousands, of years of volcanic activity.

Convergent or divergent movements form the most basic volcanoes and seamounts. In a convergent movement, the lithospheres of tectonics plates collide against each other, which can result in mountains or volcanoes. Conversely, a divergent movement causes continental tectonics to move away from each other, leaving gaps in between that leak magma. The Hawaiian-Emperor seamount chain—including Loihi - formed from yet another process.

It is speculated that the entire Hawaiian archipelago was created by a "hot spot". For this reason, they are aptly named "hot spot volcanoes." A hot spot is a thin stream of magma that spurts to the ocean surface, directly convected through a molten mantle. Though the hotspot remains at a fixed point deeper in Earth, the movement of the higher plate tectonics allow creation of complex systems of magma. Over the course of the year, the spot moves a puny 10.2 cm. However, over thousands of years it is significant enough to form structures that are considerably distant from each other. In this sense, all the islands and formations in the Hawaii radius—big and small—are trails of the moving hotspot.

Over 400,000 years old, Loihi was one of the resultant formations due to the hot spot. It rests on the sloped hill of Mauna Loa (a "shield volcano" or a volcano with steep sides) at about a 5 degree angle. Before the 1996 earthquake swarm, Loihi had two vent systems: Pele's Vents and Kapo's Vents. After the earthquake, Pele's Vents collapsed and evolved into a new vent system called Pele's Pit. As of now, it has three subsidence craters in which hydrothermal and biological activities have boomed, two of them being Kapo's Vent and Pele's Pit. At its current rate of growth and its placement in the ocean, geologists believe that Loihi could become the next Hawaiian island.

**The Hawaii Undersea Geo-Observatory (HUGO)**

After the 1996 earthquake swarm—which holds the highest record in terms of magnitude and occurrence—there was a surge of interest towards the area. In this time, there was a spike of information about the seamount. Due to the seamount's inhospitable environment, it was impossible for divers to discover much about the region; the temperature can fluctuate from a mere 30 degrees Celsius (86 Fahrenheit) to over 400 Celsius (750+ Fahrenheit), and "Black Smokers" found in the same area are known to thrust sulfate and sulfide rich smoke into the ocean that not only murk up the water, but also creates compounds that are toxic to most organisms. Among the first technologies used to explore and gain knowledge from the region was the OBO (Ocean Based Observatory). HUGO (Hawaii Undersea Geo-Observatory) was one of the most prominent OBO that was planted in the Hawaiian-Explorer seamount chain. It was first deployed in 1997, almost immediately after the earthquake swarms of 1996. Until the end of its operational years, HUGO collected data from both its own instruments and from experiments conducted by private researchers. In addition to its scientific value, HUGO was a great fiscal feat; the fiber optic cable alone is valued at about $600,000 dollars! Thankfully, AT&T donated cable for the betterment of science. At its peak, HUGO had many onboard tools such as hydrophones, seismographs, cameras and pressure sensors. Some considered it the single most useful source of information about underwater volcanoes.

Activity and ecology of hydrothermal vents were especially insightful. The Loihi seamount is home to many diverse types of organisms, ranging from bacteria that spread along its surface, to fishes and other marine animals. It is really a mysterious sanctuary, with new species and subspecies continually being discovered. Much has been learned about how life develops, in addition to seamount geological development. Findings include hydrothermal vents, microorganisms in vast numbers, and exotic species of underwater creatures. Because of the extreme growing conditions, the organisms living there are providing a wealth of information to scientists. Microorganisms in particular have gained quite a reputation. Since microorganisms can survive on almost anything, and since they play a pivotal role in the status of our atmosphere, they have been looked as a way to clean pollution. The Loihi seamount was especially rich with these organisms, its walls are layered with "microbial mats." When Pisces V dove to the site to get samples, it found both a clear jelly-like organism--which we simulate through agar--as well as other more colorful organisms. It is an important task for us to find out more about these organisms; they supply us with insight on the basic processes of life, while handing us the natural recipes to reduce our current problems, such as pollution.

In 1998, a leak in the extensive 30 mile fiber optics rendered HUGO useless, turning heads towards the robotics field for help. An answer was found in the underwater submersible, Pisces V. Our Remotely Operated Vehicle (R.O.V) plays the role of Pisces in many ways. The only major difference is that we are using an R.O.V., instead of a manned submersible. Before the Pisces V was deployed to rescue HUGO, it too collected data from Loihi, including taking samples from the bacterial mats and monitoring the activities at the seamount, similar to the purpose of our ROV. However, Pisces V uses hydraulics to manipulate its arm, while ours uses pneumatics. Our method to sample the bacteria is also similar, but we have our bacterial mat collector mounted on the bottom or our ROV, and we use pneumatic suction to get an airtight sample. Pisces V has two mechanisms to collect samples. One is to simply scrape samples into a cylindrical container, and the other is a vacuum suction that absorbs the bacteria through a narrow hose.

Through a series of events, HUGO was ultimately carried back to the surface, however the cost to fix HUGO was too great, and the project was abandoned. Fortunately, with the use of ROV's research on the Loihi seamount continues.

# Personal Reflections

**Isaac Cassar**

My name is Isaac Cassar, and I am a pretty strong member in our ROV team. The biggest things that I think I have learned this year have been about pneumatics and metal working. On our previous ROVs we built the frame out of PVC, which was very simple to cut and attach together. However, we later realized that with PVC water fills the pipes, and you then have to carry all that water around with you so the ROV is substantially heavier. In light of this, this year we built our ROV out of right angle aluminum bars, which lighten up the ROV a lot. However, in doing this we all had to learn how to cut metal properly, and then learn how to rivet it all together. Also, as the claw was one of my tasks, I had to learn how to cut all the metal and machine together a functional claw. Also, we had to use pneumatic actuators to power the claw, so I had to learn all about how pneumatic actuators and solenoid valves work. I feel that I have really learned a lot in these fields of metal works and pneumatics.

**Adam Simko**

The 2010 MATE ROV Competition marks the third year I have participated in this contest, and I expect to participate again the next year. This is because of how much fun I have had building, designing, testing, and eventually competing with an ROV that has been created with a great team. I have always enjoyed all things mechanical and technical, and this competition is the perfect outlet for my itch to create. Even though we have not yet gone on to the international competition (perhaps this year!) I find the experience incredibly fun for these reasons, as well as quite rewarding. At times, words cannot describe the sense of accomplishment and success I feel when seeing an ROV that we as a team have built, finally come together. In addition, the past years have been extremely educational. I have learned just what it takes to design and build an ROV, how they can be used, how to work with certain electronics, and how to solder effectively, among many other things. Even though things never go quite as planned, and problems inevitably crop up with days (even minutes) to the competition, I never fail to have fun, learn new things, and most importantly, feel a sense of accomplishment.

Practice. Practice. Practice!

**Connor Munger**

My name is Connor Munger and I am the captain of the robotics team. It meant a lot for me to be elected to this post and I feel that it carries a lot of authority and responsibility that needs to be used towards the right causes. I feel that being the captain of the team has helped my leadership skills much more than anything else. It has been a rewarding experience to watch over the members of my team and make sure they all work in harmony. It has helped my letter writing and emailing skills because I need to be constantly communicating with the team, our mentors, and our supporters. On top of this I have learned much more about electrical systems and metal working. I built the control box and helped build the frame along with the claw. It always feels great to be able to accomplish something, and that is exactly how I feel this year.

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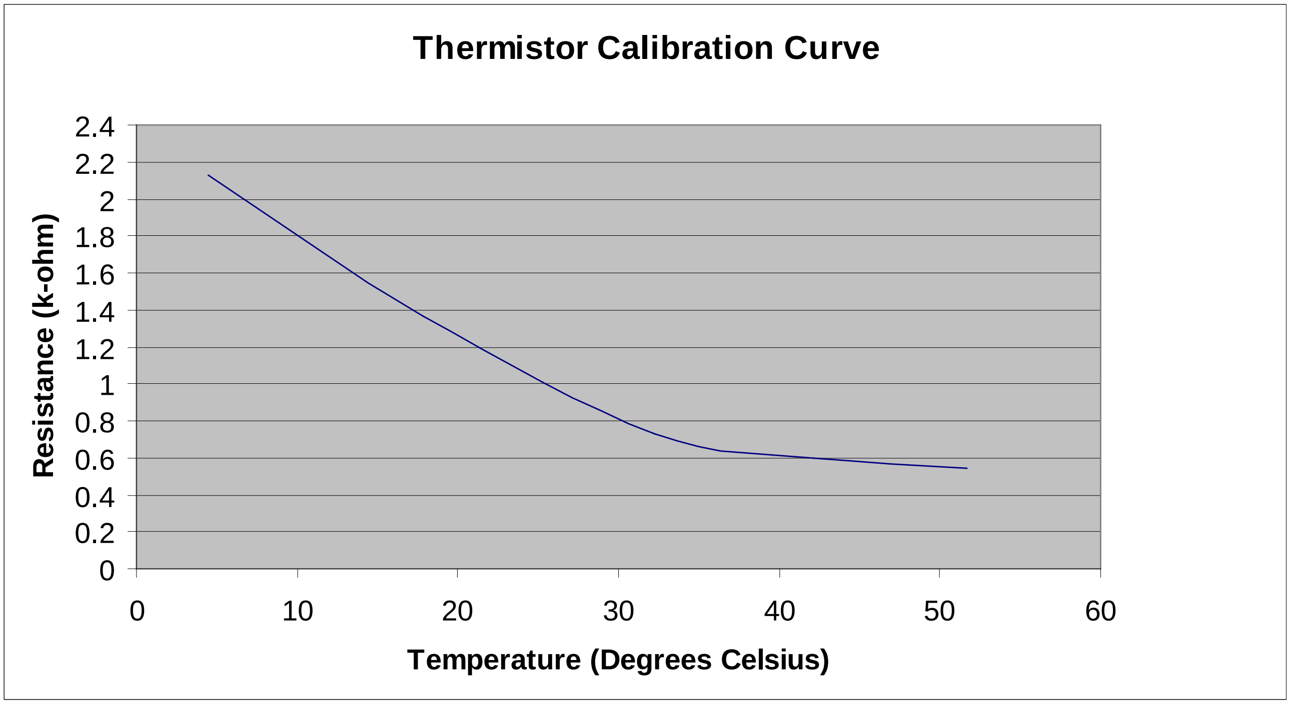
# Acknowledgements


**We would like thank:**

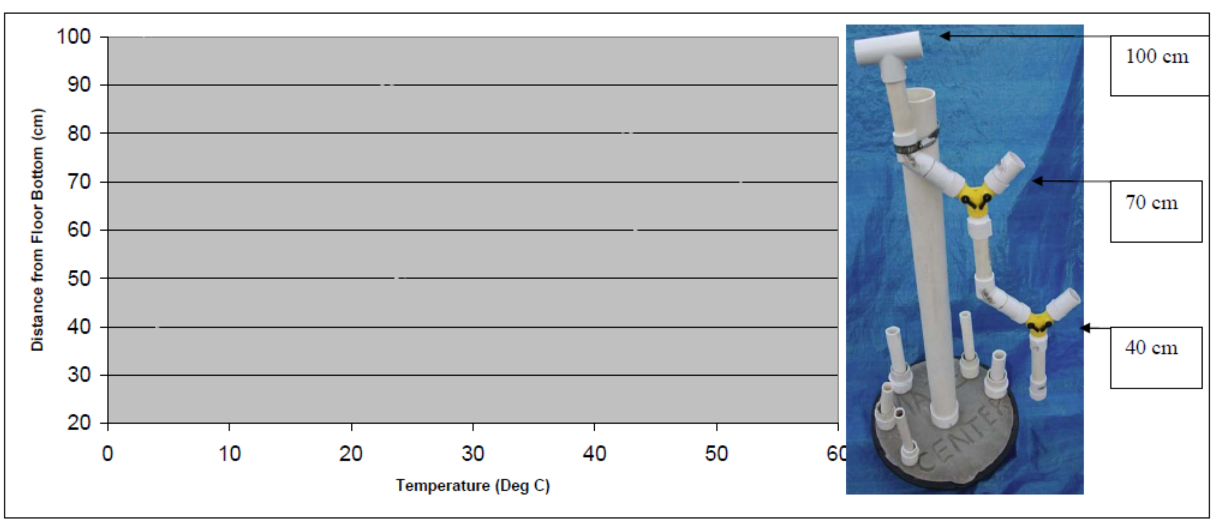
- Marine Advanced Technology Education (MATE)
- Mr. Casey O'Brien, our Principal and Aptos High School for the use of the school pool and facilities
- Mr. Joe Manildi, our staff advisor and the entire Aptos High Robotics Club
- Mr. Dan Atwell, retired engineer, for his feedback, donations, input and interest in our ROV!
- Mr. Chris Harriman, engineer, for his help with our USB relay board and software programs and for his late nights helping us out!
- The Aptos Booster Club, for their financial support of our ROV
- Mr. Willy, Mr. Munger, and Mr. Cassar for their guidance and support throughout this project
- Mr. Jim Triplett, the Aptos High School Swim Team Coach, for sharing the pool with our ROV
- All of our parents and families for their patience, encouragement and support for our Team and our ROV project. Thank you especially for feeding us during our long work sessions!!!


Seeking advice from Dan Atwell, one of our Mentors!

# Appendix




## Depth vs. Temperature Chart



## ROV USB Software Control Flow