Highlands Intermediate School

Pearl City, HI

Team Members/Grade Level:

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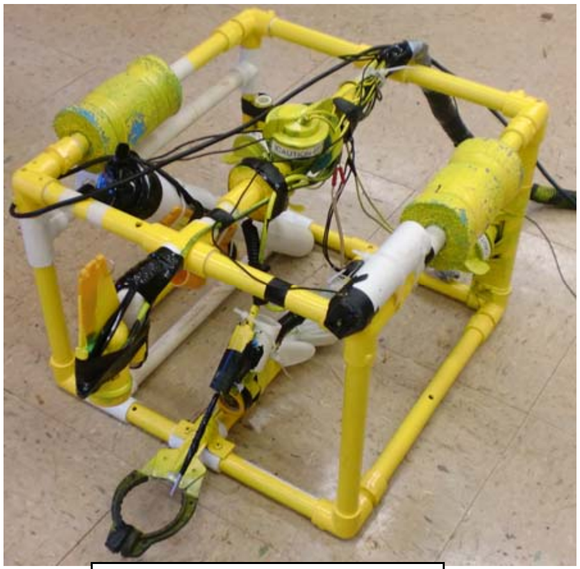
Middle row/grade: Naomi Tse(8), Devin Ajimine(7/building captain), Kasey Sugano(7), Brandon Lin(7), Brooke Ideue(7/Research captain), Shea Takazono(7)

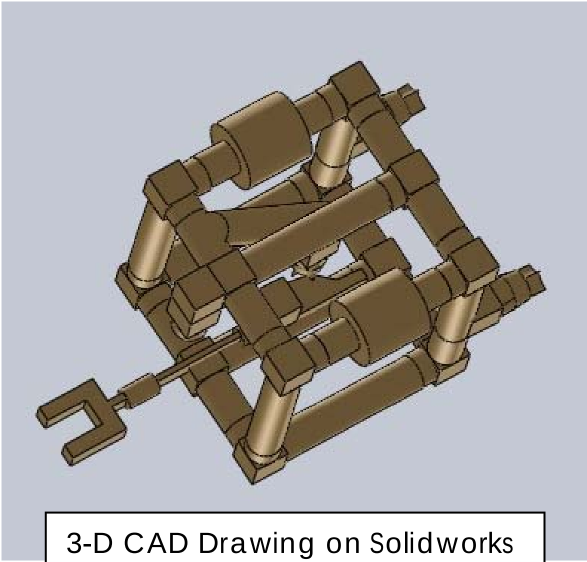
Bottom row/grade: Erika Lin(7), Kylie Swider(7), Carter Casuga(8), Nicholas Takehara(7), Austin Morishita(8), Keli Tokunaga(7/Documentation captain)



Picture of final ROV

Kui Lima
(Arm in Arm)

Instructor: Kathy Lin
Mentor: William Swider



3-D CAD Drawing on Solidworks

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ABSTRACT

For this year's 2010 Marine Advanced Technology Education (MATE) International ROV Competition, the tasks were all based on Loihi, an active undersea volcano in Hawaii. Our ROV was constructed to accomplish all the tasks: resurrecting HUGO, collecting crustacean samples, measuring temperatures, and gathering samples of the sea floor. The base of our ROV is built with PVC pipes. The ROV is powered by four bilge pumps and guided by three cameras. An arm is attached to the middle of the ROV with a mechanical claw controlled by a car door actuator. Our final product is a ROV, which has the ability to move with ease, consistency, and accuracy.

This technical report illustrates the electrical and structural design of our ROV, the challenges that we faced (troubleshooting techniques), the many lessons we learned (future improvements), and our acknowledgments. We also included background information on Loihi (our references), individual reflections, and photographs of our steps to success.

Team Organization

We had two months to design, build, test, and write the technical report for this competition. Team and time management was extremely important in completing this project to meet the required deadlines. Although we started late, we realized that we must follow the suggested timeline as posted on the2010 Mate Big Island Regional ROV Competition. We divided the responsibilities among team members based on individual strengths and weaknesses as well as preference. We started out as two teams and merged into one team after winning the regional competition.

Figure 1: Building Responsibilities

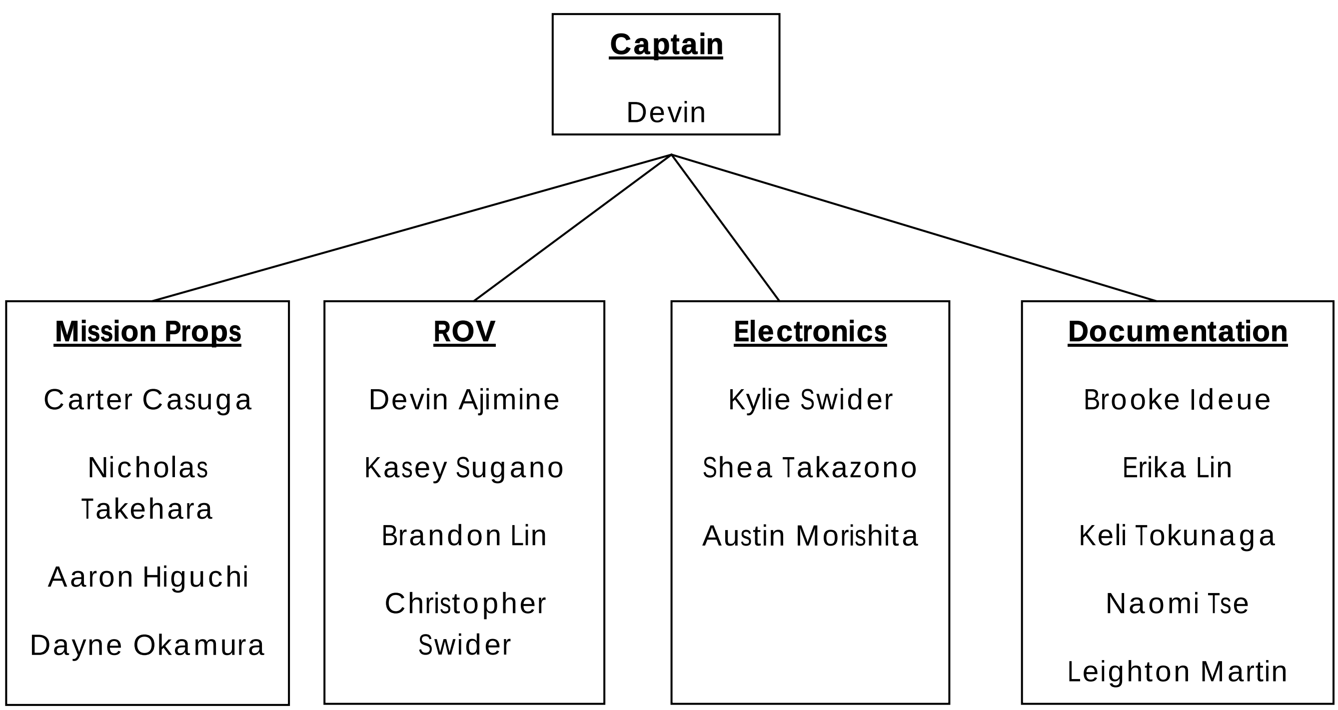


Figure 2: Technical Report Responsibilities

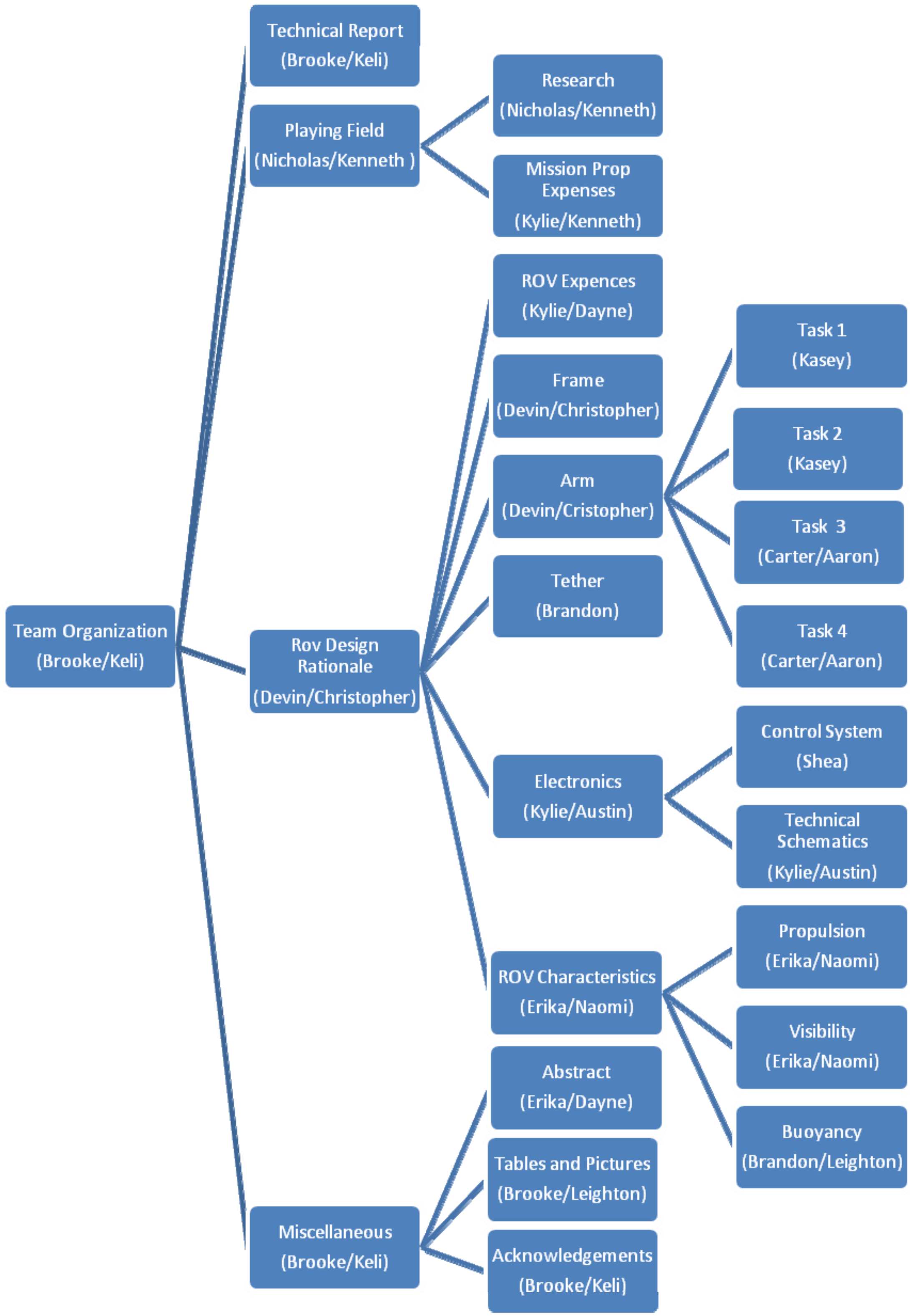


Table 1: Timeline (Schedule)

April 1, Thursday: Learned about the Competition	April 2, Friday: Looked at past reports	April 5, Monday: Preliminary Design	April 6, Tuesday: Decided on final design	April 7, Wednesday: Watched a video on soldering	April 8, Thursday: Recorded all supplies	April 9, Friday: Purchased supplies
April 12, Monday: Started to cut PVC piping	April 13, Tuesday: Finished cutting all PVC	April 14, Wednesday: Started to build mission props	April 15, Thursday: Started building ROV	April 16, Friday: Started Technical Report	April 19, Monday: Attached cameras and motors	April 20, Tuesday: Built arm and control box
April 21, Wednesday: Added foam noodles and delegated report parts	April 22, Thursday: Finished ROV	April 23, Friday: Started testing and Trouble shooting	April 26, Monday: Documented all Problems and made attachments	April 27, Tuesday: Report parts due, pieced together the report	April 28, Wednesday: Fixed arm, fixed content on report	April 29, Thursday: Recorded changes to the ROV
April 30, Friday: Finished Technical Report	May 1 & 2: Revised and proof read Report	May 3, Monday: Technical Report Due	May 4, Tuesday: Problem solved on claw controller (car door actuator)	May 5, Wednesday: Started display board, tested all task attachments	May 6, Thursday: Documented and fixed attachments.	May 7, Friday: Made ROV final adjustments
May 8, Saturday: On Deck Crew Water Practice	May 9, Sunday: Assigned parts for Presentation	May 10, Monday: Shared information on assigned topic with team	May 11, Tuesday: Last Mission Practices Prior to Regional	May 12, Wednesday: Finished Board , Packed ROV	May 13, Thursday: Practiced Presentation	May 14, Friday: Flew to Hilo for Regional, Final Presentation and Mission Practice
May 15, Saturday: Day of Regional Competition	May 16, Sunday: Flew back to Oahu	May 17, Monday: Fixed Arm and Claw	May 18, Tuesday: Look at judges scores and weak points	May 19, Wednesday: Cleaned working area	May 20, Thursday: Worked on technical report	May 21, Friday: Remade agar attachment
May 24, Monday: Work on Revised Report	May 25, Tuesday ROV Adjustments	May 26, Wednesday Final ROV Adjustments, Revised Report	May, 27 Thursday Technical Report Due for International	May 28 to June 6 Work on Display and Presentation	June 7 to June 22 Finalize ROV and Display Board	June 23 to June 26 International Competition

Information on Loihi Seamount

Loihi Formation

All the islands in the Hawaiian chain were formed by a stationary hot spot located under the Big Island of Hawaii. Unlike other volcanic islands, which are formed by the subduction of tectonic plates, the Hawaiian Islands were formed by a stationary hot spot. These types of hot spots are formed when a certain area between the mantle and core are unusually hot and causes the lithosphere to melt. Therefore, as the Pacific Plate moves in a northwest direction on top of the asthenosphere, the stationary hot spot spews magma out of the crust forming the Hawaiian Island chain.

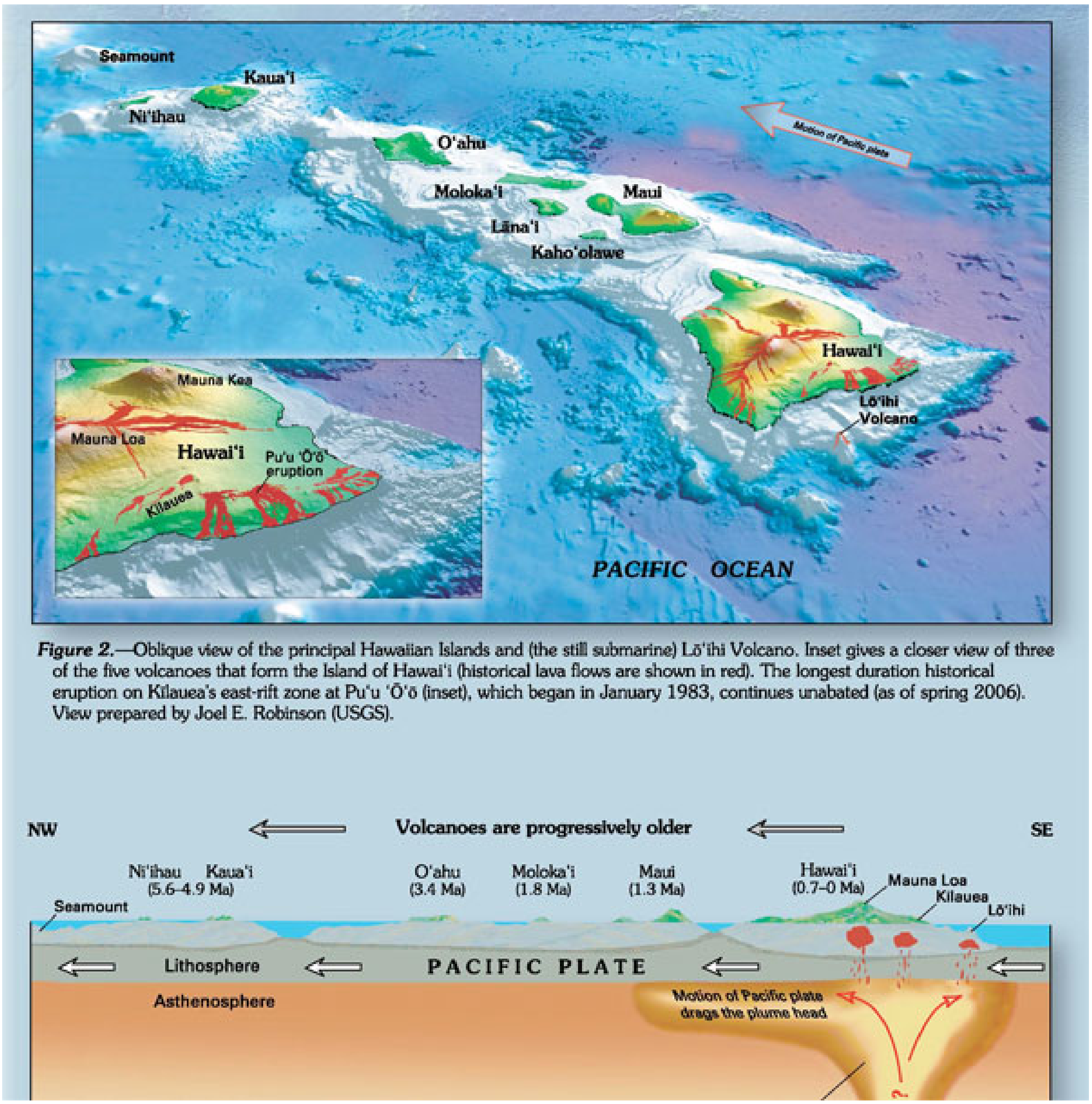


Figure 3: The movement of the pacific plate over the stationary hot spot. Diagram taken from http://theresilientearth.com/?q=content/going-deep.

Loihi Location

Loihi is an active underwater volcano about 1,000 meters below sea level. It is located approximately 35 km off the southeast coat of the Big Island of Hawaii. Loihi began forming around 400,000 years ago and, at its current rate, is expected to begin emerging above sea level about 10,000-100,000 years from now.

Loihi Recent Activity

Scientists had thought Loihi was just a dead seamount until 1970, when there was a series of seismic activity or "earthquake swarm". In August of 1996, Loihi again rumbled to life. Loihi ended up being a young, active volcano covered with lava flows and actively venting hydrothermal fluids. Between July 16 and August 9, more than 4,000 earthquakes were recorded. Most of the earthquakes had magnitudes of less than 3.0 on the Richter scale. Several hundred had magnitudes greater than 3.0, including more than 40 with magnitudes of over 4.0.

HUGO's Purpose

Scientists developed the Hawaii Undersea Geological Observatory (HUGO) as a way to study and obtain information on Loihi. HUGO was built as a more efficient way to monitor Loihi's progress. HUGO was put on Loihi's summit until it was malfunctioned by the flooding of salt water. After five years on the summit of Loihi, the cable that gave HUGO power and connection broke in 1998. The cable that powered HUGO was 47 km long, leaving about 100m of cable at shore.

UH Professor, Fred Duennbier, the developer of HUGO, wants to put HUGO back after he puts steel protection on the cables to prevent salt water problems. He also wants to improve the technology to prevent future failures.

Our work is similar to scientists' work because we both had to make a ROV that could work underwater, take pictures, record data from temperature probes, and accomplish various missions. These tasks include collecting samples of bacteria mats, study samples of a new crustacean in a place that had not been examined in a while, and take temperature readings. Our work is also similar because we do the same research, we both use similar tools, and we both make new discoveries while doing these different missions. The difference is our ROV is a lot smaller and less complex than the ones in the field.

Relationship between Mission Task and Loihi Seamount

The playing field (mission props) is key to testing the success of our ROV. In the competition, four tasks are required to accomplish the missions. Task #1 is based on the scientists' mission to "Resurrect HUGO" after HUGO's cable was flooded with salt water. The crew of Pisces V was surveying the area around Loihi and discovered little white creatures. Task #2 is to collect samples of these creatures. Task #3 is an investigation to record data about the new chimneys and vent spires which are important to Loihi . Task #4 is to collect a sample of the bacteria mat which represents the work of microbiologists on the Pisces V studying the oxidizing bacteria. The playing field was built according to the mission prop specifications as indicated in the competition rules. Accuracy of the mission props was critical to the accuracy of our ROV mission accomplishments.

ROV DESIGN RATIONALE

Frame

Figure 4: Frame of our ROV

The frame (Figure 1) of the robot was designed to be a rectangular prism with inner supports to stabilize the ROV. With a stable frame the robot will be able to withstand water resistance as well as maneuver accurately. All our team members contributed to the final design of our frame of the robot, as everyone had different ideas and building experiences. PVC, polyvinyl chloride, was our choice of material because it is light weight, durable, and previous teams in the competition used PVC piping. The size of our frame, without the arm is 25.40 cm tall, 30.48 cm wide, and 33.02cm long. The small size allows for easy maneuverability and easy access into small areas like the cave. The weight of our ROV is 3.6 kg.

A symmetrical shape will be more easily controlled since the maneuvering of a regular shape is more efficient in terms of energy usage. We strategically placed our motors (bilge pumps)so that elevating, turning, and descending will be accurate as well as efficient. By using a box shape, it was also easier to place our wires, motors, and camera. We used PVC for our ROV's frame because it could be easily flooded with water and descend faster when holes are drilled in the PVC. We wanted a very small ROV since the smaller the robot, the less energy usage for both vertical and horizontal movement.

Control System

Figure 5: Our basic control box

We first had to decide on the type of control system at the beginning of this project. Our entire team is very familiar with autonomous robots based on the NXT Mindstorms from our previous robotics experiences. After much deliberation, it was unanimously decided that NXT Mindstorms was not appropriate for this competition. A direct hardware control system was selected after much deliberation. Before building the control box (Figure 2), we figured out that the best type of control would be momentary switches. With this type of switch, we could stop or go when we wanted to. For example, if someone pushes forward on the momentary switch, the ROV would go forward. When the person lets go of the switch, it would go back to neutral. This would allow the ROV to stop quickly.

Our control box is just a small plastic box that holds three momentary switches. The switch positioned on the left controls the right motor. The switch on the right side of the box controls the left motor. The switch on the side of the box, coming out horizontally, controls the vertical movement of the ROV.

Table 2: Autonomous vs. Hardwire Control	
Programmable(Autonomous):	Direct Hard Wire Control:
Pros: 1. No need to find who's best at controlling 2. No on the spot pressure at the competition Cons: 1. If messes up, no way to restart 2. Don't have appropriate program 3. Not as accurate 4. Any difference will cause mishap 5. To accommodate problems, Programming at competition is needed But not necessary	Pros: 1. Manual, no need for buying expensive program 2. Low chance of malfunctions 3. Reach from a certain distance 4. Able to restart 5. Accuracy is plentiful 6. Cost less 7. Better control Cons: 1. More Variables 2. Needs wiring to be controlled

Electronics

The Toggle Switches are to control the vertical, horizontal, and claw movement of our R.O.V. We carefully chose our switches so it could achieve all of the tasks. We have an eight wire cord, and we put all the wires to use. Every pair of wires controls one motor. The claw control switch is attached separately outside the main control box with its own switch container. The purpose of this design is to enable a different person to control the arm so the pilot does not have to worry about making sure that the ROV is in place and having to control the toggle to operate the claw. As a safety feature, we wired the fuse between the battery and the switch box so that if anything short circuits, it will cut off all power.

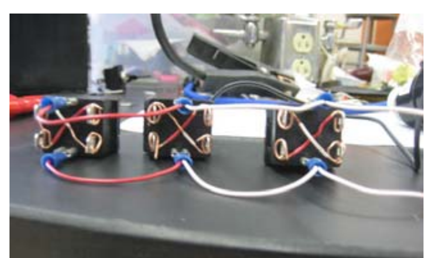
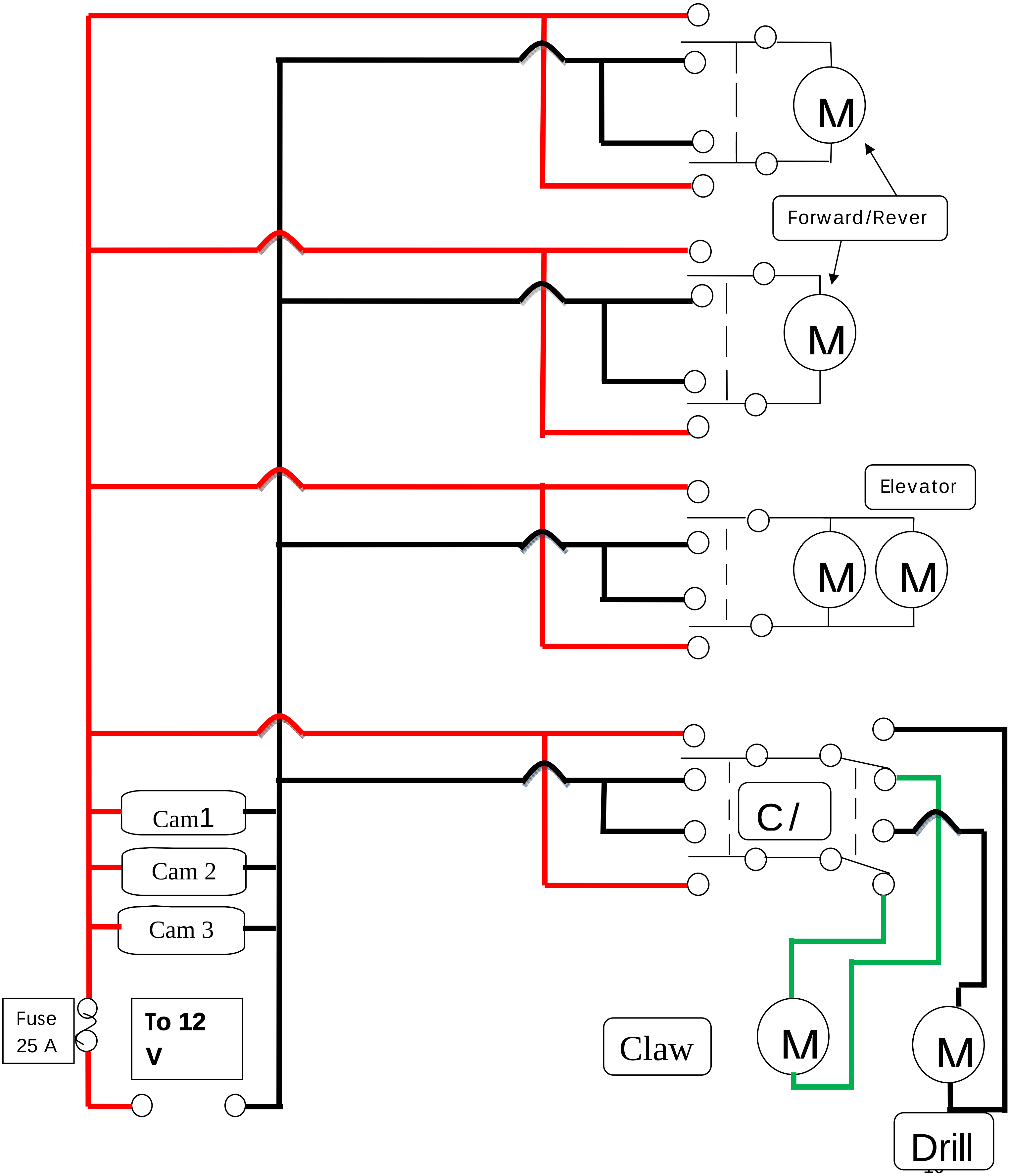


Figure 6: Inside of our Control Box

Figure 7: Electrical Schematic



Payload design function

Figure 8: Arm Controller

The payload tool we are using is a grabber that we purchased at Home Depot. We then dismantled the grabber that we had bought in order to create the type of claw that we needed to complete the missions. We used the grasping part of the gripper and connected it to a three gear system. The first two gears are connected to each grasper and the third gear is a long gear that is connected to the car door actuator. The car door actuator provides the push and pull needed to open and close the claw.

The other payload tool is a screw pump. In order to create the screw pump we placed a dirt ager inside of a PVC pipe. We then attached the dirt ager to a bilge pump which turns the dirt ager. Therefore, when the screw pump is placed in the agar, we activate the screw pump and the agar is sucked into the PVC pipe.

Arm

In order to complete each task, an arm is needed. The arm, also known as the claw, allows the ROV to move and grab materials on the underwater playing field. For task one, the arm will grab the HRH pin from the elevator and pick up the HRH. For task two, there will be a net under the arm, which will be able to pick up more than one crustacean at a time. Task three will have a claw attachment that carries the Vernier probe to measure temperatures. Finally for task four, the arm will have a plastic attachment that shovels the agar.

When the claw is not needed, it remains in the neutral closed position. The arm will be closed by ordinary rubber bands because they bend fairly well under water without breaking. A car door actuator controls the claw movement. To get the claw open, the actuator creates a push motion. To obtain greater grasping strength, the actuator will supply a pull motion to the claw. This claw control system works for all the tasks that require the use of the arm.

Alternative tools

In order to find the most effective and reliable technique to complete the tasks, we explored a number of alternative attachments. One of these alternative options was a hook instead of a claw. While we were debating whether to use a claw or hook, we listed the pros and cons of both attachments. The pros for using a claw was the ability to grasp things, while some of its cons were that we would have to add another motor and figure out how to open and close the claw. Unlike the claw, some of the pros of using a hook were that we wouldn't have to add a motor and it would be stationary, while some of the cons were the fact that the claw might get stuck on parts of the playing field or pins and we would waste time trying to untangle it. We then decided that the claw had more pros and less cons than the hook so, we added the claw.

Task 1; Resurrect HUGO

This section is about connecting the HRH's cable to the port so that it receives power and can begin to transmit data to the seismologists back on shore. We are doing this task because seismologists want to collect data on the recent earthquake activity. Our task is to find the area that is generating sound and vibrating. Then we have to remove the pin to release the HRH which will allow you to remove the HRH so it is no longer in contact with the elevator. In addition, we have to insert the HRH within a 0.5m by 0.5m square at the site that is rumbling. We have to remove the cap from the port on the HUGO junction box, then insert the HRH communications connecter into the port on the HUGO junction box.

Our design for task one was to utilize the mechanical arm on the front of the robot with a claw to grab and pull the cap off of the HUGO. The design is made to pull the pin off of the HRH and then grab the HRH with the mechanical claw and pull it off of the elevator. Task one involves many things that we had to design our robot specifically for. Specifically for task one; we had to figure out a way to identify the sounds of the 3 potential sites. That created a big problem but we have designed attachments after we, as a group, decided not to use a sound sensor because it was too expensive and we didn't know how to use it. The way that we hear the buzzer in the outcroppings underwater, is by using a navy surplus hydrophone which we soldered to an earphone jack. The jack is fed through our tether to a cassette recorder that a pair of earphones is plugged into. Because the earphones and hydrophone are connected to the recorder, even though we aren't recording, the sound the hydrophones pick up is going into the earphones for us to hear.

Task 2: Collect a Sample of a New Species of Crustacean

This task involves maneuvering into the cave and taking samples of crustaceans in the cave. We are collecting samples of crustaceans because we want to learn about the new species. Our task is to maneuver to the back of the cave, then grab up to three samples of crustaceans. Finally we have to maneuver out of the cave and return the samples to the surface.

Figure 9: Our Cave

The first thing we had to decide was whether or not we wanted the samples to be dead or alive hypothetically. We wanted to bring the crustacean samples alive which meant that we did not want to squeeze the crustaceans with the claw. To complete this without it failing, our robot needed to be small enough so that it could fit in the cave with ease and room to spare. Grabbing the samples one by one would be a waste of time so our team had to figure out a way to grab the three crustaceans and hold on to them. Our ROV has net attached to the front of the ROV, so when the ROV drives into a crustacean it tumbles into the net.

Task 3: Sample a Vent Site

The objective of task 3 is to sample a new vent site. We are doing this because in real life the Pisces V continues to descend into Pele's Pit. Scientists have been able to put in a temperature probe into a few spot s without damaging the structure. But they were unsuccessful. So our task is return back to the site and measure three different locations of the fluid coming out of the vent. Finally, we have to collect a sample of the vent spire and return it back to the surface.

To accomplish the temperature readings, we used a Vernier temperature probe. The Vernier software automatically generates a graph which is a requirement of this task. To make sure the Vernier probe can go all the way to the spires, we plugged in used USB extensions and added them to the tether. We water proofed the extensions using electrical and duct tape as wells a plastic bags.

Task 4: Sample a Bacterial Mat

Task Four is to collect a bit of a bacterial mat and bring it to the surface for sampling. The objective of it is to see what specific type of bacteria lives near the Loihi seamount. The agar in task four represents the bacterial mat that needs to be sampled by scientists. The Agar is made by combining 550 ml of water, with salinity close to the Pacific Ocean (about 3.5% of salt), with the agar base. When this mixture is heated at 85 degrees Celsius and set to cool, it hardens to a Jell-O like consistency. Although in the mission prop specifications, the color of the agar was not indicated. We decided to use orange to represent the oxidation that would naturally occur.

This was the most difficult task for our ROV. The container that the agar is held in is small and the amount of agar sample required is a specific amount. The way that we get the agar is by building a screw pump assembled from a modern day dirt auger, a bilge pump and PVC connectors. The way we put these together was by drilling a hole in the adaptor on the bilge pump to fit the end of the auger. With this hole drilled in the pump, the screw can spin like a drill when the pump spins. Once the auger was attached to the pump, we connected a ¼"pipe, which covers the screw to a ¼" connector, which fit snugly over the pump. When the screw spins at high speed and makes contact with the agar, it screws the agar up the pipe and holds it there to be delivered to the surface for sampling.

Figure 10: Agar Dril1

ROV Characteristics

Propulsion

For our ROV propulsion, we used SHURflo Aerator Cartridges, which were included in the ROV kit provided by the MATE Big Island Regional ROV Competition. There were four motors that were just the right size and came with commercial waterproofing characteristics, which allowed the ROV to move horizontally and vertically with ease. Our ROV consist of four motors for movement. There are two motors that are attached to the back of the robot. These are used for the robot to move forward and backward.

The third motor is attached to the top of the ROV, which works just like a helicopter. This motor allows the robot to ascend and descend. Just like when one wheel stops and the other keeps on going on a NXT robot, that one wheel acts like a pivot point and makes the robot turn the way the outside is going; propellers on a ROV works to the same principal. One side of the ROV stays still and the other propeller turns the ROV the way the other propeller is on. This is because one side is acting like a pivot point. The propeller at the top controls the rising and descending of the ROV by spinning one way to allow the ROV to either ascend or descend on the playing field. The same thing applies to the propellers that are attached to the rear of the ROV. Just as the rotation of the top motor allows the ROV to ascend and descend, the rotation of the two rear motors allow the robot to move forward and backwards. The fourth motor is used to control the claw motion.

Visibility

Figure 11: water proofed

Our cameras are placed to make sure that our missions can be as accurate as possible. Three cameras are placed on our ROV; one near the top and one near the bottom. Our first camera is placed directly above the claw, so that we can see what the claw is doing and is in our control. Our second camera is positioned above the arm so we can have a wide visibility of the course, and the ROV has access to each task. The third camera is positioned so we have the best possible view of the screw pump as we manipulate it. It is important to have a camera on the arm because we need the ability to see what the arm is picking up. The claw is one of the most important features of the ROV. Therefore, a camera placed directly above it is necessary. The two cameras are monitored using two monitors. A computer laptop will be used to monitor temperature changes

Buoyancy

Figure 12: buoyancy for

Buoyancy played a large role in the initial testing of our ROV. Buoyancy contributes to the movement of our ROV underwater and balances it in all conditions. For every amount of pressure that is pushed down, a certain amount of pressure is pushed up. Buoyancy makes the robot defy gravity underwater as it makes the robot float slightly underwater. That is called neutral buoyancy. To make the robot buoyant, we put foam floaters on the top of our ROV so that the foam cancels out with the weight of the ROV. Our mission is to build the ROV to have neutral buoyancy. In order to achieve that, we drilled holes into the PVC pipes to allow the water to easily flow in and out of the tubes when needed. When there are more holes, it avoids the water from leaking too slow or too fast out of the tubes. This allows the robot to descend and ascend easily. Parts of a swimming noodle were put on the top of the ROV so that the ROV will ascend and descend when needed. The foam floaters le helps the ROV float better. Just as a swimming noodle helps a human float in water, it will help the ROV float when necessary. We want the ROV to be buoyant in between the bottom of the pool and the highest object in length. With neutral buoyancy the ROV will have an easier chance of maneuver through objects underwater. If you are above the average height of the task objects, the controller will have to continuously descend underwater. If you have the ROV on the floor of the pool, it will drag and the motor propellers might possibly come off.

TETHER

The tether is a wire covered in plastic casings which controls the motors from the control box. It provides power to our ROV while it's in the water. The tether is connected to the control box, which is connected to the motor wires, which are connected to the 4 motors. The tether plays an important role in the real HUGO missions because it is the tether that failed. During our first test in water, we realized that the tether needed to be neutrally buoyant. This would allow easier movement and control for the ROV.

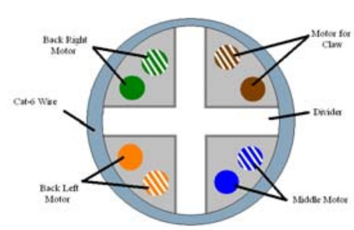


Figure 13: Tether

TROUBLESHOOTING/PROBLEMS

We encountered many problems with wiring, design, camera failures, and team dynamics. Our greatest challenge was the arm because all of our previous ideas were insufficient. The first design was to use a stationary arm but some attachments didn't adapt well enough to work for certain tasks. We brainstormed our claw design with Lego pieces. We came up with a system that utilized gears to increase our claw strength. We discovered a common household grabber that could be used with some modifications. Then, we attached it to a motor so it could open and close as we needed. This idea still failed because the claw wasn't strong enough. The current claw we are using is still the same arm that we had originally planned to use. To solve the strength problem, a car door actuator was water proofed with a special rubber was used. The modified claw is connected to the actuator by a medal bar which is wrapped around a gear so when the gear spins it pulls on the bar opening the claw. We used multiple rubber bands on the claw to keep it closed because without it, there isn't enough tension to pick up or grab.

Another problem we had was with the wiring of the control box. We do not have experiences handling electrical wiring systems. When our control system did not work, we had take apart the control box and open up the wires to check that we had connected the wires correctly. We discovered that the wires were connected to the box to the wrong control switch. A big problem occurred when we brought the ROV and the claw to the pool to test. We couldn't figure out why the claw wasn't working and the wire melted while the battery burned. The problem was the claw was over worked and the negative wire was touching the positive wire. We prevented that from happening again by adding a fuse. The fuse makes sure that if a short circuit happens, then only the fuse will burn.

Finally, we also encountered team dynamic difficulties. One problem we had was our creativity differences. Our whole team was not afraid to voice their opinion and that created disagreements. Even though some of the debates we had weren't the most constructive, we had to learn how to listen to everyone and respect their opinions. We also learned to defend our positions. Many of our disagreements were over the design of our claw which ultimately was the part that took the longest to perfect. This caused much delay in our strategy to accomplish the mission tasks. The captains also needed to learn delegation when they realized that time was a huge issue in this project. The leaders realized that they needed all team members to contribute. Everyone had to write parts for the technical report.

FUTURE IMPROVEMENTS

With more time and resources, we would try to make the ends of our PVC pipes straight so the props aren't as crooked. We would also try to test different designs such as submarines, triangles, and a V shape design like a boat. We would also experiment with different materials such as aluminum so it is stronger. A future improvement would be making the controllers wireless. We think wireless would be better because it is much easier to carry and store. To change from wired to wireless, we would probably need to buy an already made wireless controller, then figure out what each of the wiring inside means. There will be no need to carry around a large battery and having to worry about making the tether neutrally buoyant. Instead of placing the camera directly above the reader, we would have put it at an area from the left side of the robot where we would be able to see the mission being completed. Wireless connections between the controllers and the robot could be possible improvements. We can also developed a more accurate and versatile controller, such as the flight stimulator or an arcade controller. An improvement would be another way of operating the arm to do each of the tasks. We can possibly use water bottles for weight and as well buoyancy. The bottles can be filled up with water and the ROV will have an easier time descending. The right amount of buoyancy can be adjusted easily. By having empty water bottles too, it can balance the robot to achieve neutral buoyancy fast without having to cut holes in the frame. We would also like to explore the option of making a more efficient claw that is built to our specifications.

REFLECTIONS

We realized early on that we had to work efficiently due to the short time frame we had for this project. Each member of our team had responsibilities in both the building as well as the technical report. We were able to get our ROV into water in ten days time from the first day of planning. If we had more time, we would have liked to work on our weaknesses instead of doing the tasks based on our strengths. For example, the weaker writers would be in charge of the technical report.

Working on the ROV has taught us many things. One of those things was time management since we started later than other entries. Although many of team members qualified for the World Robofest, we decided to decline the invitation in favor of this competition. We did not realize that this project was so time consuming until we felt the time pressure to keep to our timeline. To make things worse, most of our team was at other extracurricular activities (i.e. Sports, band, family, etc.) so time was at a minimal. We each learned that to get things done, we had to split the work and delegate task so the parts that we need can get done. The captains on the team learned that you cannot just do it all yourself because nothing will get done, you have to give sections out to each member.

Unlike other previous competitions we have participated in, we didn't have supplies readily available. In past competitions, there were kits that you could purchase but for this specific contest, we were forced to be creative and buy our own supplies. We could not go and buy supplies when we wanted to because it takes time. We discovered that we have to make a list of the supplies you need beforehand. Time was critical and we had to have supplies when we needed them to finish on time.

Another thing that we can reflect on is the usage of wires. That is something new for all of us because we have never done it before. We had to develop a whole new way of thinking because we were used to programming our robots and not using a manual device. We not only learned how to solder and wire the electronics, we also learned important life skills such as leadership and teamwork.

Finally, it was important for all us to remember that this competition was for us to learn because we discovered that success is not easy. While this project took many hours of sacrifice, we were most happy with the camaraderie among our teammates in the end which explains our team name Kui Lima (Arm in Arm).

ROV Expenses				
Description	Quantity	Unit Cost	Subtotal	Cum. Total
0.5 in. PVC pipe	16	$1.12	$17.92	$17.92
Cable Tie	1	$6.97	$6.97	$24.89
Cleat Tubing	1	$3.87	$3.87	$28.76
8" Black Tie	1	$5.99	$5.99	$34.75
8" NTLTI100	1	$4.99	$4.99	$39.74
Spade Terminal	1	$6.79	$6.79	$46.53
PVC disconnect	1	$4.99	$4.99	$51.52
Plastic Tubing	1	$1.95	$1.95	$53.47
PVC 90 degree connector 25 pack	2	$7.00	$14.00	$67.47
PVC 25 pack coupling	1	$5.00	$5.00	$72.47
1/2 PVC 45 degree	10	$0.54	$5.40	$77.87
PVC cop	2	$0.93	$1.86	$79.73
Terminal	2	$5.99	$11.98	$91.71
Wire	1	$10.35	$10.35	$102.06
CAT 6 CMR BLU	2	$32.00	$64.00	$166.06
Nifty Nabber	1	$19.97	$19.47	$185.53
1/2 in. PVC Cap	10	$0.29	$2.90	$188.43
PVC Tee 10 Pack	3	$4.20	$12.60	$201.03
1/2 PVC cross	10	$1.06	$10.60	$211.63
PVC Tee 10 pack	3	$4.20	$12.60	$224.23
20 app switches DPDT	3	$5.49	$16.47	$240.70
Side outlet 90. 5"	20	$1.52	$30.40	$271.10
Male adapter MS 0.5	27	$0.26	$7.02	$278.12
10 pack Tee	3	$3.10	$9.30	$287.42
3/4 in. PVC	30.48	N/A	$0.94	$288.36
ABS pipe	30.48	N/A	$5.33	$293.79
PVC adapter female 2"	1	$1.59	$1.59	$295.28
PVC adapter female 3/4"	3	$0.59	$1.77	$297.05
PVC elbow 45 3/4"	2	$0.89	$1.78	$298.83
PVC Tee 3/4"	1	$0.49	$0.49	$299.32
PVC Coupling 3/4"	3	$0.39	$1.17	$416.32
1"x2' PVC	1	$1.43	$1.43	$417.75
3/4"x2' PVC	1	$0.94	$0.94	$418.69
PVC Cap	1	$0.93	$0.93	$419.62
3/4 in. Female Adapter	5	$0.65	$3.25	$422.87
Tee 10 Pack	2	$3.10	$6.20	$429.07
No HUB coupling	1	$4.57	$4.57	$433.64
Nipple 4- PVC 1 1/2x24	3	$2.59	$7.77	$441.41
2 PVC Cap Coupling	1	$0.96	$0.96	$442.37

Mission Props Expenses				
Description	Quantity	Unit Cost	Subtotal	Cum. Total
17 screws	1	$1.49	$1.49	$1.49
Tee 1-1/4" PVC	1	$1.69	$1.69	$3.18
Bushing 1-1/4"x3/4" Red PVC	1	$0.99	$0.99	$4.17
Bushing 1"x3/4"	1	$0.89	$0.89	$5.06
Galvanized Pan	1	$6.98	$6.98	$12.04
"U" Bolt	1	$1.50	$1.50	$13.54
Metric Nut	1	$0.40	$0.40	$13.94
ABS cap	1	$6.56	$6.56	$20.50
ABS Adapter	1	$4.83	$4.83	$25.33
2 PVC Cap Coupling	1	$0.96	$0.96	$26.29
2 PVC Cap	1	$1.34	$1.34	$27.63
60 lb. concrete	1	$6.42	$6.42	$34.05
Hose Hangout	4	$3.49	$13.96	$48.01
Chain	3	$0.60	$1.80	$49.81
Expand Metal	1	$21.55	$21.55	$71.36
Hose Y connector with dual shut off	2	$4.89	$9.78	$81.14
Plastic Tubing	1	$1.79	$1.79	$82.93
Metal Y hose coupling	2 ft.	$5.47	$5.47	$88.40
ABS cap	1	$6.56	$6.56	$94.96
ABS pipe	1	$3.35	$3.35	$98.31
2' ABS	1	$2.58	$2.58	$100.89
2' ABS	1	$1.87	$1.87	$102.76
Sheet Metal	1	$5.37	$5.37	$108.13
ABS pipe	2 ft.	NA	NA	$108.13
Cap 1in. S-PVC	2	$0.89	$1.78	$109.91
Cap 1-1/4" S-PCV	2	$1.09	$2.18	$112.09
Cap 1 1/2" S-PVC	2	$1.19	$2.38	$114.47
2' ABS	1	$5.33	$5.33	$119.80
PVC Cap	3	$0.93	$2.79	$122.59
	Total:			**$122.59**

Travel Expenses				
Description	Quantity	Unit Cost	Subtotal	Cum. Total ($)
Plane Ticket	17	$130	$2,210	$2,210
Transportation	3	$400	$1,200	3,410
Hotel	5	$720	$3,600	7,010
	Total:			**7,010**

Miscellaneous Expenses				
Description	Quantity	Unit Cost	Subtotal	Cum. Total
5 Piece Soldering Kit	1	$9.49	$9.49	$9.49
Helping Hands with Magnifier	2	$18.99	$37.98	$47.47
1.5 ounce Solder-0.62 in.	1	$4.19	$4.19	$51.66
Monster Fun Noodle	2	$4.59	$9.18	$60.84
Liquid Electrical Tape	3	$5.99	$17.97	$78.81
Hacksaw	2	$8.12	$16.24	$95.05
PVC Cement 1	1	$4.13	$4.13	$99.18
Primer	2	$3.27	$6.54	$105.72
PVC Cement 2	1	$5.12	$5.12	$110.84
Side outlet 90 .5"	30	$1.52	$45.60	$156.44
Electric Tape	1	$0.99	$0.99	$157.43
	Total:			**$157.43**

Donations/Borrowed Items	Market Value	Cumulative Total	Donor	
Pool	N/A	$	Swider Family	
12x20 ft. Tarp (Donation)	$20.00	$20.00	Tokunaga Family	
Television Monitors	$350.00	$370.00	Sam's Electronic Service, LLC	
Drill	$60.00	$430.00	Highlands Intermediate	
PVC saw	$6.00	$436.00	Richard Mumaw	
Screw Drivers-All sizes	$12.00	$448.00	Swider Family	
Car Battery	$65.00	$533.00	Auto Parts Sale LLC	
Playing Field- Task 1 and 4	$133.39	$649.39	Highlands Team 2	
Vernier Probe	$42	$688.39	Highlands Intermediate	
Dirt Auger (Agar Drill)	$20	$708.39	Swider Family	
Total		**$708.39**		

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