Dalbrae Aquatic Robotic Team 2010

Dalbrae Academy, Mabou, Cape Breton, Nova Scotia, Canada

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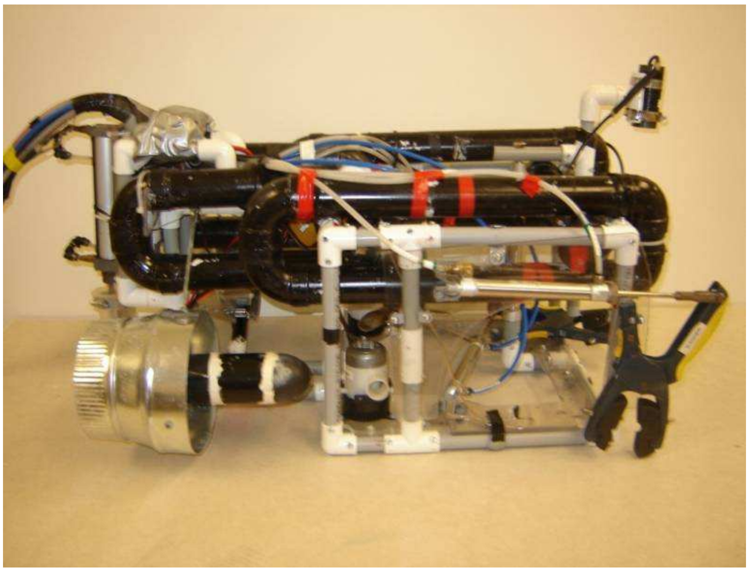
Kanaloa



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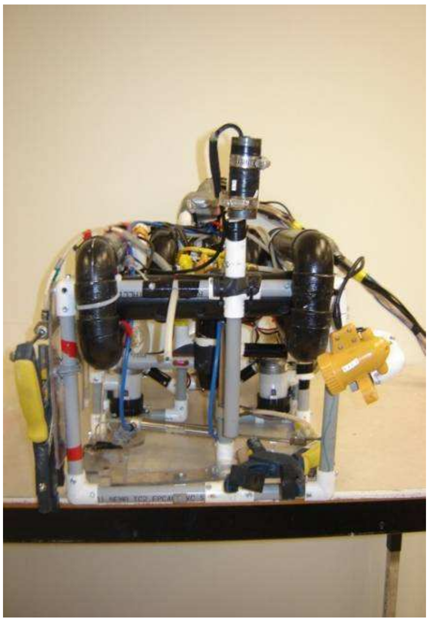


Figure 1: Kanaloa Front View

Abstract

The 2010 Dalbrae Aquatic Robotic Team consists of a mix of returning and new members. Our Remote Operated Vehicle, the Kanaloa (named after the Hawaiian god of the ocean), was built on three basic principles: safety, redundant systems and efficiency.

For the M.A.T.E (Marine Advanced Technology Education Center) competition four very tough tasks focusing on the Loihi seamount were assigned. These tasks include: resurrecting HUGO, installing the high rate hydrophone (HRH) in a site that is rumbling, collecting samples of a new species of crustacean, measuring the temperature at a vent site and sampling a bacterial mat. To accomplish these tasks, we provided our ROV with a left, right and vertical motor for moving throughout the pool. We constructed a ballast tank and pontoons to manage our buoyancy. Four cameras are strategically installed for clear vision of our tools and our environment and a system of tools and sensors have been constructed to accomplish the missions.

A syringe attached to a pneumatic piston is used to sample the bacterial mat. A horizontal and a vertical gripper are used for carrying and inserting the HRH power/communications connector into the HUGO junction box and sampling crustaceans. The hydrophone is used to transmit the rumbling to a speaker controlled by the sensory technician. The temperature sensor is used to measure the temperature of the thermal vent outputs. Kanaloa is controlled by a pilot and co-pilot operating electrical and pneumatic control boards. A sensory technician controls the calculator and CBR unit for temperature readings, creates the graphs and sets up the amplifier to receive sound from an on board hydrophone.

Safety

Safety is the primary concern of all members of our ROV Team. Safety features are incorporated into our ROV, into our control systems, into our operating procedures and throughout the building process. Precautions are taken at all times to ensure that no one gets hurt during the construction and the operation of our ROV. Safety goggles are a must when drilling, cutting or soldering. Gloves and masks are worn when using any adhesives. The pool deck is kept continuously clean and dry, and life jackets are mandatory when working around the pool deck. Our shops are kept clean and tidy. A clean shop is a safe shop. When learning how to use any new tool, we were given step by step instructions by our mentor on all features of the tool and on how to safely operate that tool. When using any major power tool, such as a band saw or drill press, supervision was given by our mentors.

In doing this project, safety has become an instinct for all of us. Before undertaking a job, we plan for problems or safety issues. Something as simple as planning your cuts or using relief cuts when operating a band saw can make a big difference. Safety features on the control system include a ready light so we can easily determine if there is power to the panel and an emergency stop (E-stop) button to cease the flow of electricity to the board. The fuse, placed at the positive side of the circuit, will blow making sure too much current does not flow through the circuit. An ammeter warns us if we are drawing too much current. The propellers for the horizontal thrusters are enclosed in shrouds to protect the ROV, the tether and anyone working around the ROV. All sharp edges are filed down and there are no loose wires or bare wires on the ROV


Figure 2: Alex working on the control panel.

When the ROV is taken out of the water or if we are working on it, the command to "kill power" is given from pool's side, the pilot repeats the command and hits the E-stop. Before launching the ROV we have developed a launching protocol. A full system check is performed with a team member at the ROV giving the command in a loud voice. For example: "Right thrusters forward". The pilot repeats the command, executes it and the thruster is observed. By repeating the command we reduce the chance of miscommunication. All motors and tools are tested using this system before the ROV is launched. Only after all systems pass do we launch the ROV. During the launch all hands are off the control panel until the ROV is in the water and the launch personnel give the "Good to go" command.

The air compressor must be empty whenever it is transported and is set to a maximum of 40 PSI output. It is the first thing plugged in during the mission set up. During the take down, the team member at the compressor warns everyone that air is being released to avoid startling people and the tank is emptied before the compressor is moved. We are proud to say that there were no injuries during the construction and testing of our ROV.

Design Rationale

Before we started construction of the ROV, we sat down as a team to discuss which of our ideas had worked and which didn't in previous years. We were able to reuse some of our own ideas from last year, make some modifications and use some completely new ideas. We then got into smaller groups and familiarized ourselves with the mission tasks. The next step was to build the mission props. Since the props are made with material similar to our ROV, building the props was an opportunity for everyone to get used to the tools and materials. Having the mission props by our side at all times ensured that we stayed focused and could check our ideas. We set a deadline of January to be in the water with all mission props and all systems operating. This deadline was met but many modifications have been made since.

When designing our ROV we built it with all the mission tasks in mind. To plan for the cave task we kept the frame small enough to pass through the opening easily. We brought the motors in at the back so we could maintain our turning capabilities while staying within the limits of the entrance. A camera and piston system allows one camera to extend upwards giving a larger field of view but drop lower when entering the cave. Our two pneumatic grippers are used to remove the J-Bolt to release the HRH from the elevator, install the HRH, remove the cap from the HUGO junction box and to collect vent spires and crustaceans.

The frame is made of lightweight ½ inch PVC conduit. There are two control panels. The electrical control panel, operated by the pilot, controls the cameras, the motors and sensory tools. The pneumatic panel directs air to the ballast tank and pistons controlling the syringe, the camera positioning system and the grippers and is operated by the co-pilot.

In addition to our grippers we have three other tools to complete the missions. For collecting a sample of the bacterial mat we have a syringe and piston system. This was positioned at the back to limit the amount of tools at the front. This position takes some weight off the front and keeps the front from becoming cluttered. The temperature sensor sits at the head of the ROV in clear view from the camera and in a convenient position to be placed in the thermal vent outputs. The hydrophone was placed in the bottom front right corner of the ROV so that it would have added protection and be easily visible.

We built this ROV to be compact, efficient and affordable. We have a limited budget and often try to salvage or create our own tools parts. To increase our chances of success we built in redundant systems. We have two grippers, both capable of performing multiple tasks, two methods to bring the ROV to the surface and two sets of pilot/co-pilot teams in case one person is having an off day. We are proud to say that the Kanaloa is able to perform all the required tasks in the time allowed.

Challenges

Our team, like all teams, face many challenges, some technical and some non-technical in nature. This year, for the first time, the Dalbrae Aquatic Robotic Team allowed returning members. Five members of last year's team decided to return along with a member of the 2008 team and two new members. Given our past years teams' successes, we knew we would be facing high expectations, from ourselves as well as others. We were also worried that our passion may not be there for a second time. Returning team members knew the commitment and challenges this project held, but decided that there was still a lot to learn and were excited to use the skills that they had developed. Once the team was formed, we completely dismantled the old ROV and held a series of frank, open meetings where we discussed what we felt worked and what needed improvement. This included ROV components, as well as team building and operational procedures. At the beginning of the year we developed a schedule to ensure that we would have a functioning ROV by January 1st. Because many of the team members had busy schedules it was difficult to stay on track. We overcame this by planning our meetings weeks in advance and worked around part time jobs and sporting events.

At first we were going out of our way to change things that simply did not need changing. We spent dozens of hours perfecting our thrusters and given that work and the success we had with these motors, we decided to use them again. Multiple bilge pumps seemed popular with other teams but they proved to be slow. With this year's busy missions time will be a factor. We listened to many teams at the international competition that experienced gripper failure so we decided to stay with the basic design for our pneumatic operated grippers that proved so successful, so we refined the systems that worked and focused on the challenging new missions. We are proud to say we were able to brainstorm and come up with solutions to all of them. Second year team members took this second chance to learn new aspects of the ROV. For example, Richard, the payload specialist from last year, joined Alex and took on the job of designing, planning and wiring a new electrical control box. Mallory stepped in with tool design and was voted team co-captain. One new member found the work too much and left while other new member Rebecca jumped in with any task and became our tether manager and co-pilot.

Our biggest technical challenge was Task #4, collecting the bacterial sample. Once we made the agar, we were surprised with its texture. Initially a hard gel, but once disturbed, it developed a slushy texture. Should it be sucked up or should it be cut? We considered using an auger housed in a piece of pipe but the challenge to turn the auger slowly for a short time was a problem. After further discussions and trials, we decided to use a syringe to take the sample. We ordered a syringe large enough to take the 150 mL sample we desired. The next challenge was to

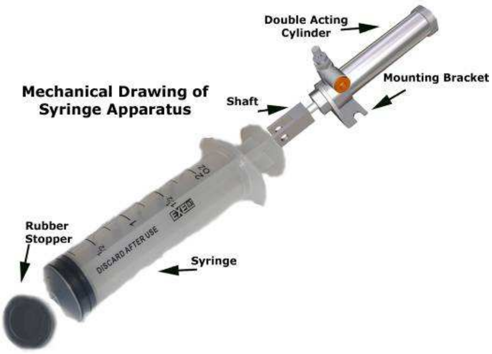


Figure 3: Mechanical Drawing of Syringe Apparatus

find a way to operate the plunger. An electric car door lock was considered, but these devices are hard to waterproof. We went with a pneumatic system and attached a double acting piston to the plunger. This system did not work at first because the unit ended up much longer than our ROV was high. We cut the majority of the plunger out and attached the seal of the plunger to the end of the shaft of the piston and mounted the piston/syringe system on plexi-glass and attached it to the back end of the ROV. When we were constructing this system we did not want to have to buy a new piston. We were able to find an older piston that we cleaned up. We then realized the throw length of the piston was about 2.2 cm too long for the plunger. The piston was dismantled and a 2.2 cm piece of heavy PVC was placed inside the piston to restrict the shaft length. The entire system was attached at the back of the ROV to offset the weight of the tools at the front. The ROV is piloted over the bacterial sample and then the pilot slowly lowers the syringe into the sample as the co-pilot operates the syringe. Initially, the syringe operated too quickly so a restrictor was placed on the air control to slow the plunger action. This system has allowed us to consistently gather a reliable sample.

Frame

The biggest challenge we faced when designing our frame was the need to make the ROV as compact as possible. We wanted to make it easier for travel and small enough to get through the 80cmx80cm tunnel. We set a maximum of 60cm wide or tall. The ROV had to be wide enough to hold all the motors and the tools as well as high enough to ensure the safe and efficient operation of the vertical thruster.

We used new and scrap ½ "PVC from the Nova Scotia Community College electrical shop for the frame and connected the PVC with various plastic T's and elbows. Self-tapping screws secure everything instead of glue to make repairs or modifications to the frame easier. A sheet of Lexon is used as a base for the grippers. The PVC allows us to have an open concept frame that permits easy water flow through the frame which makes the ROV move easier.

The basic structure of the frame is two rectangular prisms. The front of the ROV is approximately 38.8 cm wide. This is as narrow as we could get and still hold the vertical and horizontal grippers, the hydrophone, temperature sensor, two cameras and offer space for water flow. The rear of the frame was brought in to a width 11.8 cm so there is enough room for the horizontal thrusters and still maintain a maximum width of 60cm. We realized we wouldn't be able to keep the frame air tight so we drilled holes in the top and bottom allowing it to fill with water. This way no air pockets would form throwing off our buoyancy.

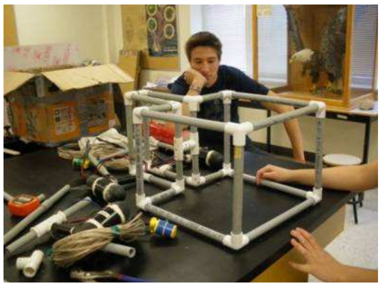


Figure 3: Construction of the Frame

During early trials we experimented with placing the motors inside the frame and closer together. We liked the idea of a narrower ROV and protected motors. However this dramatically reduced the turning capability of the ROV. We then moved the motors outside the frame to provide maximum torque and turning capability while keeping the ROV as narrow as possible. Our motors are enclosed in metal shrouds made of 7” to 6” ductwork reducers to protect the propellers, the tether, and personnel. This allows increases forward thrust by funneling the water. The maximum width between each of the outside shrouds is 56.5cm. The height had to be high enough to fit the vertical motor and keep it from touching the ground. After a lot of planning and experimentation the final dimensions were as follows:

Front Section Length- 39.5 cm Width – 38.8 cm Height – 30.4 cm	Rear Section Length – 22.8cm Width – 11.8cm Height 30.4 cm

Buoyancy

We decided to make our ROV neutrally buoyant because most of the tasks must be completed mid-water. Early in our team’s development we spent a couple of after school sessions performing experiments and calculations to familiarize ourselves with the basics of achieving neutral buoyancy. To begin our calculations we applied Archimedes’ Principle, which states that the buoyant force on a submerged object is equal to the weight of the fluid displaced by that object. To achieve neutral buoyancy, we had to make the volume of the ROV equal to the mass, giving us a density of 1 which is the density of water.

To calculate the buoyancy, we found the mass and volume of all the major parts of our ROV. This included the three Sevlar trolling motors, each with a mass of approximately 1500 g and a volume of 600 ml, our three pneumatic pistons, and our two bilge pumps. We weighed the entire ROV which had a mass of 16.4 kg, to determine how much extra buoyancy we would need.

Initially our mass was much more than our volume so we determined how much extra buoyancy was required. We needed a light weight material which would not absorb water or compress under the pressure of the depth. We decided to build four pontoons constructed from very light weight but strong 2” PVC and four 90 ° elbows used in internal vacuum systems. The pontoons are U-Shaped and are attached to the top of the frame of the ROV. Having our buoyancy on the top makes the ROV stable. The pieces are sealed using 3M marine adhesive. Before sealing the pieces, they were filled with expansion foam. The marine sealant should stop all leaks but the foam could act as another barrier if a leak occurred since the water would have to displace the foam to enter the pontoon.

Figure 4: Ballast Tank

The two longer front pontoons are 38 cm long, with a total volume of 2350 ml_each and a mass of 575 g creating a net upward force of 17.5 N. The two smaller pontoons, placed at the rear, have lengths of 21 cm long and have a total volume of 1680 ml and a mass of 390 g each. We made the pontoons about 4 cm longer then the frame of the ROV so that they can be slid forward or back as needed to make the ROV sit level in the water. This feature is very useful as pieces are added, removed, or relocated through the evolution of the ROV.

It is very challenging to make an ROV exactly neutral buoyant so we added a ballast tank that allows us to fine tune our buoyancy when needed. Our ballast tank is made up of a bicycle inner tube inside a 1½ inch PVC piping that is attached to a length of ¼ inch pneumatic hose to a regulator and a pressure gauge on the co-pilots control panel. The ballast tank is incorporated into the front of the frame where most of the extra weight will be when completing the missions. The ballast tank can fine tune our buoyancy, provide additional lift when carrying heavy objects and bring the ROV to the surface should our vertical thrusters fail or experience difficulty.

Tether

When designing our ROV, we looked at the depth of the pool mission specs and computed that the length of the tether should be 20 meters. Our tether is composed of 9 wires, nine ¼ inch pneumatic hoses and a length of tuna fishing line. There are 4 cameras wires, 3 motors wires made of 16 gauge speaker wire, an 18 gauge speaker wire for the hydrophone; the wire for the temperature sensor is CAD 6 cable. We experimented with different positions for the exit point of the tether. From the results of these experiments as well as research into commercial ROV's the tether exits out the middle of the back of the ROV from the top to offer minimal interfere with mobility.

All of the tether is permanently connected to the ROV and disconnects at the control panels. We knew that we did not want the ROV, the tether and the Control Panels to be permanently connected. This would make transportation far too cumbersome and increase the chance of damage. We disconnect from the control end rather then the ROV ends because it is very hard to water proof every connector if we disconnected from the ROV. Right from the beginning we knew there was possibility of damaging the ROV by putting stress or pulling on the tether. To avoid this danger we incorporated two stress relief systems: an inner tube and a strong tuna fishing line. The inner tube is wrapped around the entire tether and secured to the frame such that there is always slack on the wires. If the tether is pulled, the tube would stretch and no tension would be put on the wires or hoses. The fishing line runs through the entire tether so if the ROV is ever disabled we can lift from the tether. If there is a complete system failure we can safely lift the ROV out of the water with the tuna line and rubber transmitting all of the force to the frame. To keep the tether straight there is a U-shaped piece of 2 inch PVC that acts as a support where the tether exits the ROV.


Figure 5: Tension Relief System

Before competition, we always straighten and uncoil the tether. We experimented with two techniques for wrapping the tether. One was to lay all the components parallel along the pool deck and wrapping the tether. This was done to avoid twists or knots. Our second technique was to twist the tether 90 degrees every half meter. The rational being that since the tether is usually coiled in a bag we did not want to have the same wire always on the outside being stretched. This technique was discovered while talking to an engineer who works in the field of ROVs. We found that the first technique resulted in a tether that was easier to handle.

We have developed a tether protocol. During the operation of the robot one person is always focused on feeding the tether. The tether manager stays focused on the ROV in the water and does not speak to the pilots except to inform the pilot when running short of tether. The last 10m are numbered to inform the tether manager when we are in danger. A second team member makes sure the tether is not tangled on deck and launches and retrieves the ROV. Positively buoyant glow sticks are added to the last 5m of our tether so we are able to see where our tether is located when backing out of the cave. Since most of the tether consists of pneumatic air lines we did not need to add much buoyancy to the tether.

Electrical

We used a hard ware approach instead of a soft ware to control our ROV for a variety of reasons. We maximized the learning process by building all components from scratch. By designing and constructing all features we made an ROV that is easy to trouble shoot and easy to repair. There are three main features that are powered by our 12 V power source. These features are: four cameras, three 12V Sevylor motors, and two lateral thrusters. All of which are controlled by the pilot from the electrical control box. Before beginning to create the control system we spent a couple days in the lab, learning and reviewing the basics of soldering, wiring and testing circuits. We then decided what features were needed to run through the panel and how they could be operated. The switches are placed in a natural position so the pilot can comfortably and instinctively control the ROV. We knew we had the placement of the switches correct when we first operated the ROV and we noticed that the pilot never had to look down at the panel when driving.

Figure 6: Constructing the control panel

Our control system is housed in a modified aluminum tool case which is easily transportable but very solid. A sheet of aluminum is used as the base to support all of our switches on the panel, and two pieces of angle iron steel to support the aluminum base. Our finished control panel consisted of three thruster connectors, five toggle switches, four double pole double throw momentary on/off switches, emergency stop, ready light, three trailer hitch connectors, ammeter, a fuse, and two jack posts for power input.

Power enters the box from the jack posts with leads running to the 12V power source. The power then runs through the 25 amp fuse, a ready light and an E-stop all wired in series before being relayed to the control switches and finally exits to the tether. We incorporated toggle switches to turn the cameras on or off. If something went wrong with a camera like a short circuit, we could remove it from the circuit. The video jack runs directly into one of our three monitors. One monitor can take two video inputs so we can switch back and forth to the desired view.

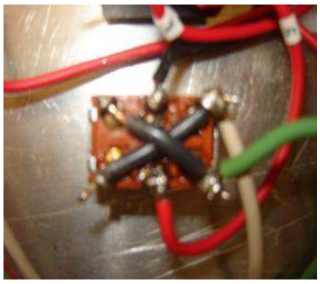


Figure 7: H-Bridge

We incorporated another toggle switch that is connected to both right and left thrusters so we can invert the polarity of the direction of those motors using an H-Bridge. We wanted to add this feature so that when the pilot looks at the rear camera while exiting the cave forward it will stay the same as normal operation. We

Figure 8: Control Panel

control our three main thrusters through the use of double pole, double throw, momentary on/off switches wired in parallel. The momentary switches are spring loaded to return to the off position automatically when not in use. The two lateral thrusters are controlled by one double pole, double throw, momentary on/off switch also wired in parallel to two 1100 GPH Bilge Pumps which we use to move our ROV laterally. Pushing the switch to the left activates the bilge pump on the right which pushes the ROV to the left. Only one switch was needed since both motors never run at the same time. This branch of the circuit exits the panel to four prong trailer hitch which can be connected to its color coded mate on the tether. The tether then runs 20 meters to the ROV. The right, left, and vertical motors were both incorporated with high and low speed. However, our tests showed very little difference in the operation of the motors at various speeds so we decided to remove low speed. Pilots pulse the motors to control speed.

To keep organized we created a wiring schedule chart with each wire numbered. A copy of the wire schedule is attached to the bottom of the control box for easy trouble shooting and repairs.

Four safety measures are incorporated into the control panel including an emergency stop, a fuse, an ammeter, and a ready light. The emergency stop is our major safety feature. It allows us to shut all of the power going to the control panel off in the case of an emergency such as something caught in the propeller or whenever someone works with the ROV. The 25 amp fuse limits the amount of power used by the ROV at any one time. The ready light lets us know if there is power to our panel. The E-stop, fuse and ready light are wired in series so they cannot be by-passed. Our experience has taught us that if a motor is failing, it will draw more amperage. The ammeter was placed in the control panel to monitor the total current running through our system allowing us to check how the motors are working and to gauge if we are close to the 25 amp limit. The wires running to the three thrusters exit the control box terminating in three color-coded female extension cord plugs. The matching male end is attached to the tether.

<u>Electrical Schematic</u>

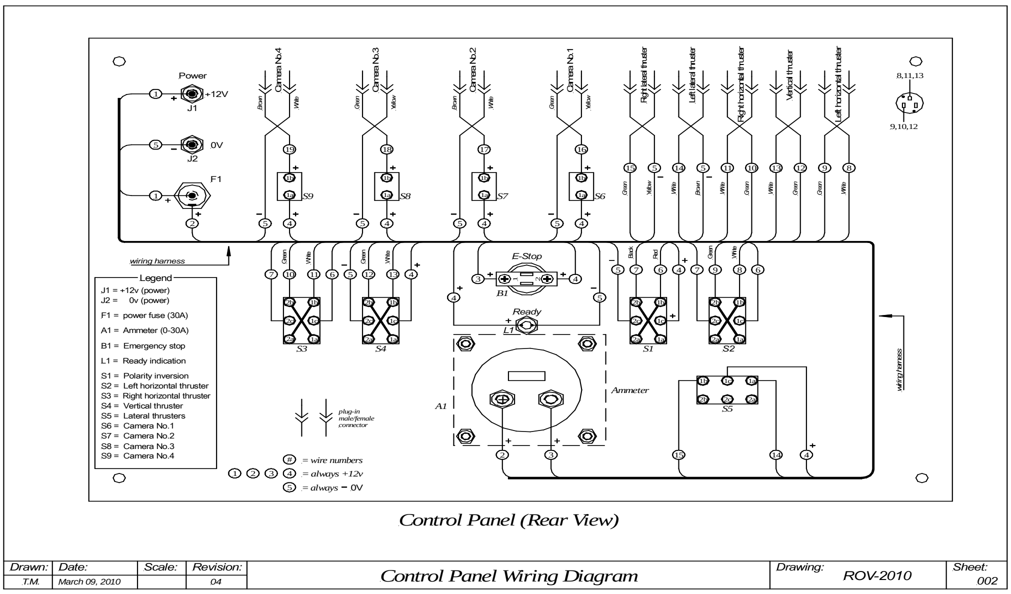


Figure 9 Control Panel Schematic

Trouble Shooting

When taking on this project we knew we would undoubtedly be faced with many problems and complications. In order to overcome these problems as quickly and efficiently as possible, we developed a trouble shooting protocol early to use when some component of our ROV is malfunctioning.

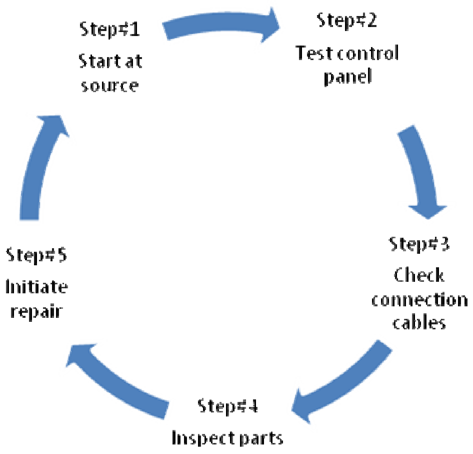


Figure 10: Trouble Shooting Method

Our multiple cameras and ammeter are able to easily see when a system component such as a motor or gripper is malfunctioning. Given the amount of time we spend flying the ROV, our pilots can quickly sense when it is not operating as usual. Once we realize there is a problem we always begin at the source, whether it is the battery for the electrical system or the air compressor for the pneumatic system. The ready light can quickly tell us if there is power to the panel. The compressor has a pressure output gauge that should be set to 40 PSI. If the problem is not at the source, we check our electric or pneumatic control panels to ensure all of wires and lines are connected. Third, we follow our tether all the way to the robot, checking for nicks, holes, or loose connections in any wires or pneumatic lines. Finally, we inspect the actual component of the robot causing the problem. If we locate the problem we then initiate a solution, if not we start our trouble shooting method again performing a more detailed check. Once we initiate a solution we test our solution before re-entering the pool. We are quite confident with this method because it has served us well in the past and allows for a very thorough review of the entire system.

While practicing in the NSCC pool, a motor failed while operating at the bottom. Our first fear was a motor failure but we followed our trouble shooting method and quickly established the problem while inspecting the control panel. The power source was fine and the panel had power and the other motors were fine. We switched the connecting wires and realized the left motor would operate fine from another switch. By following this method, we concluded the switch was the problem and it was replaced. This was much easier than taking apart a motor, only to find that nothing was wrong with it. With each problem we encounter and solve, the team has gained confidence. Initially problems were met with fear or nervousness, now we almost look forward to the challenge of solving the problems

Motors

Our ROV utilizes 3 modified trolling motors and 2 bilge pumps for propulsion. The majority of our propulsion is provided by the three modified12 volt trolling motors. Two 1100 gph bilge pumps are positioned in the middle of the ROV for lateral motion. All motors are controlled by the pilot using toggle switches on the control box and with all motors operating under load they draw about 13 amps at 12 Volts.

When we first bought the trolling motors they had a meter long shaft attached to a throttle. We cut this shaft down to 13cm and inserted a piece of ½ PVC into the shaft sticking out of the end so the motor can be attached to the frame. These motors are plenty powerful as they are designed for use on watercraft and are capable of moving a small boat. Unfortunately, they are only designed to be about 30 cm underwater. The pool we use at the NSCC campus is 4.5 meters deep, putting the motors under a much greater pressure. Previous experience taught us that the motors would not be able to withstand this pressure without modifications. There are four areas where water could enter the motors and each area has additional waterproofing added.

The easiest access point for water is the shaft which we to cut to size. The end of this shaft is designed to be out of the water, attached to the throttle control and therefore was not initially waterproof. To waterproof this section we placed cotton balls at the base of the shaft to keep any adhesive from entering the motor chamber. We filled the shaft with a marine grade sealant recommended by one of the faculty members at the college. The O-ring on the propeller shaft was seen as a weak point so we added a high pressure o-ring seal donated by Ed's Hydraulics of Mabou. The O-rings on the main body of the motor were another weak point so a bead of the flexible marine sealant was placed around the o-ring. These modifications have enabled the motors to handle the extra pressure without failing over the many hours of operation as we trained for the missions.

Figure 11: Right Thruster

There are left and right motors positioned horizontally and one vertical motor for moving up and down. The horizontal motors are positioned at the back to better manoeuvre and to compensate for the weight of the payload tools at the front. The left and right motors are positioned outside the frame to provide better water flow and to maximize torque for turning. To protect the propeller and personnel, we surrounded the motor with shrouds made from 6" to 7" ductwork reducers. The shrouds are attached to the shaft and fin of the motors. A threaded rod running from the shroud to the frame aids in their stability. The rods also reduce the chance of the tether getting caught between the motor and the frame. The larger diameter end of the ductwork reducers face forward, funnelling the water providing addition forward thrust.

The vertical motor is placed at the center of gravity so that the ROV will stay level when ascending and descending. It is placed so that the prop is above the pool bottom to avoid damage with objects on the pool. The motor is attached to the frame by the shaft at one end and a second piece is fitted to the fin on the other side. Great care was taken to ensure the motor sits level in all directions.

For lateral movement, two bilge pumps were attached near the center to move the ROV from side to side. This was a help when doing precise jobs such as taking the temperature or grabbing the J-bolt. If the pilot is slightly off, a quick pulse of the lateral thrusters pushes the ROV in place without having to back out and make another attempt. The bilge pumps force water to either left or right and move the ROV to the opposite side.

Figure 12: Lateral thruster in position

Pneumatics

When designing our payload tools we looked at the required tasks and designed tools to quickly and efficiently complete the tasks. The restrictions of cost and amperage led us to choose pneumatics, instead of electrical tools. Commercially available electrical grippers were over $1000 and outside our budget. When operating under load and with all cameras operating, electrical tools may put us over the 25 amp limit, giving us further reason to go with pneumatics. When listening to other teams at competitions, it seemed that failed grippers were a major problem. Our pneumatic piston/gripper system is very versatile and very reliable. To this day we haven't had any problems with them other than making adjustments and upgrades.

Hydraulics was another option but we knew that the chance of a loose fitting connecter or a hose leaking during our initial experiments was high. We would not want to pollute the pool. A leaking pneumatics part would simply release air bubbles, so from an environmental perspective air was the obvious and green choice.

Our ROV uses pneumatics to operate two grippers, a syringe which is connected to a piston, a camera that is connected to another piston which can be raised or lowered to focus to the driver's preferences, and a ballast tank. All components are connected by 1/4 inch pneumatic hoses throughout the tether to a pneumatic control box which is operated by the co-pilot. The control box is connected at the main air input to an air compressor which is set at an output pressure of 40PSI or 273kPa. The four pistons are double acting pistons with one air line required to extend the shaft and one to close it. The hoses connect to the various components using friction lock connectors.

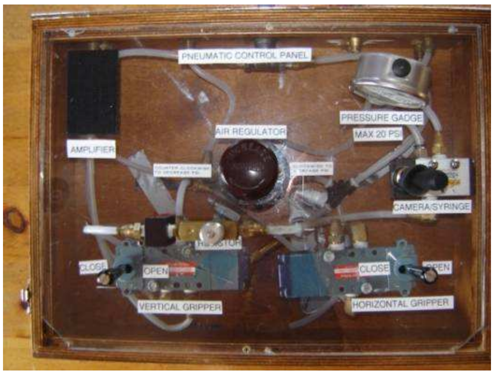


Figure 13: Pneumatic Control Panel

The optical zoom for the camera and the syringe each run on their own piston but operate from one controller on the box allowing us to eliminate two pneumatic hoses from our tether, reducing the size of it. The hoses split off at the ROV. With our mission protocol these two systems operate independently.

Air enters the control box at the rear and splits off to the input of the three controllers and the regulator. The regulator is attached to a pressure gauge so the co-pilot can monitor the pressure in the ballast tank with a maximum of 20 PSI or 137 kPa. The 6 lines from the control valves and the one for the ballast tank connect to friction lock connectors at the rear of the box. Each connector is color coded and numbered to the corresponding number and color on the tether end for easy and accurate set ups.

The control box is constructed from a custom built wooden box with a plexi-glass top and a hinged bottom. The clear top makes it easy to see any disconnections and the hinged bottom allows easy access to the system for repairs. Extra pieces of hoses and connectors are attached inside the control box.

Tools of the Remote Operated Vehicle

On our ROV we have three main tools. We have two grippers and a 150mL syringe. All of our tools on our ROV are custom fabricated by us. All of our tools are pneumatically operated and are under the control of the co-pilot. We considered using a soft ware approach, but went with hard ware because we would have control over all aspects of the system. We felt that with a hardware approach we could maximize learning by designing, building, and modifying all components ourselves instead of purchasing a magic box. This would give us a better understanding and would be easier to fix if something went wrong.

Our two grippers, one vertical and one horizontal, are constructed from modified vice grips. Our grippers are controlled by double acting pneumatic pistons. These pistons are in turn controlled by two pneumatic lines each. We decided to hand craft the inserts of our pneumatic grippers by using hockey pucks cut and shaped to fit our desired needs. We used hockey pucks because the rubber is firm and strong, like metal, but malleable enough to be shaped into very reliable tools that won't allow objects to slip out of our control. The grippers are used when removing the J-Bolt to release the HRH from the elevator, installing the HRH, removing the cap from the HUGO junction box, and when collecting vent spires and crustaceans.

We decided to use both vertical and horizontal grippers because this incorporated redundant systems. If one gripper failed or could not reach something, the other gripper could do the job. Our vertical gripper is positioned so it can reach to the bottom of the pool floor to capture the crustaceans, and the horizontal gripper can pick up items in front of our ROV.

The grippers are fixed in place by first being attached to a poly-carbonate sheet which is then attached to the frame of our ROV. The piston and gripper are positioned to allow free motion without any extra stress on the handle of the gripper. When ordering our pneumatic pistons, we computed the shaft length required to have full motion of our grippers, and ordered accordingly.

The syringe system we created to take the sample of the bacterial mat is constructed from a 150mL plastic syringe and a double acting piston which controls the plunger. This was also added to a piece of plexi-glass and then attached vertically to the rear of the ROV. A pneumatic restrictor was added to the pneumatic lines of the piston controlling the syringe in order to allow for a slower pull ensuring a good agar sampleThe syringe is clear and graduated so that we can determine the size of the sample and the plunger is set up to take the desired amount, between 100 and 175 mL. We discussed using an auger system to pull up the agar. This would have required a system to turn the auger. We used the syringe instead because it worked well and we were unable to find a mechanism that would be able to rotate the auger that would extract the agar.

Figure 14: Horizontal Gripper

Cameras and Sensors

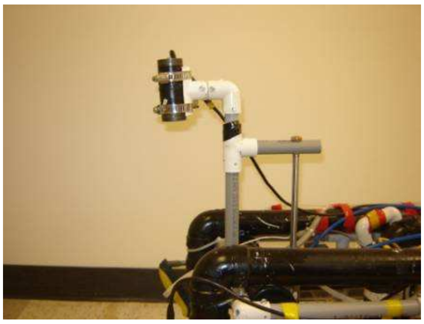


Figure 15: Top Camera Extended

Kanaloa has four cameras. The three front cameras each point along a different plane providing us with a three dimensional view of our tools and our surroundings. All of the cameras we purchased seem to be built to look at objects in the distance and they tend to zoom in when underwater thus providing a smaller field of vision when looking at objects up close. This is a problem when you have a short ROV and you want to see the tools and the objects around it. Due to the restricted height of our ROV created by the need to enter the cave, we developed a system to allow one of our cameras to be raised to create a wider field of view and lowered when entering the cave. The camera is connected to a piston so when it is raised we have a full view of our payload tools and temperature sensor and is lowered before entering the cave. The camera is attached to a piece of PVC so it rides smoothly and stays in place. The side camera allows us to see our vertical gripper, the hydrophone, and the environment to the right of the ROV. The middle camera faces forward and is used to see where our ROV is going, our front payload tools, and the mission props. The rear facing camera allows us to see our syringe when collecting the bacteria and to see if there is anything behind us that could get caught in our motors. It also makes backing out of the cave easier.

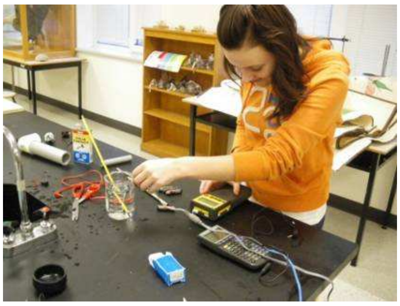


Figure 14: Mallory testing the temperature sensor

Our ROV is equipped with two sensors. The temperature sensor allows us to sample the temperature of the water coming out of the thermal vent. This information is sent to a Texas Instrument hand-held Calculator Based Laboratory System that works in conjunction with a TI-83 graphing calculator. The calculator runs the program to activate the temperature sensor and has the height of the vent output spots stored in a list. The sensory technician need only record the temperature, enter these values in a second list and then easily make a graph of Temperature versus Height. The temperature sensor originally had a 1m long cable. We spliced into the cable and soldered on 20m of CAD 6 cable. The ROV end of the probe is potted in a 6 cm length of hose and attached to the top front of the ROV. This device has proven to be fast and very accurate.

A search of hydrophones on line found the cost prohibitive so we constructed our own hydrophone from a design found on the website http://www.ganteschnigg.net/doku.php?id=hydrobioakustik:diy_hydrophone_en. We built the hydrophone by using a piezo ceramic disc removed from a $5 buzzer and soldering it to speaker wire. The disc originally acted as a speaker when current is feed to it, causing vibrations and producing sound. We reversed this process. As sound hits the disc it vibrates, producing an electric current which then travels to a mini-amplifier so we can listen for the rumblings. Once removed, the disc was epoxied to a small disc of plexi-glass. An O-ring was placed round the disc and a second piece of plexi-glass was cut for the top. The two pieces were bolted together and further sealed with silicone. A 20 m length of 12 gauge speaker wire was soldered to the wires on the piezo disc and exits through the top piece of plexi-glass. This hole is sealed to prevent leakage. We wrapped the hydrophone in a thick condom sealed at the end as an extra barrier. We practice safe ROVing! An output jack was soldered onto the end of the speaker wire to allow us to connect to the mini amplifier. The hydrophone is built safely into the frame at the front of the ROV so we can fly over the possible sites until we find the one which is rumbling.

Figure 17: Temperature Sensor Setup

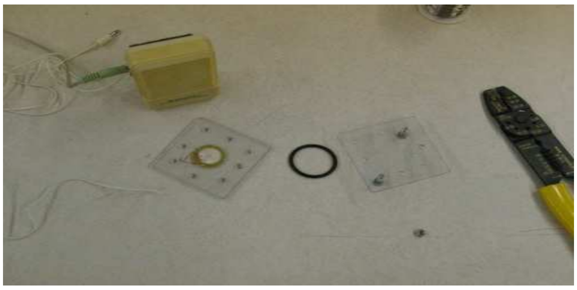


Figure 18: Hydrophone under Construction

Future Improvements

If we were given the opportunity to do this project again we would like to experiment with having an electronic controller operating our pneumatic pistons. Having every tool operating on pneumatics means a large amount of pneumatic lines in our tether. A light, thinner tether would offer less interference to the movement of the ROV. Having the electronic controller on our ROV sending air to the various pistons and ballast tank would allow us to have only one pneumatic line running to it. This suggestion came up towards the end of preparation for Internations, but in our team decision making procedure, each member voted and it was felt that the time and risks did not warrant making this change at this time. We are fully aware that this change could be a big advantage for our tether but it could also be a great disadvantage. Having this controller on our ROV would mean that it would have to be completely water tight. If it is not sealed properly water would get into the controller. If the controller stopped working, troubleshooting would also be a challenge because it would have to be taken apart and inspected every time something goes wrong or modifications were made. Most commercial ROV's have electric control panels on board so the opportunity to familiarize ourselves with the different techniques would be interesting. Perhaps this challenge can be met at another time.

Lessons Learned

The MATE ROV competition is beyond a doubt the greatest learning experience any of us have ever had. There are so many lessons learned. The project brings topics such as forces, circuits, and algebra to life. There are numerous tools that we didn't even know existed until we discovered it was perfect for the job. We all now feel much more comfortable tackling jobs around the house. Our co-captain Mallory was very proud the day she was able to use her electrical skills to troubleshoot and replace a bad wire on her family's fridge. Much of this comfort came from the stress our mentor placed on safety and planning. Once we understood all the features of a tool and how to safely operate it, we were much more comfortable using it. We learned that planning ahead can eliminate a lot of so called "accidents".

Figure 15: Alex and Rebecca during marine survival training

The greatest lesson learned is the importance of teamwork. We had a number of team building activities early in the process including a marine survival course taken at Nova Scotia Community College to help us bond. With a diverse group of six strong willed people totally committed to a task, we needed to learn how to work together. We had to learn to respect and listen to each other's ideas and we had to learn to trust each other. This is not a one person job. Whenever a major decision had to be made, all members came to the table and each member had to give their opinion on the topic. No one was allowed to pass on the topic and everyone felt challenged to be as informed as possible before speaking. This helped everyone develop a greater understanding of all components of the project. Once everyone spoke, a consensus was reached. Through this process we learned that your idea may not always be chosen or be the best, but once a decision was made it was important to support the decision and do everything in your power to make it work. This process helped all team members feel valued and involved.

Performance Results:

Throughout the building of the ROV we performed basic tests of its performance. The tests would show if the ideas were working and if there were problems with any components. The final results are summarized below.

THRUST AND SPEED RESULTS			CURRENT DRAW
	THRUST (N)	Speed (m/s)	Forward (Amps) 8.5
Forward	25N	0.33 m/s	Reverse (Amps) 7.7
Reverse	10N	0.16 m/s	Left motor 4.5
Up (Thruster)	8N	0.15 m/s	Right motor 4.2
Down	9N	0.23 m/s	Lateral Thruster 3.5
Up (with ballast)	14N	0.32 m/s	

All motors Current Draw

	Forward and Up (Amps)	Reverse and up (Amps)	Forward and Down (Amps)	Reverse and Down (Amps)
All motors	12.2	9.5	10	9.5

The Loihi Seamount

The Loihi Seamount is a large underwater volcano 30 km from the coast of Big Island of Hawaii. It is 3000 meters above the floor of the Pacific Ocean, 969 m below sea level, which makes it bigger than Mt. St. Helens before it erupted. Loihi was thought to be an ancient, extinct volcano until the 1970s. It was then discovered that Loihi was still active and repeatedly shaken by earthquakes. Most of the surrounding volcanoes were mostly 80 to100 million years old. Loihi is the youngest volcano in the Hawaii chain.

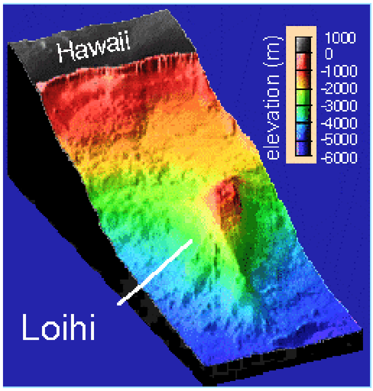


Figure 21: Loihi Seamount


Figure 22: Pisces being launched

The true nature of Loihi was discovered by scientists while exploring an earthquake swarm. Earthquake swarms are intense and repeated seismic activity. The volcano stayed relatively quiet until 1996 when it became active again. This activity was the first confirmed historical eruption of the seamount. Since then it has remained active with earthquakes up to five on the Richter scale. On 13 May and 17 July 2005 there were earthquakes of 5.1 and 5.4 magnitude. The seismic activity continues with swarms of hundreds of quakes in various magnitudes over the years. Between 17 July 1996 and by the end of August there were 4000 earthquakes.

The USGS-ANSS (Advanced National Seismic System) have been studying the seismic activity of the seamount. Pisces V, a manned submarine, was deployed by the Hawaii Undersea Research Laboratory (HURL) many times to explore the surrounding area. It measured the temperature of the hydrothermal fluids issuing from vents and found temperature up to 200 C.

Hawaii Undersea Geo Observatory (HUGO) was put in position in October 1997. HUGO was designed to send information about the activity around Loihi. It was equipped with a hydrophone designed to pick up sounds that could be earthquakes, a seismometer, and a pressure sensor. Although communication was lost for a while, it began transmitting again on January 19, 1998.


Figure 23: HUGO

Pisces V went down to explore the problem and it was determined that water had leaked into a connector in the Junction Box. HUGO was recovered in November 2002 so new technologies and repairs could be made. They are hoping that one day it will monitor eruptions, geology, geophysics, biology, hydrothermal venting, and other activities.

Our ROV, Kanaloa, does many of the same jobs HUGO and Pisces V do in the industry. For instance, our ROV is equipped with a hydrophone. During the mission when we are listening for the buzzer, this simulates searching for noise generated by seismic activity. This is important in studying Loihi to understand how the volcano is erupting. We also have a temperature probe that records the temperature of a simulated hydrothermal vent. The cave mission simulates the exploration of surrounding areas of Loihi. Our ROV can grab simulated crustaceans much like the ones found on the slopes of the seamount. Since the earthquakes change the structure of the seamount the ROV exploring the area have to be ready for changes in terrain. Out ROV takes samples of a simulated bacterial mat much like the bacteria samples being analyzed from the Loihi seamount. We also perform similar tasks to Pisces V with the mock HUGO.

Although Kanaloa is not capable of tasks preformed by Pisces and HUGO, the thought process and problem solving is similar to that of professionals. By doing this project we have become familiar with the ROV industry.

References

1) "HUGO--The Hawai'i Undersea Geo-Observatory." *SOEST | School of Ocean and Earth Science and Technology*. SOEST. Web. 2 Mar. 2010. <http://www.soest.hawaii.edu/HUGO/>.
2) "Lo`ihi Seamount, Hawai`i." *USGS Hawaiian Volcano Observatory (HVO)*. USGS, 26 Mar. 2000. Web. 2 Mar. 2010. <http://hvo.wr.usgs.gov/volcanoes/loihi/>.
3) "Loihi." *SOEST | School of Ocean and Earth Science and Technology*. Hawaii Center for Volcanology, 19 Jan. 2006. Web. 1 Mar. 2010. <http://www.soest.hawaii.edu/GG/HCV/loihi.html>.

Acknowledgements

This project could not be accomplished without the help of our many supporters. We would like to begin by thanking NSCC Strait Campus for letting us use their pool, allowing us access to their shops and for organizing the regional competition. MATE deserves so much gratitude for putting this whole project together. Of course, we would like to thank the judges and everyone involved in organizing the competition for all the time and thought they put into the project.

Living in a small economically depressed area made fund raising a constant challenge. We attempted to salvage and recycle parts as much as possible and to keep cost to a minimum. Funds were raised using bottle drives, raffles, working for the Lions Club, holding teas at musical events, soliciting donations of money, and parts from businesses and government. The local communities have enjoyed following our teams' successes and deserve our thanks for all their support in our fund raising efforts. People were great to buy tickets or offer refundables during our bottle drives. This is life in a small town, when someone succeeds the town succeeds. Special thanks go to John and Theresa VanZutphen for generously letting us use their pool, for buoyancy testing and early trials. We had a media/sponsor night in June where we invited media and sponsors to an evening where we demonstrated the ROV and made a point to thank all sponsors. We also worked hard to thanks sponsor whenever speaking to media.

We would like to thank Tom Malloy, a retired electrician, who was there to answer questions, to set a high standard of excellence and for helping us turn our circuit diagrams into CAD diagrams. Most importantly we would like to thank our mentor Mr. Ed Dunphy. He puts an extraordinary amount of time running around behind the scenes making sure all the pieces are in place for us to reach our potential. Mr. Dunphy encourages us to set the highest standards for ourselves, think for ourselves and, when needed, will push us to reach those goals.

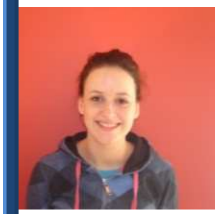
Reflections

Elizabeth Chisholm (Bouyancy/Co-pilot): Being a second year member on the Dalbrae Aquatic Robotic Team, I got to spend more time doing actual work and calculations rather than learning the basics. I focused a lot of time on buoyancy this year and I enjoyed the problem solving aspect of it. This project helped me make a decision about the career path I may take. It also helped me in physics when studying forces. When I graduate I hope to study sciences at McGill University.

Alexis Dunphy(Tools/Sensory Technician): I was part of the 2008 team, specializing in pneumatics. This year I learned more about electrical and tools, and being two years older, I had more confidence when faced with new challenges to speak up with solutions. As co-captain I also learned about leadership and responsibility that will help me any time I work in a group. The problem solving, organization, and way of thinking I used in this project will help me in my future career of sciences at Dalhousie University next year.

Rebecca Dunphy(Tether): Although this was my first year on the ROV team, I have been aware of the project for a few years. Being the only first year member of the team, I knew nothing about pneumatics, electrical, and especially using power tools. The team made sure that I knew what was going on. I feel privileged to have been able to work with such a talented group of people. I joined ROV in hopes of learning more about hands on work, problem solving and team work. Now I feel I am capable of facing any problem thrown my way.

Alex MacDonald(Electrical/Pilot): Milton Berle once said that, “If opportunity doesn’t knock, build a door.” That is exactly what I have done. I have looked for the opportunity to gain knowledge and perspective on my future career aspirations as an engineer. This ROV project has never stopped opening doors for me. It has provided expanded career possibilities like electrical engineering, which I was not considering until I started ROV.



Mallory MacDonald(Tools/Co-pilot): I came into this project with a knowledge a little knowledge of electrical systems but was limited in my understanding of other aspects of the ROV. This year I focused on the tools of the ROV; I really enjoyed brains storming the construction of tools. As co-captain I gained organization and people skills as well as communication skills when speaking to sponsors or media. These skills will help me immensely with my future plans of becoming a nurse.

Keane MacLean(Pneumatics, Pilot): Before returning to this project for my second time I worried if I’d be able to fit the time in with my heavy course load at school, but after thinking about how much I’d learned, how much I used these newly acquired skills in my everyday life, and how much fun I had, I felt I could contribute to the team once again. What I learned this year is that when drawing or brainstorming ideas on paper, assuming that they are going to work, doesn’t mean that they will always work.. After getting to know a lot about ROV’s and building them, they’ve intrigued me in pursuing a career as a ROV technician, which is the main option I am considering after high school.

Appendix A

DART Budget Revenue 2010

Name	Amount $	In Kind
Ideal Concrete	250	
B&N Distributors	100	120
Pauls Auto Glass		70
Whycocomagh Lions Club	200	
Nova Scotia Community College	2800	
Van Zuthphen Construction	1000	
Strait Regional School Board	4000	
Enterprise Cape Breton Corp.	5000	
Canso Ford	100	
Pearo Construction	200	
Total	13650	190
	Money Earned	
Xmas Raffle/Hockey Pool	1600	
Teas and canteens	340	
Bottle Drives	4520	
Bingos and Clean up	325	
Business Clean up	850	
Total money earned	7635	
Total Money In	**21285**	

Appendix B

Expenses

New Expenditures	COST
Mission Prop Expenses	75
Pnuematic Piston	59.13
pneumatic hose	42.5
nuts and bolts	40
pnuematic connectors	25.25
shrink tube	13.99
switches for motors	85.25
Speaker wire for motors	175.2
Tiburon underwater camera	155.38
glues	11.27
Buzzers for hydrophone	15.9
report covers and binders	38.33
marine silicone	22.59
silicone	13.5
2" PVC for pontoons	12.5
Printing of Poster	75
aluminum brief case	18
self tapping screws	26
inner tube for ballast tank	9.9
Friction lock connectors	35.97
tie wraps and tape	78
Tiburon Camera	189
Team T-shirts	290
	75.38
Total Expenses	**1583**

Donated/Salvage Items	d	s	Est. $
Underwater cameras		s	240
3 Syvylar motors		s	451
Pneumatic hose		s	20
elbows and tees	d		48
180 ft of speaker wire	d		45
pnuematic piston		s	70
mini-amplifier	d		45
pnuematic controller		s	55
1/2" PVC conduit	d	s	46
ballast tank PVC	d		3
Temperature probe	d		45
Ammeter		s	30
Lexon Sheet	d		70
Pressure gauge and regulator		s	90
air compressor	d		123
Jacks for Electrical Control Panel		s	50
Total Donate/salvaged			**1431**

d=Donated s=Salvaged

Travel Expenses

Meals	2430
Travel	13500
Accommodation	2010
Total Travel Cost	17940

Total Expenditures	**20954**