Dalbrae Aquatic Robotics Team
R.O.V. Project

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The Millennium Falcon

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From left to right: Erin, Spencer, Linda, Colin, Brittany, Johannes, Chris, Dustin, and Ian.

International Polar Year

International Polar Year (IPY) is the largest international program of scientific research focusing on the Polar Regions. This program started on March 2007 and it goes on for 24 months. There will be over 60 nations and thousands of participants from all over the world.

Polar History

The first people that lived in the Arctic were Inuit. The Inuit were there long before the Europeans. Most of the Inuit journeys went undocumented. They had been traveling over thousands of years in search of food and supplies. Around 330 BC came the first European explorer who was a Greek navigator named Pytheas. The Norsemen settled in Iceland around 850 AD. Gunnbjorn Ulfsson was the first person to see Greenland, but Eric the Red was the first person to visit and to set up a colony there between 982 and 986.

Polar Culture

As the commercial whaling industry and exploration by Europeans, American, and Canadians increased, the Inuit's way of life changed drastically. By 1960 there were few traditions left. Skin kayaks were replaced by motor boats. Harpoons and lances were replaced with rifles. Dog sleds were replaced with snowmobiles. Snow houses were replaced with prefabricated houses. They also have new ways of entertainment, such as: televisions, tape recorders, and telephones.

Works Cited

http://www.ipy-api.gc.ca/index_e.html
http://www.quarkexpeditions.com/arctic/culture.shtml
http://www.allthingsarctic.com/exploration/index.aspx

Abstract

When the D.A.R.T. (Dalbrae Aquatic Robotic Team) found out about the M.A.T.E. Remote Operated Vehicle (hereafter referred to as R.O.V.s) Competition, we were intrigued by this challenge that we hoped would teach us new skills that we wouldn't have an opportunity to learn otherwise. The R.O.V. required mechanical innovation in order to complete three separate tasks. The tasks included three diverse environments in which the R.O.V. had to function: a current of 0.1 m/s, water temperatures of -1 degrees Celsius (under an ice sheet), and surface waves in a chlorinated pool. To complete this project, we used engineering plastic resins such as polyvinyl chloride (PVC) to create a light and durable frame. We had three cameras: one for wide-angle vision (orientation), one camera focused on the gripper, and the other looking above to focus on the view overhead (specifically for task #3). Our gripper was supported by Plexiglass, and composed of a clamp, wood, and a pneumatic piston. Our primary power source was a twelve-volt battery. Our mobility system was composed of three motors (one vertical, two horizontal), and an inner tube (for variable buoyancy). Our design is simple, functional and classic.

Frame

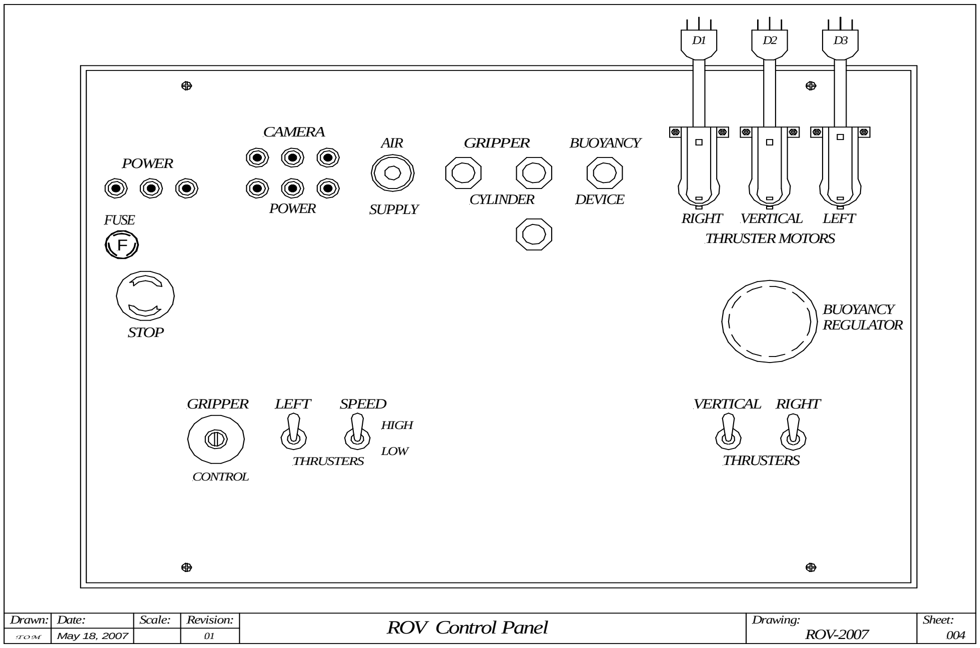
When we first began this project, our theoretical design was quite different from our final product. All of our designs were composed of PVC pipe, mostly because it was donated to us by the Nova Scotia Community College (NSCC), Strait Area Campus. It is light-weight and easy to use. Originally, the frame of our ROV was cumbersome and large, with the height double the length. The maneuvering motors were situated on the bottom sides of the ROV, which we found (in the end) gave us the most mobility. However, before we decided to go back to the thrust motors on the outside, we experimented with the idea of having them situated at the back of the ROV (to give us better reverse and perhaps maneuvering). We also experimented with the idea of having the thrust motors tucked in on the sides of the ROV, not protruding out of the main frame. This actually made it very difficult to reverse, and reduced our forward speed. We also played with the idea of curving the front end of the machine to make it more hydrodynamic, but it turned out that such a shape obstructed our arm, and made it more difficult to attach our arm. After much tweaking and experimentation, our final machine was similar to our original, but much more efficient and compressed. The final design is a rectangular prism which is simple and easy to adjust. Our vertical motor is situated in the middle of the ROV, sheltered by the frame, and giving us the best results when traveling up and down from the surface. This design also cuts down on surface area. Our left and right motors are situated on the sides, about an inch away from the back of the ROV. They balance out the weight of the arm (located on the bottom floor of ROV) and cameras (situated on top). The motors are situated to have a center of gravity in the middle of the ROV. The horizontal thrusting motors have shrouds surrounding the blades for protection. This also focuses the water flow from the propellers, helping our reverse movement. Our first camera looks down upon the gripper, and the second camera is situated on one of the top PVC pipes for a wide-angle view. Our third camera can see above or below the ROV. All wiring is attached to the sides of the frame to keep them out of the way, and then join in the tether in the top back PVC pipe.

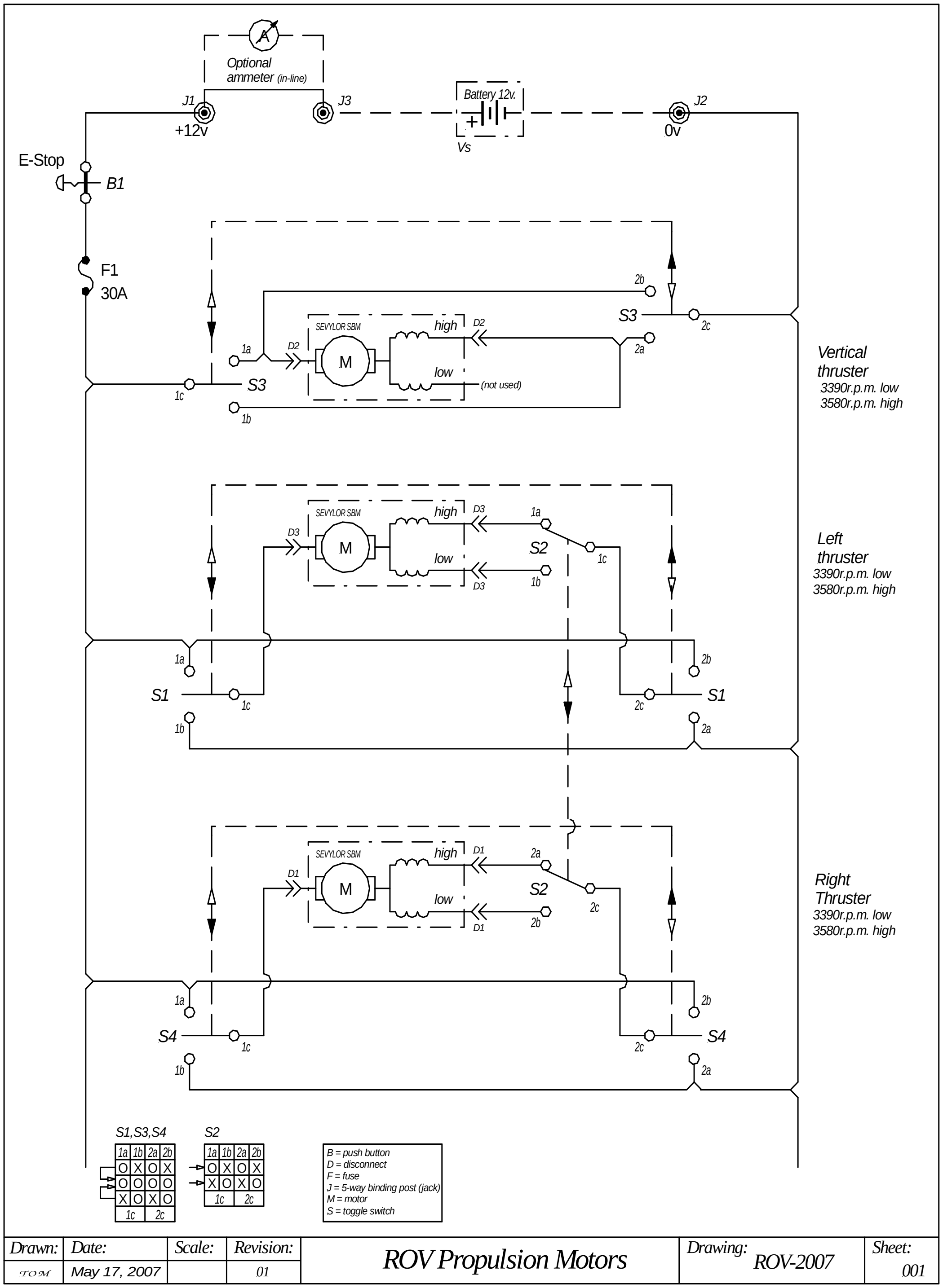
Dimensions:
Total side length: 62 cm
Length sides spilt into: 39 cm and 28 cm
Total length of widths: 33 cm
Centre Pipe Lengths Supporting Vertical Thruster: evenly split 14 cm for each PVC length, factoring out the length of the vertical thruster.
Weight: 15.2 kg
Total Height: 33 cm
Length of PVC Pipe Attaching Horizontal Motors: 13 cm

Control System for Motors and Gripper

To control our three directional motors, we constructed an electrical toggle system to regulate the electrical current for each individual motor. Our motors were powered by a 12 volt battery, connected onshore by two 22 meter lengths of #18 AWG speaker wires, which ran through our control console and 25 amp fuse to the R.O.V. Our control console consisted of three toggle switches, which controlled the left, right and vertical motors. Our pneumatic gripper was controlled by a two-way pneumatic valve, which permitted the gripper to remain in either the open or closed position. The air supply consisted of an 18.9 liter air tank, with which the operator could control pressure by an air regulator. The entire control panel is integrated into a suitcase for facility of transport, and all cables in the tether are completely detachable from the control panel.

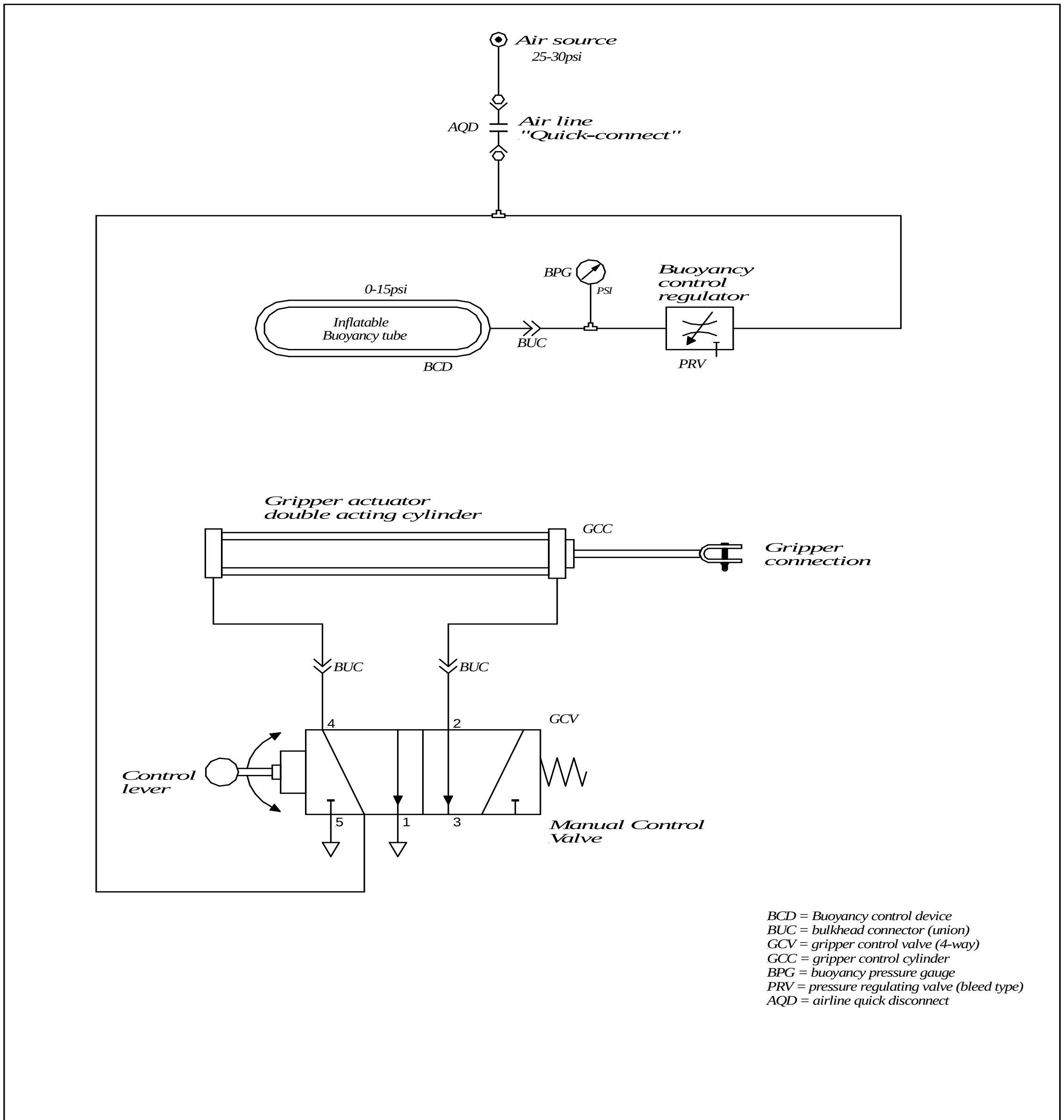
Control System





Propulsion Motors

Pneumatic Controls



Drawn:	Date:	Scale:	Revision:	ROV Pneumatic Controls	Drawing: ROV-2007	Sheet:
TOM	May 18, 2007		01			003

Propulsion Motors

Three Sevylor 12 volt boat motors make up the propulsion system. Each motor weighs 1.8 kg, for a total of 5.4 kg. We initially wired the motors so they always went on high speed but changed it so they can run fast or slow, to allow for a slower approach to the target. The motor spins at 3580 RPM. With no load, each motor draws 1.75 amps.

Current Draw		
All motors	18.87 amps	
Left motor	6.40 amps forward	6.35 amps reverse
Right motor	6.23 amps forward	6.25 amps reverse
Vertical motor	6.24 up	6.49 down

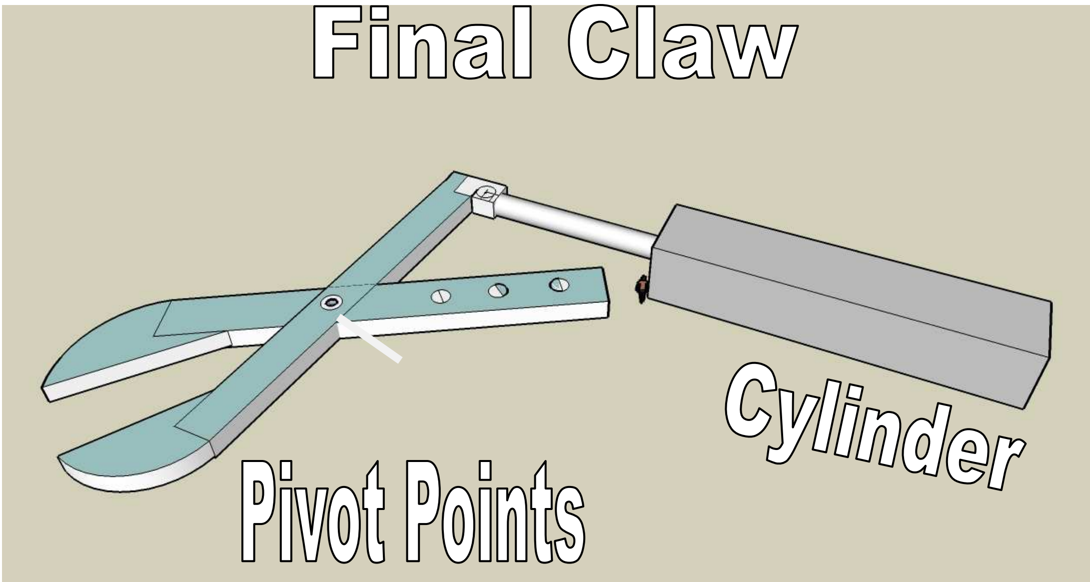
The two horizontal motors are positioned parallel to the length of the R.O.V.'s structure. The two thrusters are supported by the frame and placed outside of the frame. See picture below for view. We have placed shrouds around the props to afford them better protection. The shrouds had an added bonus of increasing reverse speed by approximately 20 %. The propeller blades for the vertical thruster were heated and bent to a greater pitch. This increased the upward thrust. The vertical propeller is housed inside the frame, providing the blades with some measure of defense from loose cables and ice. All motors were attached with lengths 1.27 cm of PVC pipe, screws, glue and T-connectors. The position of the horizontal motors allowed for maximum maneuverability. Once we achieved neutral buoyancy, vertical motion was smooth and quick.

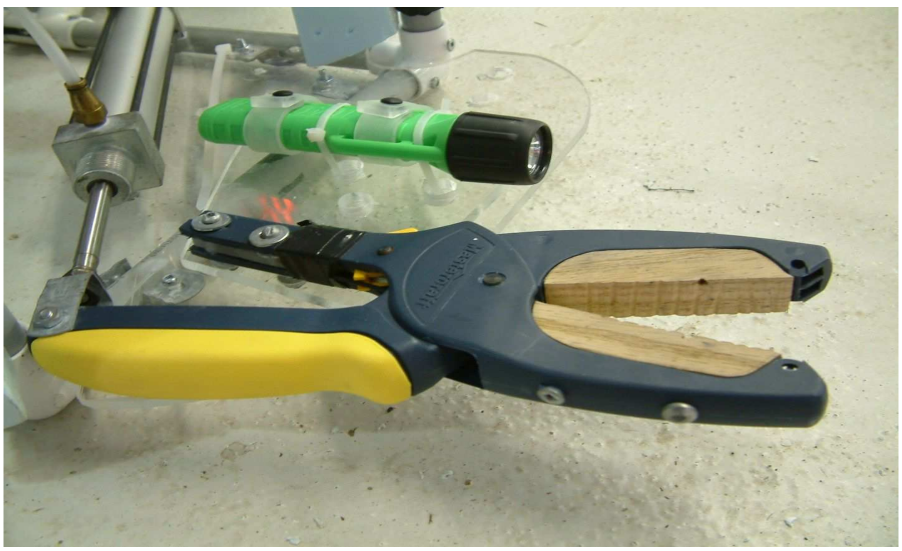
Forward speed was recorded as 0.51 m/s
Downward thrust of 10.0 newtons
Forward thrust of 24.5 newtons
Reverse thrust of 6.0 newtons

Motor plus shroud

Gripper

We knew that we would have to design and build some sort of device that would allow us to grab or manipulate objects. Our initial plan was to purchase a fully functional arm, but after spending several hours searching the web, we could not find anything to fit our needs (e.g., inexpensive and functional). So back to the drawing board we went, where we decided to create our own arm. We spent several weeks on our first prototype trying to construct it and get it working to our specifications. It was to be constructed completely out of metal. We were unable to make our first design work the way we wanted it to. This was due to the difficulty of precise machining that was involved in this project. Then we came up with a much simpler solution; using a Master Craft clamp gripper. This device's original function is to secure materials to the work bench and hold them in place tightly. We removed the locking mechanism found on this gripper, and cut a hole in the left handle where the cylinder was later attached. We filled the gripping mechanism with hardwood, in which we drilled a hole where the wood came together, at a 45 degree angle to facilitate the handling of the hot stab in task #3. The left handle was securely attached to a piece of plywood on the prototype, and later replaced with Plexiglas for our final product. The Plexiglas was chosen for a number of reasons; it was transparent, and fairly durable, as well as easy to cut and drill. The most difficult aspect of building the gripper was getting the arc movement correct. Our salvaged cylinder's stroke was too long, so we had to construct a metal bushing to be mounted in the cylinder to limit the stroke. The 861 kilopascals-rated cylinder is fed by 2 pneumatic lines, one to open and one for closing action. The lines are fed with air by a conventional 125 volt air compressor, located above the surface. We are very pleased with the versatility of our gripper. We feel that one very solid, functional tool is much better than a number of task specific tools that would need to be attached and removed between missions.





Master craft clamp gripper

Camera

At the beginning of the project, we were donated an outdoor security camera for use on our ROV. It was not waterproof. This camera was placed inside a 5.08 centimeter PVC pipe, and the back was sealed with a layer of epoxy, followed by cotton balls. We then sealed everything off with silicon. A piece of Plexiglas was placed on the front of the camera, and then sealed with silicon around the front. After a trial of the first design, it was realized that the camera was not watertight, so a new idea was implemented. The back, originally sealed with silicon and cotton balls, was taken out and replaced with paraffin wax. This design was not successful either, as water was still able to leak into the front of the camera. Later, the camera was redesigned with the same case, sealed with **silicon** at the back, and with the Plexiglas **epoxied** at the front.

Later into the project, we purchased a Sea View SuperMini 50 Series Black and White Camera, to supplement the donated camera. This camera was mounted to a horizontal bar at the top of the ROV, acting as our guide camera, giving us a vision of the gripper and surrounding area. The picture was found to be much clearer and more effective then our original camera. This camera draws 0.159 A. As a prize for winning the provincial competition we were loaned 2 colour underwater cameras, which we placed as our close up camera over top the gripper and the other one on the back, right hand side of the ROV to view what is above us for the second mission. This completely eliminated the need for the nasty camera. Each of these cameras draw 0.090 A.

Safety

While developing such an advanced system, safety features were essential for the well being of the people involved and for the mechanism itself. This would insure that little mistakes would not physically damage a person or ruin all the work that was put into the machine.

By placing shrouds over the horizontal motors, this ensured more protection for our motor blades and meant that no one would be hurt during experiments. By placing the shrouds over the outside motors it greatly reduced these risks and also enhanced the reverse speed by about 20% – an unexpected bonus. As well, we modified the shrouds by attaching them to the top of the frame by a metal rod. This had two purposes- to prevent the various tethers from tangling in the ROV, and supporting the shroud.

While practicing the missions, it came to mind that installing an emergency stop button on our control box would be extremely practical. This was chosen so that the driver would not harm anyone that was handling the R.O.V by accidentally pressing a button. If something was to go wrong a simple press of the button would stop all connections to the battery and shut off all controls. Also during these practices we would call out to the driver when the gripper was “OPEN” or “CLOSED” so that no one would be hurt around the gripper, thus ensuring all fingers would stay attached to the body. Though it worked beautifully during the practice missions, this would not be sufficient during the actual competition. That is why we developed the thumbs up signal in front of the camera to signify to the driver that all systems were ‘Mission Ready’.

During all working sessions in the shop and all trials in the pool the mentors constantly stressed the need for proper practices and the use of safety equipment such as safety glasses and life jackets until it became second nature.

ROV Handling Procedures

Having too much tension on the tether was always a huge concern of ours. We did not want any damage to the cable or put too much strain on solders or other connections. That is why we decided to put a piece of cut inner tubing around the top half of the cable, and attach it to the sides of the ROV, so it would act as a strain relief of the cable.

When attaching the control box to the machine, we decided to place plugs on the end of the tether and the control box, to allow easy connecting and maneuvering. When deciding what plug end went where, we decided to place the female plug end on the tether as to not allow any mishap to occur, such as someone mindlessly plugging the tether into the wall and destroying our motors.

Out tether is fitted with floatation about 1.0 m from the ROV end to allow the tether to float and reduce any downward forces. We also placed floatation at the point along the tether which would be at the water surface.

During this process, we thought a lot about the consequences of doing something wrong, which is why thinking about the safety of the ROV and the safety of anyone around the machine, always came first!

Our Challenges

We encountered many challenges during this project due to our numerous experiments and desire to build the most productive, efficient ROV. The first issue was choosing the best group of students that would each provide their own unique ideas and knowledge to the team. Many students expressed interest but after realizing just how much time each member would need to put into this project, most dropped out. Ten students were chosen, later one misjudged her prior commitments and resigned. When we started meeting as a team, we began discussing fundraising opportunities. Collecting such funds proved to be more time consuming and tedious then originally expected. Writing out detailed letters to every business in Inverness County did not give us the support we initially thought we would receive from our community. Through our distress we managed to fundraise doing bingos, manning canteens, and selling tickets to create a respectable ROV.

The geography of our team members was so diverse a lot of time was spent traveling to our designated working area. In actuality, time proved to be one of our most challenging aspects. To finish this project, 3 days a week were put in by each member, two after school hours and one weekend, full day get-together.

A flaw that our group found is the fact that each member is a perfectionist. Much of our time was used up by experimentation and small tinkering with the frame, and trying to make it the best it can be. This resulted in us building at least 7 actual R.O.V frames before deciding on this particular one. The frame we went with was small in width and longer in length to allow it to be as streamlined as possible. Finding the perfect place to situate the motors was also very challenging due to the weight of the mechanisms (1.4 kilograms each). With so much weight on each side of the R.O.V, it changed our plans with what to use as flotation devices and buoyancy. 4.2 kilograms of motors on this rig made it very cumbersome. Finding something to protect the left and right motors without being too heavy was also an experiment. We tested out chicken wire covers but the use of heating duct reducers as shrouds worked amazingly well and also increased our reverse movement. However, when we placed one on the middle vertical motor, it proved to be more of a burden, reducing the speed efficiency of the thruster. We took that shroud off immediately. Since the vertical motor is inside the frame we are not as concerned about material catching in the prop or the open prop being a safety concern.

Our gripper was initially designed by the team and attempted by a student at N.S.C.C. millwright program. Unfortunately, this undertaking proved too difficult and what was done was poorly done. With quick thinking our team was able to design and produce an arm more than adequate for completing every task. This arm uses a piston and air compressor to open and close.

Finding the perfect place to place the cameras was also a consideration, but once we built our gripper, we were able to focus the close-up camera on the gripper. We hung the wide-angle camera in the middle pipe, hanging down with the vertical motor attached to it. We positioned the camera so part of the frame is in view. This assists the driver with orientation.

Buoyancy is the key to a successful R.O.V. Without it, it would be very difficult to maneuver and stay at one level in the pool. As we added parts onto the R.O.V we realized we had to add more foam to keep the machine balanced. We noticed how bulky our R.O.V was getting with all the components and foam so we decided to hide some spray expansion foam in the pipes. This, however, proved to be a very bad idea. After some time in the pool, the spray foam began to act as a sponge, sucking up water until it was a heavy rock at the bottom of the pool. It was a mistake that forced us to rethink our idea and create a new frame. Our buoyancy is being acquired through the use of Poly-Stern installation attached to the inner edges of frame (making is less bulky and keeping it stream lined and more hydrodynamic). We also are using an inner tube on the top, attached to an air compressor and regulator, for raising the R.O.V quickly out of the water and for fine tuning buoyancy in different water conditions or when carrying loads.

Day after the foam

After attaching every component to the R.O.V., we needed to find the cable and tubing that would have the most flexibility, and strength to endure being pulled through the water. We measured the amount of each cable we needed and joined all these wires with electric tape. Our first sections of tubing were donated to us, but they were old, and had many leaks throughout the length of them. We later acquired some lengths of better, newer tube from a donor company. B & n Distibutors

Late in the project we attempted to put an air regulator on our R.O.V. and we hooked it up to the tube. It didn't work as well as we hoped. We needed approximately 21- 34 kilopascals in the inner tube to fill it. We tried to use the air regulator to keep the buoyancy of the R.O.V. neutral at the different depths. However, as we tried to adjust the air level in the tube, the length of the tether delayed the arrival of the air. For example, if we were rising, and wanted to remove air, we would still accelerate upwards, inflating. During one experiment with the inner tube (for controlling our buoyancy), we traveled all the way down to the bottom of the pool. At the bottom of the pool, the atmospheric pressure and weight of the water increased, to the point that it pushed the air out of the inner tube, into the tether line. We lost buoyancy but our air pressure guage read 207 kilopascals at that time. We actually had no air in the inner tube, and the gauge was reading the pressure of the water on the tube and the air pressed into the tether. Alarmed, we tried to raise the R.O.V. to the surface by adding more air. The driver opened the regulator to bring air to the tube but when we started rising, we accelerated very fast, and air continued to fill the tube. The length of the tube made quick adjustments very difficult. Once the R.O.V. reached the surface, the inner tube exploded from the pressure within.

After all was seemingly secure and we thought everything was coming on our side of the fence, one of our motors began to have technical difficulties. We took an ammeter reading, and found that it was drawing too much current. It eventually stopped working. Disappointed and very anxious, we took it upon ourselves to find out why this was so. Opening up the motor we found out that water seeped into the inside of the motor. We were unable to afford a new motor for this project. However, we did not let that stop us from reaching our goal. We cleaned out the motor, rewired it, and resealed it so that nothing can seep into the motor again.

This project, as you can see by our extensive list of complications was a long learning experience and we have gained a wealth of knowledge about creating a Remote Operate Vehicle.

Lessons Learned

After many hours of work, we have learned many interesting facts about the world of electronics, pneumatics and engineering. We have also learned a lot about team work, time management, and respect for people who take time to work with students even though they had many other things to do during that time. We could not have done it without them. We have learned that the basics of electrical wiring are difficult, but not beyond us. We learned the hard way that a short circuit is created when the positive and negative wires are allowed to touch if they are not taped separately. We were somewhat intimidated by the concept of pneumatics, but in the end it was not at all challenging to grasp. Basically it's air in and air out. Just make sure that all of your connections are leak-proof. Although most of us felt confident in our computer skills, we did need to learn a number of new skills. Mr. Malloy was great in helping us take our hand drawn circuit diagrams and make them look more professional with AutoCad light. We panicked at first when our technical report was way over 2Mb but converting our photos to jpegs enabled us to get our file size down. Buoyancy has taught us that there is not always an easy equation where we can solve for a variable and find the unknown. Some problems require experimentation and brainstorming to solve.

Here are some thoughts from the team members themselves:

Linda: "I have learned about the world of engineering, how pistons work, how hydrodynamics is very important and how complex robots can be made."

Brittany: "I found out that designing, developing and working a Remote Operated Vehicle is very tedious and I am at awe to anyone who does it for a living. I salute you."

Chris: "I learned how to use Solid Works, a lot about schematics and that buoyancy is a touchy area."

Colin: "I learned the importance of how little mistakes can screw things up in a major way."

Johannes: "The importance of getting a bunch of crazy teenagers all working on one task."

Ian: “I learned that things that do work on land do not work in the land of aquatic engineering.”

Erin: “I learned a lot about engineering, design, and the importance of trial and error.”

Spencer: “I learned a lot about electricity and circuits and would like to have a future career with electronics.”

Dustin: “I learned that when you go into projects, you won’t be flying through. So be prepared for lots of hard work.”

In essence, we all felt that a great deal was learned about the world of engineering, pneumatics, electronics, and hydrodynamics. We discovered that certain things do not work, not matter what the manufacturer ‘guarantees’. This project was very much worth the time and effort that was put into it by all of the members of the team.

Future Upgrades

If our school’s team were to attempt this competition in the future, there are many things that we would change to make our R.O.V. more reliable, quick and smooth. Instead of the cumbersome vertical motor, we might try a bilge pump and a ballast tank to facilitate travel up and down. We would release air to travel downwards, and increase air to send it back up. This would greatly speed up the missions, as well as giving us a great advantage for staying buoyant.

We would also increase the intensity of our fundraising to supply us with the funds for better equipment. Although we did fundraise, we could have done a more satisfactory job at raising the necessary finances. Time and luck were working against us on this project. This is something we would pay more attention to if we had to do this all over, and start earlier to try to minimize time lost to mistakes.

Team Evaluation

Overall, this has been a great learning experiment, for students as well as mentors. We found that the most rewarding thing was finally finishing something, and getting it to function just the way we wanted it to in the water. Most of our meetings were very successful, but occasionally there were times when we had trouble keeping everybody organized and on task. One of the things that I think we would do differently is trusting ourselves more, and not passing any task off to unreliable people. All in all, our team has worked very hard, and extremely well together. We have really bonded as a team.

Acknowledgements

Throughout our learning experience of designing and creating our R.O.V., we have been touched by the assistance of many friends, families, strangers, and companies. We are very grateful for the thoughtfulness, time, and energy they have given to us.

Our mentors were Ed Dunphy, Nelson McEwen, Stanley Cameron, and Dan MacPhee. Their encouragement, expertise, and quick thinking were instrumental in getting us to the end of this project. They have coached us and helped us complete things on time. They make sure that we worked safely and that we were given the chance to take control of this project and make it our own. Tom Malloy was a great help in all of our schematics. Brenda Dunphy was the event organizer for Nova Scotia. She was a great help with her knowledge of the competition, and her positive attitude. As well, Bob the security guard, who has always been there to open the doors, and give us a hand and a key for opening various rooms.

Our finances have been supplemented by the generosity of many businesses, both big and small. The companies that have helped us out include Home Hardware, Central Supplies, B n' N distributors, Ceilidh Co-op, Freshmart, Dalbrae Academy, Van Zutphen's, NSCC, East Coast Credit Union, Snows Econoprint and the Whycocomagh Lion's Club. Our school and communities were very supportive of our fundraising efforts such as canteens and ticket sales

We also would like to thank NSCC College Prep that has organized the regional competition, and given us the chance to take part in this great learning experience. Without this opportunity given to us, we never would have learned the things that we now know. We would have never had the chance to find out more about the careers in ocean related jobs.

Budget

	EXPENDITURES	Money In	Source
School start up grant		400	
Ceilidh Fisherman's Co-op		100	
Ideal concrete		100	
Mabou Freshmart		200	
Movie		104	
Snow's econo-print		50	
ticket sales on rug		50	
Port Hood Co-op		50	
Whycocomagh Lions Club		125	
East Coast Credit Union		100	
Track and Field Canteen		450	
compressor	112.91		
battery charger	50.25		
Epoxy ,contact cement	31.62		
plumbing supplies for task apparatus	235.5		
PVC pipe and muffler clamps	14.22		
Light	15.99		
underwater light	45.59		
inner tubes	27.54		
underwater camera	223		
Tape ,mirrors, tie wraps	34.56		
PVC connectors	20.35		
Bungees ,clamps, hose	45.35		
Tools and tool box	226		
silicon, tape, glue, tie wraps	55.29		
Donations			
3 motors			NSCC
security camera			NSCC
60 ft pneumatic hose			NSCC
elbows and tees			D&R distributors
180 ft of speaker wire			Home Hardware
pneumatic piston			NSCC
Two underwater cameras on loan			NSCC
Duct work pieces			NSCC
Total expenditures	1138.17		
Total Donations		1729	