A.C.E

Atlantic Canadians Eh!

Figure 1: ACE the ROV of the Nova Scoceaneers

Nova Scoceaneers
Students of Auburn Drive High School

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ABSTRACT:

This is a technical report of the Remotely Operated Vehicle (ROV) ‘ACE’, constructed by Auburn Drive High School students as an entry for the 2006 MATE competition. The challenges our ROV was constructed to face are three: The ROV must place a simulated communications module (a Plexiglas box) into a trawl-resistant frame; the ROV must open a door and insert an instrument cable connector into a port inside the communications module, and the ROV must remove a release loop to release an acoustic transponder. These tasks must be completed in approximately twenty minutes, or shorter, and may be done solely via remote control and remote vision via any sensors attached to the ROV. Ultimately, our efforts will be compared to other teams in competition attempting the same goal, at the Marine Advanced Technology Education Center event. This technical report shall chronicle in detail the methods used to defeat these challenges, our construction methods and design methodology, and our skills and knowledge acquired as part of this unforgettable experience.

PROJECT SPECIFICATIONS:

Frame: The frame is constructed of one-inch (2.54cm) diameter PVC pipe and connectors for PVC pipe, including T, Cross, 45° joints, 90° joints, and miscellaneous others. ACE's frame is composed of two main segments: a lower rectangle with a size of 32 by 39 and a higher rectangle of dimensions 50 cm by 37 cm. These are joined by PVC pipe of length 39.5cm. In addition, each rectangle has another PVC pipe running through it's midsection, though the upper PVC's bisector is made lower than the other two sides by use of 45° joints and T-Joints. An assembly of many joints and pipe form "hooks" to hold the pneumatic buoyancy tube in place on the upper part of the ROV. Also, PVC pipes extend from the back and from the middle of the ROV to provide mounts for cameras. Finally, "feet" of PVC extend approximately 5 cm below the frame to hold securely on the electronics module.

Video Cameras: The cameras are located in two places: one, camera provides a general view of the ROV in it's surroundings, and is mounted on pipe extending behind the ROV's main body, while the other is closer to the ROV's two mechanisms, the pneumatic claw and module release mechanism. The cameras are both identical Lorex CVC 6991 cameras, with one hundred feet of cord, are submersible to one hundred feet, have a 3.6 mm wide-angle lens, and a CCD chip that provides extremely good resolution images of 350 lines, and a light-sensitivity of .1 Lux. They were purchased after the team decided to buy waterproofed cameras rather than attempt to waterproof them ourselves. The cameras are waterproof and have been tested to work more than adequately at all depths that we have been able to test our ROV in.

Figure 2: A video camera

Control System: The controls of ACE work by a relatively complex series of switches and relays, which provide the single controller a low amount of current and direct the flow of current to the thrusters, using eight buttons of the controller. This controller is a modified ‘Micro Vindicator’ 6-button PC game pad with an additional 4-directional direction pad. This system is purely on/off and is capable of moving forward, turning, or backing the ROV, provided the motors function correctly, with a single button. The ROV’s pneumatic manipulator and electronics module release mechanism are controlled by the controller. See Appendix A for detailed schematics.

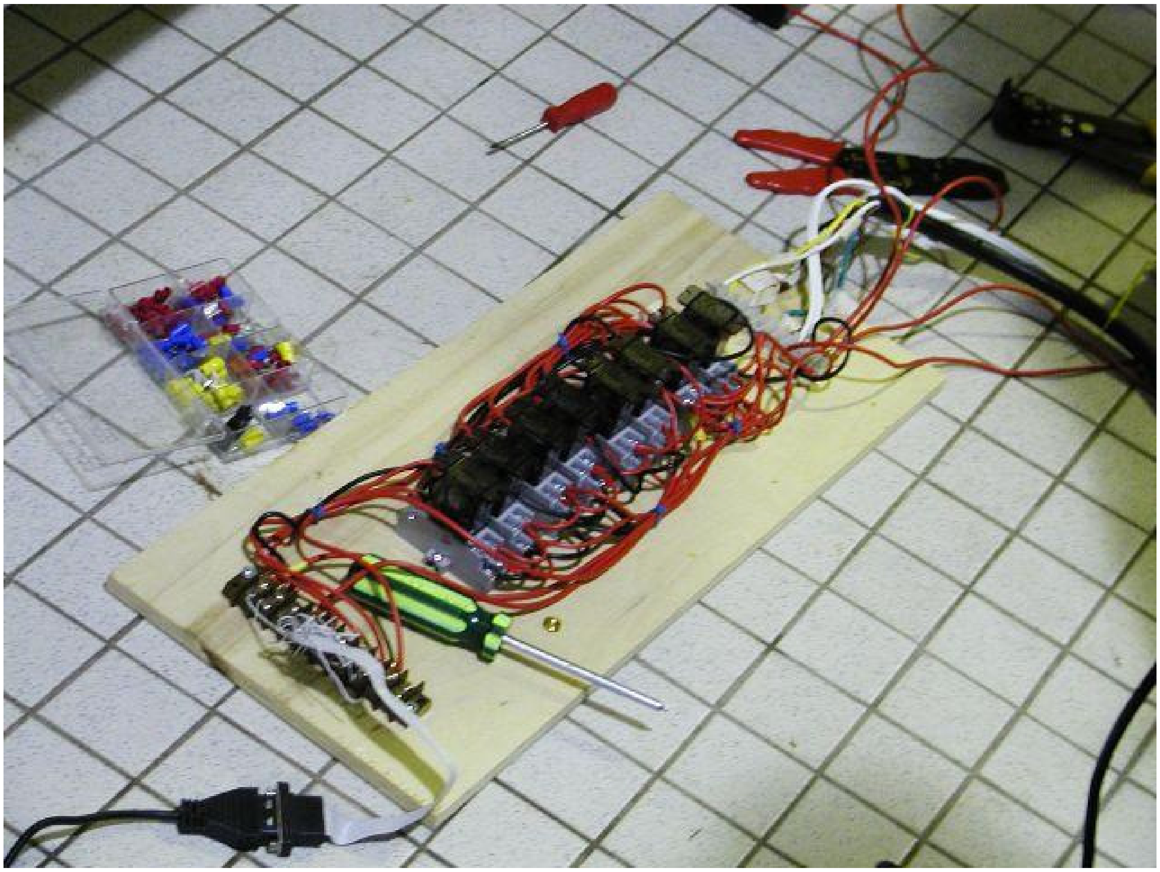

Figure 3: Prototype of Electrical Control System

Thrusters: The ROV has a total of three thrusters, all identical Sevylor boat trolling motors of the following specifications according to the manufacturer: 12 Volt Boat Motor, weight: about 1kg cut down as on ROV, low speed mode 3390 RPM 2 kg thrust drawing 5.8 amps without shrouds. Once disassembled and fixed by reducing the motor’s stiffness, they consumed approximately 7 amps when moving forwards and 7.5 in reverse, each. They also produced approximately .9 N of force in the forward direction, and .3 N in reverse, tested by measuring the amount of force a motor produced when lowered into water. This was increased to an approximately 10 amp draw, with approximately 1.0 N of force both in forward and reverse, by modifying the propellers. They were waterproofed by drilling holes through the side of the plastic pipe built into them, running cables through these holes, and then applying waterproof silicone sealant. They were otherwise waterproof already. Two of these motors serve as forward, reverse, and turning, and are mounted on ACE's lower sides, outside the main body of the ROV. The third is mounted near ACE's top and serves as an additional vertical thruster, and is not shrouded. The diameter of the three-bladed propellers is approximately 12 cm. The two forward, reverse, and turning thrusters are shrouded.

Figure 4: Thruster, with manufacturer's propeller attached.

Pneumatics: The ROV has three systems that work via pneumatics. A module release mechanism is primarily a pneumatic piston from which the electronics module is held by its center U-bolt. The claw is also a pneumatic piston that adjusts the position of a claw by means of an attached plastic rod, allowing the claw to open and close horizontally. Finally, a tube inflates or deflates to raise or lower the ROV even under extraordinary loads.

Tether: The tether is composed of multiple cables tie-wrapped together approximately every meter or so, and is approximately fifteen meters long. These cables include two camera cables, eight power cables for motors, and three air hoses for the pneumatic systems of ACE which add buoyancy to the tether, along with pieces of extremely buoyant bubble wrap and foam that further add buoyancy.

BUDGET:

Tools	$350
Components	
• Material Construction	$400
• Motors	$255
• Electrical	$375
• Pneumatics	$430
• Video System	$250
Pool Rental	$250
T-shirts	$915
Total	$3225

DESIGN & TESTING PROCESS:

The group met every Thursday evening (6P.M.-10P.M) and Sunday (10A.M. 4P.M.) to design and build ACE from the month of February to the start of the competition. We first built a prototype, which worked poorly, but the experience of building it taught us a great deal of building ROV's and thus prepared us to build ACE. Much of the control system was originally used with the prototype and survived mostly unchanged except aesthetically to the final version, ACE. Typically, on any given day between one and four group members would be missing due to other activities, and anywhere from three to eight mentors would be present. ACE was built frame-first. Thrusters were then added on, as were the cameras. Originally, a system involving a bilge pump and plastic tubing was intended to release the electronics module, but it lacked enough force to push the pipe as intended in the design. Also, a simple hook of PVC pipe proved practical for the opening of the door and the removal of the release loop in the mission, but experimentation proved that attempting to pick up the communications cable with the hook was difficult. Finally, we had impossible difficulty raising and lowering the ROV using solely a motor. Therefore we 'killed three birds with one stone' by introducing the pneumatics system. Throughout May and June we were able to test our ROV in a pool for two hours per week, which allowed us to test and modify our ROV extensively with knowledge of the results of our latest idea. This allowed us to test much of our ROV as it was being constructed.

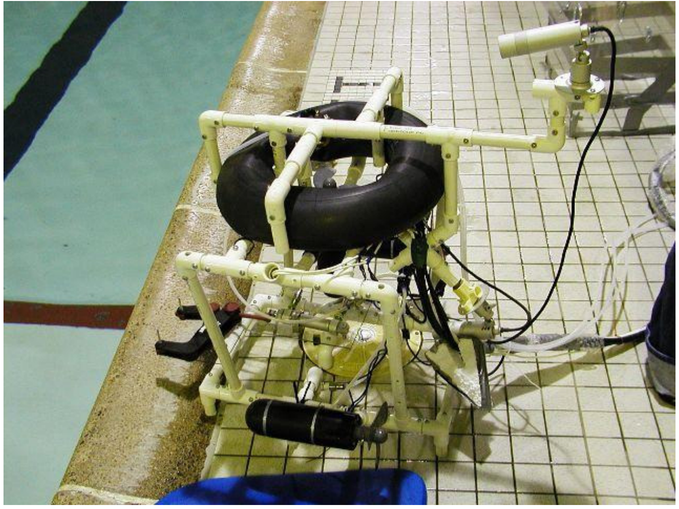

Figure 5: Partially Completed ROV about to be tested in water

DESIGN RATIONALE:

Frame: Members of the team decided to build out of one-inch PVC pipe, as it was light, durable, rigid, and inexpensive. While other materials were considered, it was decided that it would be best to use a material that was easy to modify by cutting and drilling, and was relatively safe to work with. The ROV was initially to be held together by glue but it was soon decided that screws were infinitely preferable as they allow for mistakes and modifications much more than glue. The shape grew from mission specifications: the bottom was designed to fit between the other U-bolts of the electronics module, while the upper area was larger to allow for the pneumatic tube and to allow for more distributed buoyant material, as well as better support for the motor shrouds.

Video Cameras: We decided as a group that we had adequate funding for two video cameras, and that we did not want to spend time attempting to waterproof them ourselves when there were so many other difficulties to assail as well. Therefore, we purchased two video cameras suitable for underwater work, selected on basis of their features and price, and mounted them to the ROV by means of a piece of pipe originally intended to connect multiple PVC pipe at a wall drilling a hole into the cameras stand. The cameras were placed as they were on the ROV to provide a general overview for maneuvering, navigation, lowering of the electronics module, and so forth along with a close-in view showing the manipulating claw and the release mechanism to better control them. We attempted multiple different places for the cameras and found this optimal through trial and error.

Control System: We discussed moving the ROV purely by switches, but decided on a joypad or joystick as being easy enough to implement and much easier to control. The relay system was used because it was (relatively) uncomplicated for students to understand, and no student on the team had expertise with programming computers, so due to time constraints a relay system was used. The controller, the Micro Vindicator Six Button PC controller, was selected because it was quite simple and uncomplicated to modify while possessing enough functional buttons to be of use.

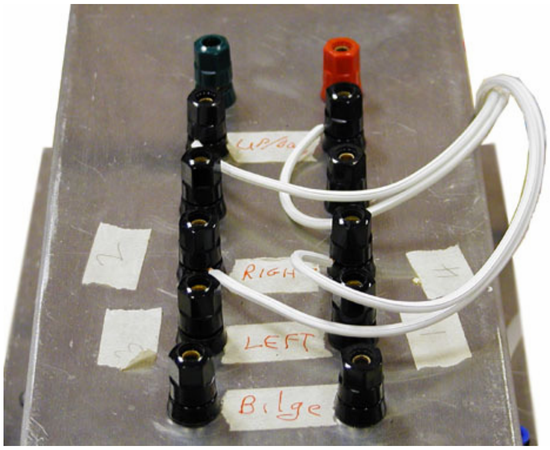

Figure 6: Exterior of the prototype of the control system

Thrusters: A mock-up of the Plexiglas box that is the electronics module we must transport to the trawl-resistant frame indicated that we would experience a lot of drag as we went through the water, so these trolling motors compensate for that by being quite powerful. While we still could not lift the module using solely thruster power, these allowed us to at least maneuver fairly fast with it. Our motors were shrouded in spite of the fact tests indicated that the thruster were more marginally less efficient with shrouds. Also, going in reverse was less efficient going forwards. This was initially demonstrated with the use of a single shroud on one of the two identical forward and reverse motors causing the entire ROV to turn quickly in the direction of the not shrouded motor when moved in forward and the same to happen in reverse. This proved empirically that the shrouds decrease the motors' efficacy. This was further emphasized when tests showed the following:

All statistics are per motor	Original Propeller Without Shroud	Original Propeller Shrouded	New Propeller Without Shroud
Force (forwards)	.9 N	.8 N	1.0 N
Force (reverse)	.3 N	.2 N	0.9 N
Amperage (forwards)	7.0 amps	7.5 amps	10 amps
Amperage (reverse)	7.5 amps	7.8 amps	10 amps

These results were obtained by testing the propeller in water connected via the control system to a battery, and measuring the amount of force produced with a spring scale on pipe the motor was attached to, then calculating to adjust for the distance the measurement was from the force that was measured.

We decided as a group long before doing this test that shrouds were a necessity as long as they didn't reduce efficiency too much, as they would stop cables from tangling in propellers, as one of our earliest experiences with the ROV indicated was extremely likely to happen. Heating and bending the manufacturer's propellers into a more angled shape made propellers that proved remarkably better at both forward and reverse motion Also, for use in the vertical motor a normal propeller was attached upside-down so that the downward direction could receive maximum force while the motor's weight remained towards the bottom of the ROV.

Pneumatics: We needed to have the capability of lifting the module in order to reliably drop it into the trawl-resistant frame. This meant we would have to have some form of ballast, as even the best of motors we had using more power than would be available at the competition proved unable to lift the frame. This meant we needed a ballast system that could become neutral after dropping the container – so naturally pneumatics came to mind, as the team had already prohibited the idea of trying to pump water in and out of areas and other forms of ballast. This led us to consider using pneumatics for the other applications of the claw and the module release mechanism, which proved extremely effective. We decided to mount the pneumatic solenoid controls on the controller rather than on the ROV itself. This allowed us to use standard solenoids that did not need to be waterproofed. A consequence of this decision is that the system required three separate air lines on the tether rather than only one. However, it also meant a smaller number of electrical wires was required on the tether.

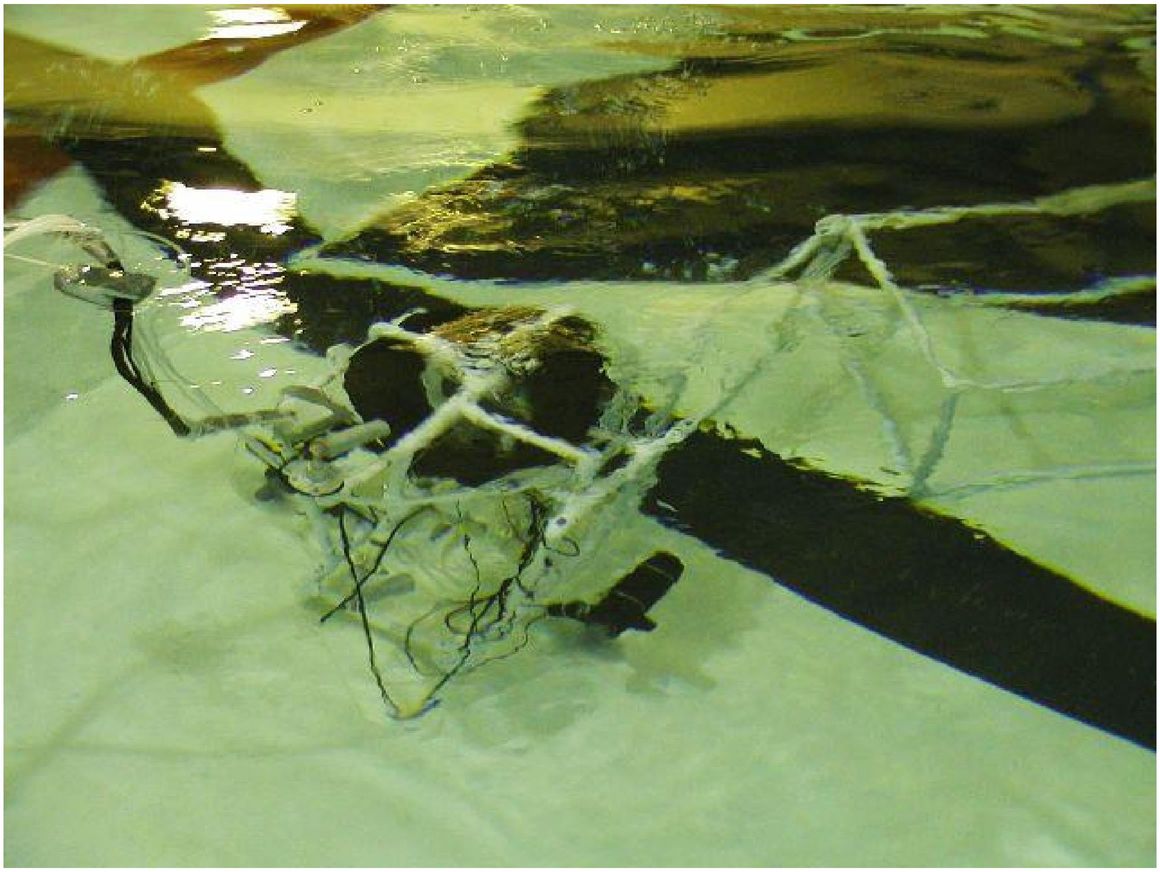

Figure 7: The Pneumatic Claw In Use (Opening a Door)

Tether: Tether with sufficient wires to the ROV with buoyancy added and so forth proved to be extremely expensive, so we made do by using ‘homemade’ cable tether instead. The tether of the ROV was assembled from many distinct cables tie-wrapped together, including three air hoses, two camera wires, and eight electrical wires.

CHALLENGES:

Technical: Several technical challenges beset us from the beginning.

A) The Module: We knew it was going to be difficult, but we all underestimated the difficulty of lifting and dragging the electronics module using the ROV. It continually sunk us, dragging us quickly to the bottom of the pool. This was completely unacceptable to us, as we did not want to maneuver the module in by luckily driving it in before it dragged us to the bottom, our only other option. We overcame this by adding "removable ballast" to our ROV in the form of a pneumatically inflated buoyancy.

B) The Module Release Mechanism: We were for several weeks unable to dependably release the module. Our initial designs revolved around using a bilge pump on a large piece of pipe to propel the large piece of pipe over smaller pipe releasing the U-bolt that had been caught by the large piece of pipe. In a sink, it looked to have enough power and slide easily, but it was found in the pool that the power wasn't enough to overcome the force of friction and the pipes' tendency to bend when pulled downwards. This was also solved with the introduction of pneumatic pistons.

C) Electronics: We had many electronic difficulties relating to the ROV's controls. There were many faulty wiring due to student inexperience and wear-and-tear on the equipment while we were testing other things, etc. On one memorable occasion all of the circuits of the ROV were short circuited to the same metal panel by accident, causing a massive short-circuit. Eventually, all the bugs were fixed and the joints all soldiered or otherwise secured, but there were many unfortunate problems.

D) Voltage Drop: Originally, we had a tether greater than 30m in length. We lost an extremely large amount of voltage running through this tether and it's wire, as well as the wire of the control system, and therefore had less efficient motors. We reduced our tether to a much more reasonable size, paralleled it's wires, and rebuilt the control system entirely our motor's power improved remarkably. As a result, we reduced voltage drop greatly.

Personal:

A) Attendance: We were missing students virtually every day, due to other activities. This unavoidably disrupted work and caused us to lose valuable time. This was a constant battle with attendance rather than any particular incident. This was enhanced by difficulties getting time during school hours during which we could work on ACE.

B) Insufficient Planning: We ended up having to build and rebuild the ROV multiple times because we were constantly changing our ROV. For example, we implemented and removed an extremely large motor twice first because we wanted the power. Afterwards, we didn't think we'd need as much as we had so removed it for efficiency. We then found that we needed extreme amounts of power to lift the Plexiglas box, and finally found we couldn't lift said box using even more power than we'd be allowed at competition. This resulted in wasting a great deal of time adding and removing the motor. This lack of planning and occasional absence of team coordination manifested itself additionally as difficulty meeting during school hours, and difficulty obtaining components (running out of PVC t-joints twice, for example).

C) Arguments and Disagreements: There were many heated discussions about the various ROV design decisions. For example, there were many disagreements about the method of propulsion, the method of grasping the electronics module, and so forth, as well as disagreements between different groups about various procedures such as whether it was valuable to go to the pool every day possible or not.

TROUBLESHOOTING TECHNIQUES:

Typically, our troubleshooting technique was a two-phase process. We first assessed the problem via testing the ROV in a pool. This assessment was to attempt to see if the problem was temporary (i.e. a wiring error) or chronic (a design flaw). The assessment also decided our response: if a system almost worked, we redesigned or modified it. If it failed completely and had no hope of ever working due to a critical oversight, we began brainstorming then implementing new ideas. An example of this 'complete failure' was our attempt to build electronics module release mechanism of a bilge pump, using the pump's thrust to move some PVC pipe over other, similar PVC pipe. Though the idea worked well in a test in a sink, with the weight of the electronics module and under a great deal of water, the test proved a failure, even after extensive modification- there simply was nowhere near enough thrust, and adding more or more powerful bilge pumps was infeasible given limited space and difficulty running more lines of wire through the tether. Another example of this was the trolling motor's propellers providing insufficient force in the reverse direction, a problem that caused almost insurmountable difficulties maneuvering, until it was resolved with the introduction of a new propeller (manufactured by heating the old propellers and bending the propellers' into a new shape) that had equal force in both forward and reverse at the cost of some additional current draw.

Our troubleshooting process of the more 'minor' problems can be delineated into two phases: locating and identifying the problem, and fixing it. The most difficult usually proved to be finding the problem. For example, we had problems with motors not responding at all to the controls, so we separated the motor and wiring systems, tested the motors with a battery to see if it was a mechanical issue and tested the wiring system connections with a meter. If it proved to be a problem with the motor, we took said motor apart, tried waterproofing differently, etc, and if it was a problem with the wiring we checked connections etc. Both problems happened multiple times, so we became quite experienced at the search for flaws. Sometimes, however, problems' sources became blindingly obvious- For example, once when wiring the controls into their current configuration, and adding a new metal board to mount connection points to the ROV's tether on, we accidentally shorted the entire system through the control board, a problem which became obvious extremely quickly with the melting of some wires. Fixing that problem was the most tedious part of that particular incident, as it was necessary to change some parts and insulate others.

LESSONS AND SKILLS GAINED

The lessons learned on technical and teamwork issues alike were quite numerous. For example:

- Alex Smith: I learned the lesson that hard work is usually rewarded- by more hard work!
- Kaitlin Wierstra: Throughout this experience, I have learned the importance of co-operation and teamwork.
- Timothy Pohajdak: During this project, I learned a great deal about building and submersibles, particularly the importance of a keeping the weight towards the bottom and buoyancy at the top, the importance of keeping as much heavy material as possible towards the ROV's center, and about simple electrical systems and circuits. I also learned about trying to keep ideas **simple**!
- Jamie Williams: I learned about the importance of hydrodynamics and ballast when building an underwater vehicle.
- Megan Henry: I learned about the various uses of tie-wraps, pipe fittings, glue, and how to use a number of tools.
- Sara Brushett: This has been great experience learning new and interesting things, making new friends and having great mentors that help us achieve our goals. My favorite part was the hands on experience.

FUTURE IMPROVEMENTS

- The tether of our ROV is distinctly unrefined and "messy". While we've been able to work with it by adding buoyancy and tie wrapping it together, it should be possible to make a better tether than we have currently.
- The ROV's shrouds could perhaps be improved in their method of attachment to be more sturdy and less easily moved, as currently it is quite flexible, though functional enough.

APPLICATION OF ROV'S

Two of the Nova Scoceaneers' supporting organizations use ROVs as an important part of their operations. Environment Canada uses ROVs to inspect water courses and to retrieve soil and water samples for further analysis. This work is important to ensure the future quality of Canada's natural water resources. Canadian Superior employs ROVs to observe and inspect oil and gas drilling operations in harsh offshore environments. ROVs help companies like Canadian Superior be more productive, and be using ROVs instead of divers, oil and gas companies eliminate any risk to human life. These organizations thus serve to support ROV technology by using and funding this technology.[1] Environment Canada purchases ROVs for use in underwater exploration, particularly of sunken vessels that may pose an environmental risk, as well. Environment Canada's Office of Enforcement runs marine operations in support of environmental protection above and beyond it's own mandate including partnering with many other regulatory enforcement agencies as well as the police, in bodies of water on Canada's east coast. Environment Canada's projects include searching for and recovering evidence of illegal ocean dumping of material, locating stolen vehicles, finding human remains and illegal weapons, obtaining videos of fish kills near industrial outfalls due to pollution, searching for illegal substances on the hulls of ships, and supplying records for ecological impact appraisals and criminal investigations.[2]

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[1] Pers. Com. Steven Foran, Director of NSCC's Energy Group, Institute of Technology Campus.
[2] http://www.deepocean.com/html/body_environment_.html, "Environment Canada Chooses HD2".

ACKNOWLEDGEMENTS

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Glenn MacLeod
Dave MacPherson
Dan Bolivar

Teachers at Auburn Drive High School:

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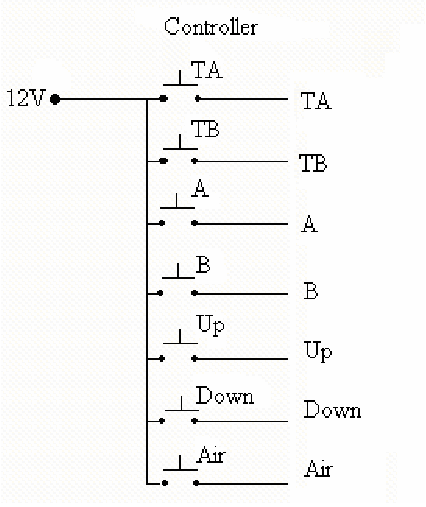
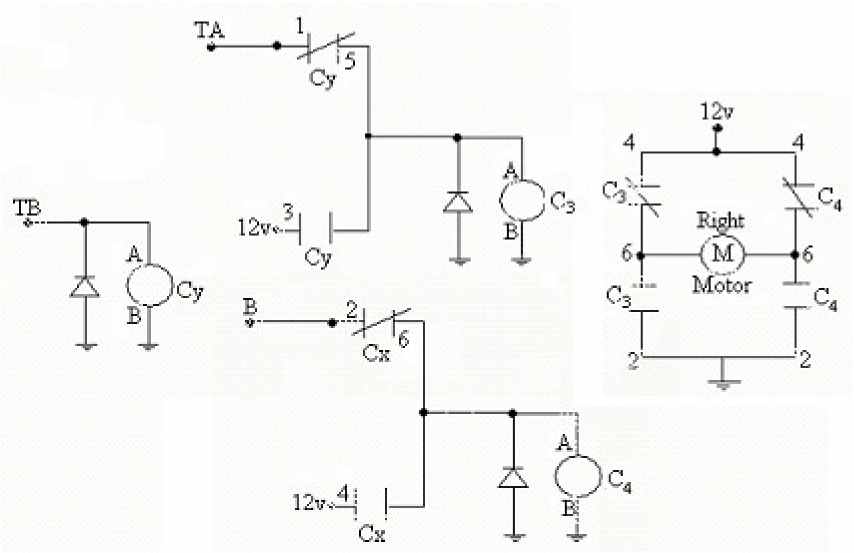
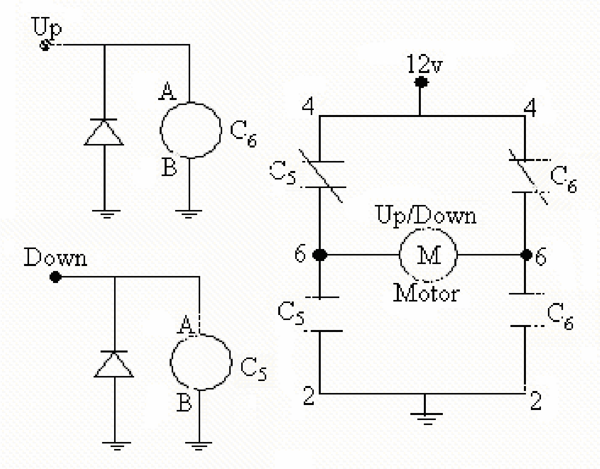
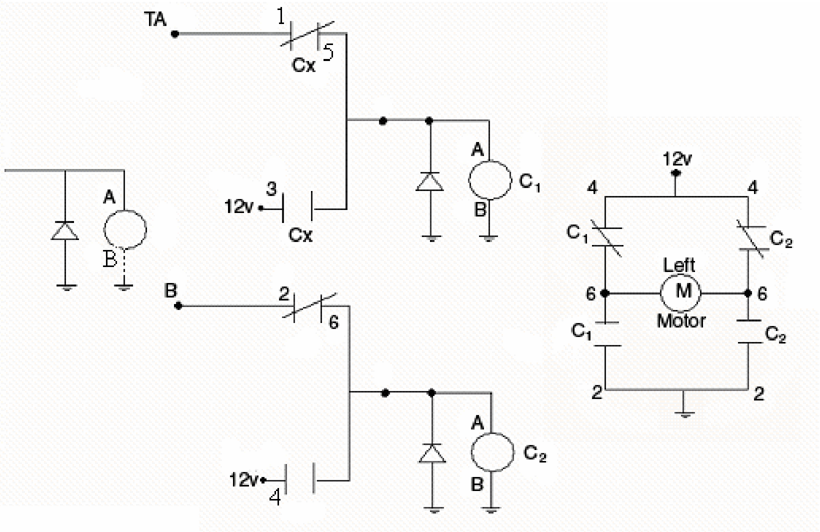
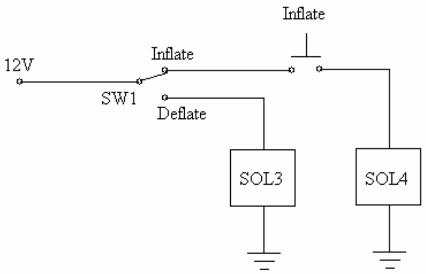
APPENDIX A: ELECTRICAL & PNEUMATIC SCHEMATICS.

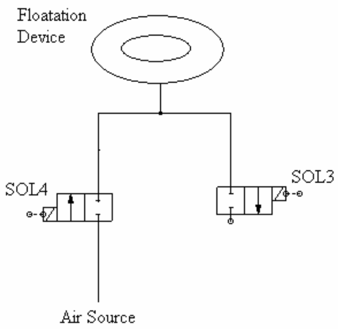


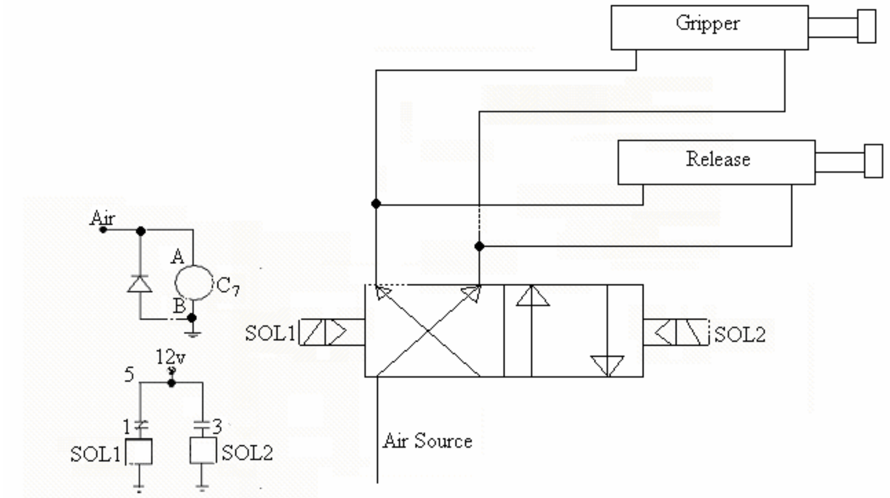








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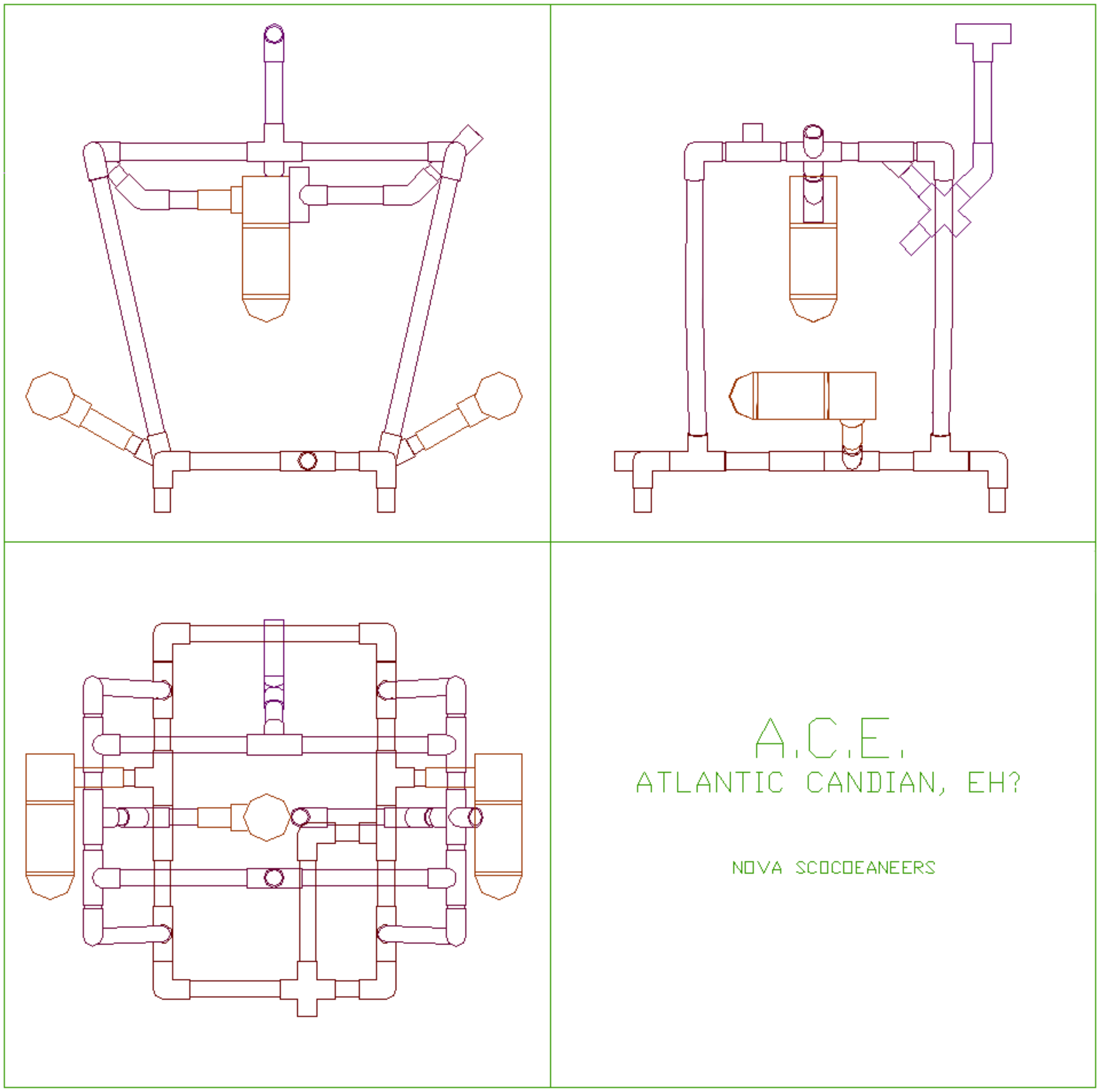
CAD DRAWING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