Cougar Robotics

Featuring: ROV Pele

Clarenville High School

Newfoundland, Canada

2010 MATE International ROV Competition

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Abstract

It is estimated that there are currently 5000 active underwater volcanoes worldwide, some stand alone, some form ridges with others, some are big and some are small. The submerged part of the Hawaiian Islands however, is one of the world's longest, largest and most famous volcanic ridges at over 2,400 km long. The 2010 Marine Advanced Technology Education (MATE) remotely operated vehicle (ROV) competition focuses on the amazing underwater volcanoes of Hawaii. Since there are four different and challenging tasks outlined in the Ranger class, we designed our ROV to be precise and agile to efficiently carry out these missions. Because the tasks were so diverse and challenging at times, Pele had to be well designed, tested and built which required an agile and stable frame, effective sensors, useful end effectors and a reliable propulsion system. A well calculated form of buoyancy and proper wiring were other necessities. We also had to be ready to overcome the challenge of different ideas and opinions as well as any possible technical problems. There were many innovative ideas and also many obstacles along the way but we are confident in saying that Pele is finally completed.

The Clarenville High Cougars of Clarenville, Newfoundland, Canada are proud to present the following technical report complete with the details of Pele. Included in this document are specific descriptions of Pele's key components, techniques used for troubleshooting, reflections, budget, as well as acknowledgments for those who donated, helped, and supported us in any ways. We have also included possible future improvements, the mistakes we made, lessons we learned and obstacles we overcame.

Figure 1: ROV Pele

Design Rationale

The Clarenville High Robotics team made major attempts to construct the ROV hand-crafted components. Very few parts on the ROV were acquired from over the counter products. Learning from past experiences, it was determined that using common household materials was the most efficient way to create parts. Supplies and materials such as plastic pop bottles, mesh, tin and aluminum are some examples of simplistic objects that added to the overall design.

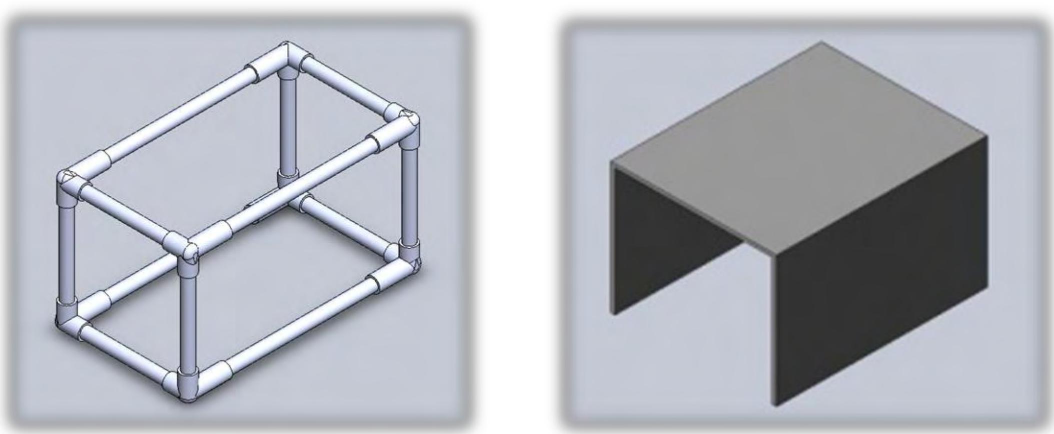
Throughout the project the team followed a five step design process. While developing components the team first determined exactly what was required, researched solutions, constructed prototypes, and finally tested and finally evaluated the design.

The function of the ROV has been optimized through the design and modifications which were made throughout this process. We strategically chose all systems, end effectors and tools, to maximize efficiency and maneuverability of the ROV Pele.

Figure 2: Design Process

The Frame

Two options were considered for the framing material and design. The first option was a square frame constructed from 0.031m ID (1.25 inch) Polyvinyl chloride (PVC) pipe and fittings. The other option was a U- shaped frame contrived from 0.0047m thick sheeted material. Both frames were initially drafted in Solidworks and tested using COSMOS Floworks.



Material: 0.031m ID (1.25 inch) Polyvinyl chloride (PVC) pipe

Material: 0.0047m thick Polycarbonate resin thermoplastic

Figure 3: Frame Options

COSMOS Floworks enables engineers and designers to simulate complex and 3D fluid flow which will provide insight to how a fluid will flow through the model. By performing a drag simulation on each frame, we were able to determine which model exhibited less drag and exactly where fluid flow was obstructed. From simulated tests of both models in water at a speed of 0.30m/s (anticipated speed of our ROV), it was determined that PVC piping experienced a horizontal translation drag of almost three times that of the sheet material.

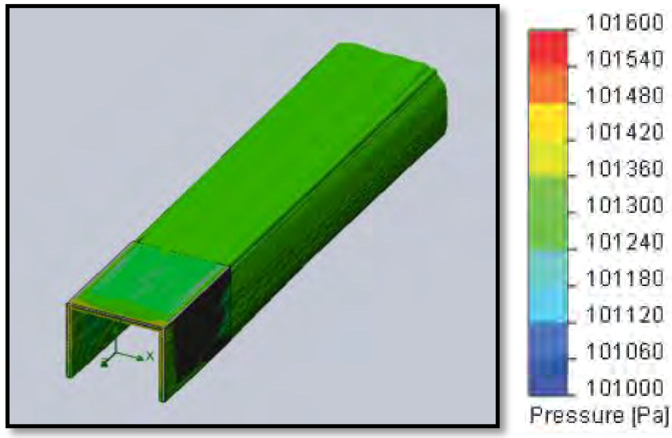


Figure 4: Drag simulation and data

COSMOS Floworks Data			
Frame	**Drag**	**Pressure**	**Shear Stress**
0.0047m Polycarbonate resin thermoplastic	-0.29845 N	101598 Pa	6.4249 Pa
0.031m ID (1.25 inch) Polyvinyl chloride (PVC) pipe	-0.84657N	345727 Pa	16.6572 Pa

To verify the data obtained through the simulation, we calculated drag using the drag equation $\mathbf{F_d=1/2\rho v^2C_dA}$. Where $\mathbf{F_d}$ is the drag force, **ρ** is the mass density of the fluid, **v** is the speed of the object, $\mathbf{C_d}$ is the drag coefficient for the surface (Flat plate=0.1 and sphere=.47) and **A** is the reference area. It was calculated that the drag on a pipe frame was still significantly greater. Our results differed slightly from the simulation due possibly to the variation between drag coefficients used by the simulation and our calculation.

Drag - Sample Calculation

Fresh water @ 20 ^{o}c

$F_d=1/2\ \rho v^2 C_d A$

$F_d=(0.5)\ (999)(0.3^2)(0.01)(0.97)$

$F_d=0.436\ N$

Lexan 9030 sheet - Standard grade

Density	1.2 g/cm³
Water absorption, 24 hours	10 mg
Water absorption (saturation)	0.35%
Mould shrinkage	0.6-0.8%
Impact, notched	35 kJ/m²
Tensile Stress @ Break	60Mpa
Hardness	95 MPa

After testing, we chose to construct the frame from a single sheet of 0.0047m thick polycarbonate resin thermoplastic (Lexan© 9030). A Thermoplastics polymer differs from thermosetting polymers in that it can be remelted, remoulded and easily cut. In addition, Lexan 9030 sheet combines high tensile strength, hardness, and is temperature resistant with low water absorption and optical clarity. The Lexan was shaped to form a U-shaped box measuring 0.46m x 0.35m x0.30m. The open-ended design was chosen as it was tested to provide minimum translational drag and sufficient space to mount thrusters, effectors and buoyancy.

Figure 5: Initial Frame Design

Propulsion

ROV “Pele” is propelled by six strategically placed thrusters constructed from 12V - 500GPH bilge pumps. The motors were extracted from the bilge pump housings and dismantled. Mechanisms originally used to pump water were removed and replaced with a brass hub and propeller.

A series of tests and comparisons were performed to determine the optimal number of thrusters and type of propeller to use. We experimented with three available propellers: a double, triple, and four blade configuration. The two blade propeller had a slightly smaller pitch but a larger diameter blade than the others.

Figure 6: Thruster & Bilge Pump

2-blade 3mm - 50mm

3-blade 4mm - 40mm

4-blade 4mm - 40mm

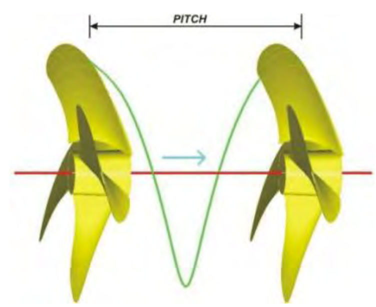


Figure 7: Propeller Pitch

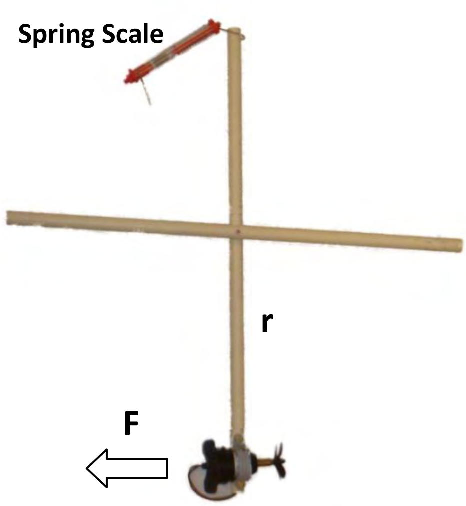


Figure 8: Bollard Test

A series of small scale bollard tests consisting of a spring scale and lever were used to determine the force of pull by each propeller. Torque was calculated using the equation, $\tau = rF\sin\theta$ where τ is the magnitude of the torque, r is the length of the lever arm (a vector from the point from which torque is measured to the point where force is applied) and F is the magnitude of the force. θ is the angle between the force vector and the lever arm vector (in our case 90^o). It was determined that a four-blade propeller provided considerable more torque than the others. We also used an ammeter to measure the current drawn by each thruster in and out of water. We found that the type of propeller had very little effect on the amount of current drawn. However there was a significant difference between the current drawn under load (in water) compared to out of water.

Torque - Sample Calculation

Fresh water @ 20 ^{o}c

$\tau = rF\sin\theta$

$\tau = (0.9)(3.1)\sin(90^o)$

$\tau = 2.79\ Nm$

Bollard Test Results and Measured Data				
Prop (Diameter)	**Pitch**	**Current**	**Force**	**Torque**
2-blade – 50mm	3mm	3.0 A	3.1 N	2.79Nm
3-Blade – 40mm	4mm	3.2 A	3.5 N	3.15Nm
4-Blade - 40mm	4mm	3.2 A	3.8 N	3.42Nm

From the data collected during the bollard test and the measured current used by thrusters, effectors, camera, etc., it was determined that powering any more than six thrusters and end effectors at one time would be close to exceeding the 25 Amp limit. In the end, we chose to use six thrusters (2 for vertical translation, 2 for turning left, and 2 for turning right).

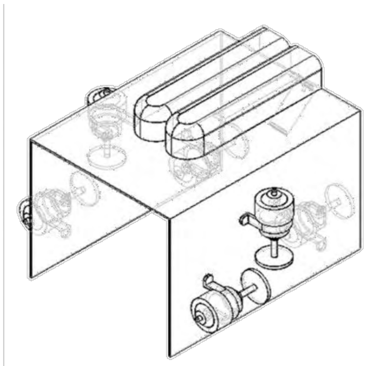


Figure 9: Thruster Placement

Next we considered the placement of the thrusters. This step is a very crucial component when building an ROV. Attempts were made to mount the thrusters as low as possible to obtain a low center of gravity and also direct propeller backwash away from other thrusters and end effectors. Two thrusters were placed on either side of the ROV to obtain vertical lift. Two thrusters were placed at the aft of the ROV to provide forward propulsion. The final two thrusters were mounted at the outside front of the ROV at a 35 degree angle. The reason for this position was to ensure that the water flow from the front thrusters would not interfere with vertical thrusters and create drag. The position of the thrusters also maintained balance of the ROV. The thrusters were attached to the robot by "U" brackets that were glued on and attached with nickel plated nuts and bolts.

Electrical System: Fuse/Controller/Tether

Figure 12: Controller

ROV Pele was powered by a 12v 17Ah lead acid battery and protected by a 25 Amp blade fuse. The fuse is placed on the positive side of our power cable which leads into the controller. In case of increased current flow due to a short circuit, overload, or device failure, the fuse will blow, thus protecting both the team and ROV from injury. The control system for our ROV was thoroughly thought out and planned. When designing the control system there were two considerations: the choice of a proportional control system using computer software or the option of a manual based system of momentary switches. After much deliberation, the team decided to use a system of switches. This decision was solely based on simplicity and the possibility of troubleshooting a failure during competition. It would likely be much quicker to fix a problem with a manual based system than with computer software and control. The controller on our ROV consists of three momentary switches to control ROV movement, a single dipole switch to shut down power and an ammeter to monitor current. The controller was designed and sized so the pilot could easily access the switches. To do this, we considered ergonomics, measured the driver's hands, and placed the switches where they felt right for the driver.

Figure 11: 25A Blade Fuse

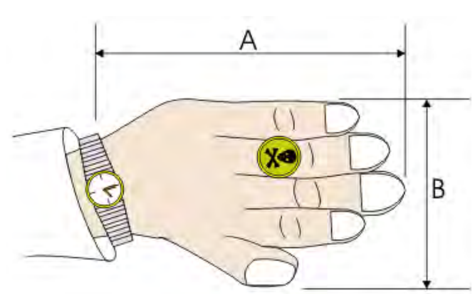


Figure 10: Typical Ergonomics Measurement

The tether measures 15 meters and provides contact to the ROV with the surface. It consists of eight pairs of 22G conductors, a video coaxial cable and shield pair of 26G audio wires. This provides us with sufficient paths to receive signals and power effectors and thrusters. The wires are enclosed with buoyant filler and a polyurethane shell to provide a slight positive buoyancy and waterproofing to a depth of 100 meters.

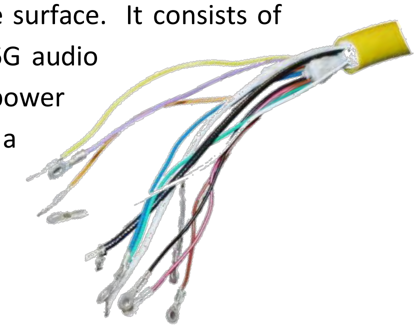


Figure 13: Tether

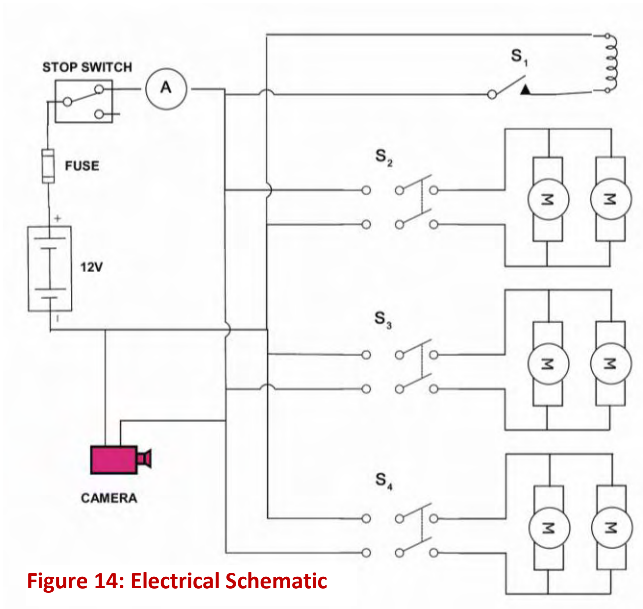


Figure 14: Electrical Schematic

Tether Spec.	(per meter)
Wire	0.123 kg
Fiber	0.021 kg
Tubing	0.234 kg
Total Mass	0.378 kg
Tubing	2.223 cm OD
Buoyancy	0.388 kg lift

Camera

The camera we chose to use was a LCA7700C underwater camera from Lights Camera and Action. It boasts a field of vision of 54 degrees underwater and a picture element of 260,000 pixels. It can operate at low light conditions at 0.03 Lux and to a depth of 200m. We chose to disconnect its external cable and connect the camera directly to our tether. Considering the 54 degree field of view we used simple trigonometry to define an equation for how far back our camera should be placed for optimal view. L=x·cotθ, where w is the width of the ROV, x=1/2w, and L is the distance from the lens to the front of the ROV.

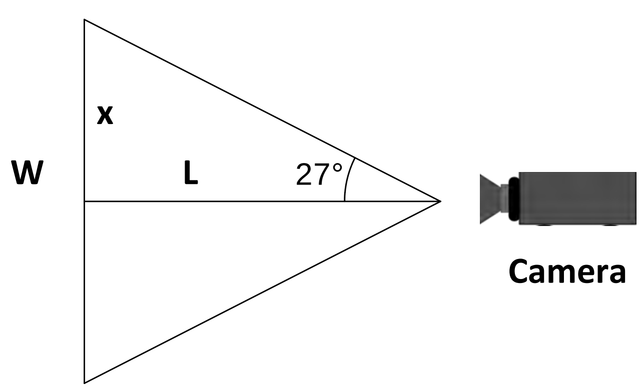
Figure 15: LCA7700C camera

$x = h \cdot sin27°$ $L = h \cdot cos27°$

$$\frac{x}{sin27°} = \frac{L}{cos27°}$$

$$L = \frac{x \cdot cos27}{sin27°}$$

$L = x \cdot cot27°$

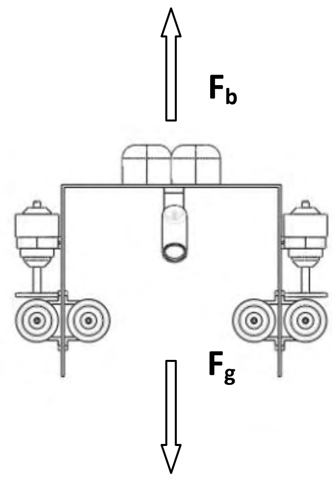


Ballast System

Figure 16: Deep Sea Net buoy

To control the vertical motion of our ROV, we considered two possibilities: first, a pneumatic system using a ballast tank and air, and second, the use of foam for floatation while vertical thrusters provide the necessary vertical translation. We chose the second option as it is much simpler and provides less chance of error during the missions.

Since our ROV was totally dependent on its vertical thrusters for motion in that dimension, it was important that it remain stable when the thrusters were not in operation. This would require that the net vertical force experienced by the device, while the vertical thrusters were not operating, be as close to zero as possible. To accomplish that state of neutral buoyancy, the gravitational force experienced by the ROV had to be equal to the buoyant force. Archimedes stated that the buoyant force acting on an object immersed in a fluid equals the weight of the fluid displaced. Therefore, the weight of the water displaced by the ROV must equal the weight of the ROV.



The buoyancy was constructed from a bullet-nose deep sea net buoy. The buoy was chosen for its high density and bulk modulus, since it experiences minimal compression as the ROV dives deep below the surface when compared with other materials. Compared with common Styrofoam foam, for example, which yields 10% deformation at 100 kilopascals of pressure, the deep sea buoy only yields 5% compression at 100 Kpa of pressure. We used enough foam so that the upward buoyant force provided by the foam was a little greater than the weight of the ROV making it rise slowly in the water ($F_b > F_g$). Then we made adjustments by placing the ROV underwater and measuring the time required for it to surface. We continued to remove small amounts of foam until the ROV remained stationary.

Physical Property and Test method	Net Buoy	Insulating Styrofoam
Compressive Strength, ASTM D1621, deformation at 100kPa	5%	10%
Maximum Use Temperature (°C)	N/A	74
Water Absorption, ASTM D2842, % by volume, max.	0.2	0.9
Buoyancy per Kg	6.4 Kg	N/A

To maximize stability and maneuverability of the ROV, we realized that it was important to place the center of buoyancy directly above the center of gravity and to separate the two as much as possible to keep the ROV level in the water. To accomplish this, all of our buoyancy was placed at the top of the ROV and the bulk of the mass, contained in the thrusters, was placed low and distributed evenly around the perimeter of the ROV.

Features to Accomplish Missions (Payload Description)

Task #1: Resurrect HUGO

This mission task involves:

- Identifying which of three potential sites is rumbling.
- Removing pins to release the HRH from the elevator.
- Installing the HRH at the site that is rumbling.
- Removing the cap from the port on the HUGO junction box.
- Inserting the HRH power connector into the port on HUGO.

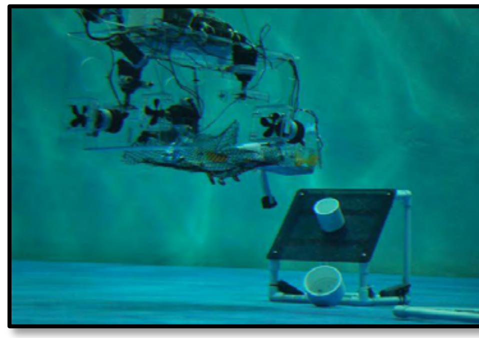
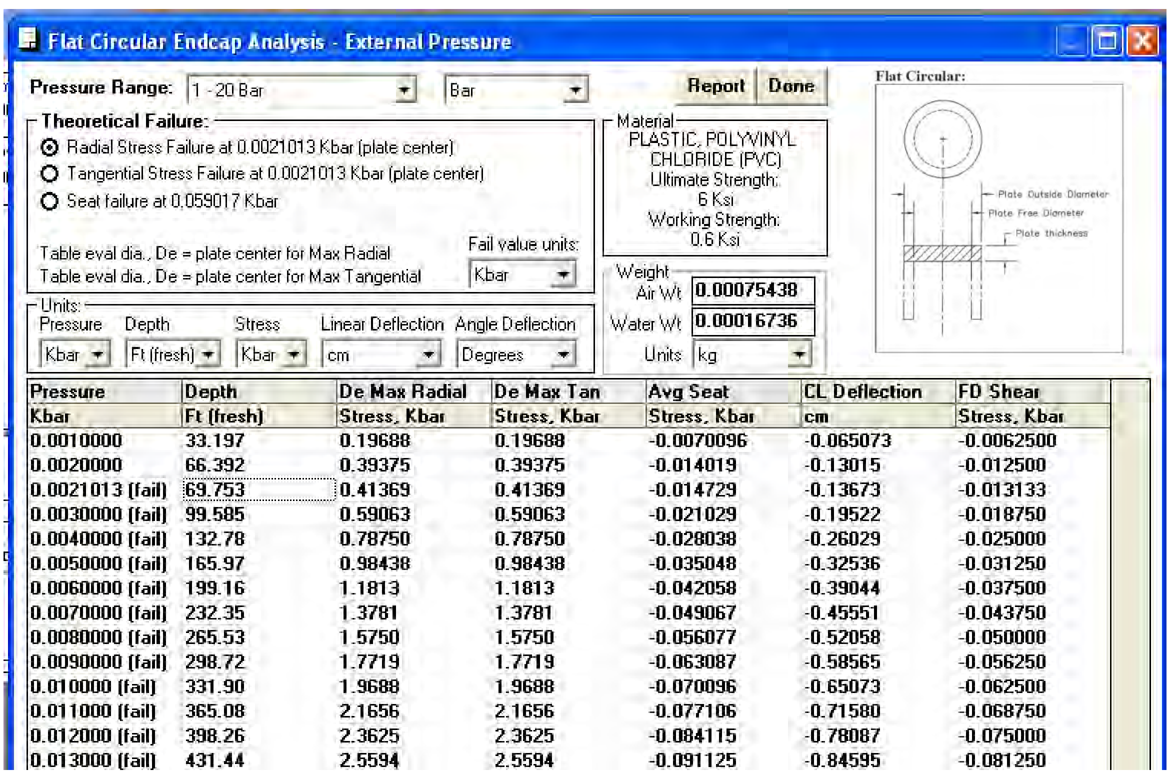


Figure 17: Inserting the Power Connector

To identify the rumbling site, the team constructed a hydrophone using a microphone, 0.025m O.D PVC pipe and a 0.001m diameter plate. The microphone was place inside the pipe, sealed on one end with epoxy and covered on the other end with a vinyl cap. There was much concern that the vinyl end cap could possibly collapse under pressure. To test our assumption we used a piece of software called Under Pressure 4.5. Industry uses *Under Pressure* as an engineering design tool to aid in the design of pressure housings and pressure vessels. The software evaluates structural capabilities, deflections and weights of common pressure vessels, as well as, it reports stresses and deflections for external pressures over a user-selectable pressure range.

The data reported that a Radial Stress Failure would occur at 0.0021013 Kbar (plate center) of pressure. This equates to 69 feet (21 meters) below sea level, which is 6m deeper than our tether allows.



Pressure Kbar	Depth Ft (fresh)	De Max Radial Stress, Kbar	De Max Tan Stress, Kbar	Avg Seat Stress, Kbar	CL Deflection cm	FD Shear Stress, Kbar
0.0010000	33.197	0.19688	0.19688	-0.0070096	-0.065073	-0.0062500
0.0020000	66.392	0.39375	0.39375	-0.014019	-0.13015	-0.012500
0.0021013 (fail)	69.753	0.41369	0.41369	-0.014729	-0.13673	-0.013133
0.0030000 (fail)	99.585	0.59063	0.59063	-0.021029	-0.19522	-0.018750
0.0040000 (fail)	132.78	0.78750	0.78750	-0.028038	-0.26029	-0.025000
0.0050000 (fail)	165.97	0.98438	0.98438	-0.035048	-0.32536	-0.031250
0.0060000 (fail)	199.16	1.1813	1.1813	-0.042058	-0.39044	-0.037500
0.0070000 (fail)	232.35	1.3781	1.3781	-0.049067	-0.45551	-0.043750
0.0080000 (fail)	265.53	1.5750	1.5750	-0.056077	-0.52058	-0.050000
0.0090000 (fail)	298.72	1.7719	1.7719	-0.063087	-0.58565	-0.056250
0.010000 (fail)	331.90	1.9688	1.9688	-0.070096	-0.65073	-0.062500
0.011000 (fail)	365.08	2.1656	2.1656	-0.077106	-0.71580	-0.068750
0.012000 (fail)	398.26	2.3625	2.3625	-0.084115	-0.78087	-0.075000
0.013000 (fail)	431.44	2.5594	2.5594	-0.091125	-0.84595	-0.081250

Figure 18: Under Pressure Analysis - Screenshot

Confident that the vessel would not fail, we connected the hydrophone to a computer on the surface via the tether. To identify the rumbling site, we use software called Audacity which allows the user to both hear sound and view the audio frequencies recorded by the hydrophone.

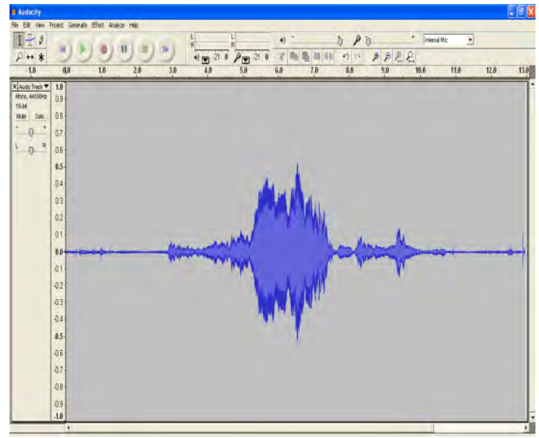


Figure 19: Audacity screen shot showing frequency

The second part of the mission required the ROV to pull a pin to release the HRH. The pin is a common J-bolt constructed from zinc-plated steel. Steel, a ferrous metal, (iron content>80%) is strongly attracted to magnets. This gave us the idea to design an end effector consisting of a strong magnet at the end of an arm. When nearing the pin, the magnet, is easily attached to the HRH allowing the pilot to pull the pin by reversing the ROV thrusters. The same end effector would also be used to remove the cap from the port on the HUGO junction box.

A second end effector was created to transport the HRH to the rumbling site. Since the HRH was constructed from a PVC pipe framing, the team designed a simple effector from a Lexan sheet that contained a vertical spire on the end which could be used as a hook to carry the HRH.

Figure 20: Magnet and Hook

Figure 21: Machining End Effectors

The final effector was needed to retrieve the HRH power connector and insert it into the port on HUGO. This tool proved to be slightly more complicated, so the team decided to design it in Solidworks and later cut it on our CNC router. This involved a three part process, CAD, CAM, and CNC. Once the part was designed in Solidworks we had to import the part into Feature CAM, where a computer code could be produced to instruct the router to machine the part.

In the end we machined a Y-shaped tool with a 30mm slot from 0.004mm thick Lexan. The slot would be maneuvered along the power connector, cradling the Tee of the connector so it would not fall out. The ends were bent on a 45 degree angle which helped keep the connector in place but also allowed the connector to be released once it was delivered to the port.

Task #2: Collect samples of a new species of crustacean

This mission task involves:

- Entering the cave.
- Collecting up to three samples of crustacean.
- Maneuvering out of the cave.
- Returning the samples to the surface.

Figure 22: Mission Crustacean

Figure 23: Crustacean Vacuum

This task basically had three requirements, to build an ROV small enough to enter the cave, to capture the crustaceans, and to hold onto them long enough to return to the surface. The ROV was constructed to be approximately one third the width of the cave so maneuverability would not be a problem. We designed a unique end effector consisting of a section of ABS pipe, a 12v 500 GPH bilge pump, 90 degree elbow and tee. The bilge pump was wired through the tether to the controller and operated by a single dipole momentary switch. Once triggered, the pump would suck up the crustaceans and capture them in a container thus preventing their escape.

Task #3: Sample a new vent site

This mission task involves:

- Measuring the temperature of the venting fluid along height the chimney.
- Creating a graph of the temperature data versus chimney height.
- Collecting a sample of a vent spire and returning it to the surface.

Figure 24: Spire Capture Tool

To capture and transport a sample spire, we built an end effector using the top of a plastic bottle and a piece of a vinyl sleeve. The vinyl sleeve was placed over the mouth of the bottle. As the tool was lowered onto a spire, the spire was squeezed up through the sleeve. The sleeve acts as a one way valve. Once the spire is captured it cannot fall back through the sleeve since the vinyl tends to bunch up and hold the spire in place with friction.

To measure the temperature of the vent spire, we placed a Positive Temperature Coefficient (PTC) thermistor on the ROV. The thermistor is wired through the tether to a multimeter at topside. In PTC type thermistors, the electrical resistance increases with temperature. Change in resistance is converted into electric signal and this analog signal is converted into digital output using an Analog to Digital Converter (ADC).

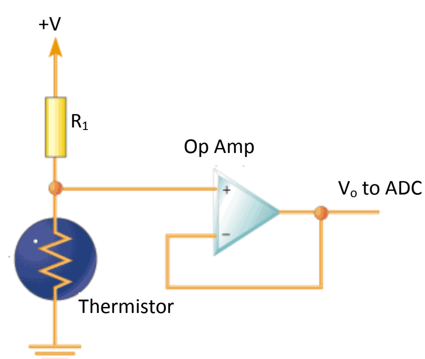
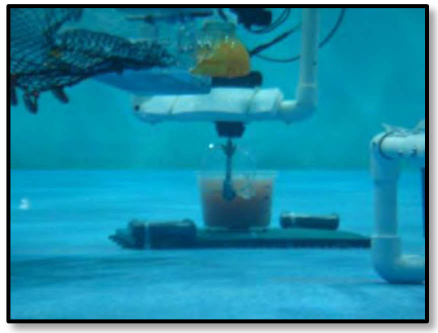


Figure 25: Thermistor Schematic

Task #4: Collect a sample of a bacterial mat



This mission task involves:
• Collecting a sample of a bacterial mat.
• Returning the sample to the surface.

While attempting to recreate a sample of the bacterial mat (agar), the team discovered that the product could have a variety of consistencies. Often the agar would be very dense while at other times it would be a more jelly-like substance. To accomplish this task, the team constructed two detachable end effectors which could be quickly replaced depending on the material presented.

Figure 27: Auger

The first option, to be used if the agar is less dense, models an auger type mechanism. The tool was constructed from a bilge pump, auger plate, and plastic enclosure. The tool was basically drilled into the agar capturing a sample inside the enclosure. The second tool was constructed using two sizes of pipe, springs and a release mechanism. The pipes were placed inside one another allowing them to slide along their length. Prior to completion the interior pipe was retracted inside the large pipe and attached to a release mechanism. Two springs placed on either side of the pipe provided a force along the vertical edge. Once the release mechanism was triggered the inner pipe was fired down into the sample of agar similar to firing a bow and arrow. By moving the ROV forward and backwards, a sample of agar was broken free allowing it to be returned to the surface.

Figure 26: Plunger

Safety Precautions

While building the ROV safety was always a major concern. The team took many different safety precautions and followed a Safety Checklist (Appendix B). Safety glasses were mandatory. Guards were built to protect the motors from getting tangled during missions. Each person on the team received training on the correct use of all tools that were used in building the robot. There are no bare wires on the ROV which reduces the chance of getting an electric shock. It has an emergency On/Off switch. Should anything go wrong this switch can immediately shut the ROV down. There are no sharp objects on the ROV which reduces the chance of injury during the operation of the ROV.

Figure 28: Safety Glasses - A Must!

Challenges


Figure 29: Mark and Nolan sharing ideas

Throughout the building process of our ROV, "Pele", we encountered many avoidable challenges and problems. First, the project began late in the school year which limited our time for needed revisions. Also, we experienced periodic poor student attendance which resulted in slow progress at times. Furthermore, our meetings often lacked organization which resulted in considerable time wasted on problem-solving. In hindsight, a more constructive approach could have been to make to-do lists and delegate specific job tasks to each member of the team. Finally, communication was sometimes an issue. There were times throughout the project that members failed to express their thoughts, ideas or concerns and did not request assistance when needed. To overcome this problem, we assigned dedicated roles to team members and made a greater commitment to the project. In the end, our group's team approach improved. We began to share our ideas more effectively and the team really pulled together, giving us a great sense of accomplishment and resulting in a very well constructed ROV.

Troubleshooting Technique


Figure 30: Chris Designing in Solidworks

Constructing effectors for an ROV can be time-consuming and expensive, especially if errors are made. Rebuilding parts can waste both materials and time. Throughout the process, we avoided many problems by first designing parts using CAD software. We chose to use Solidworks as it allowed us to build and test virtual parts without putting a part into production. This software is particularly beneficial as it allows the designer to actually see and modify objects until they reach the desired outcome. In this way we could troubleshoot problems in the original effectors on the computer before re-fabricating them. This troubleshooting method proved to be especially effective during the design, testing, and final manufacturing of our power connector tool. It allowed us to design the tool in a variety of shapes; virtually test the tool's usefulness for the task; and cut the tool out of Lexan using a computerized router. Without the Solidworks software our troubleshooting method would have been the age-old "trial and error" method. This would have wasted materials and slowed our progress considerably.

Future Improvements


Figure 31: Sarah Placing Effectors

Overall, we are very pleased with our ROV. It would seem, however, regardless of how much time you have, there are always elements which can be improved upon. If we were to make future improvements, we would probably invest more time into the frame design. The options of materials' shape and size are endless. We would like to experiment more with aluminum, pipe, and plastic injected frames to learn how each would compare and react in water. Another interesting addition would be to study a variety of frame structural designs. A U-shaped design offers minimal horizontal drag but is slower through vertical translation. One consideration could be to slope the upper surface of the frame to allow water to be directed away when surfacing. Finally, adjusting the size of the ROV would be an option. Increasing the size would increase surface area for tool placement, but also increase drag. All these ideas provide a basis for future improvements and something we will certainly consider next year.

Lessons Learned

We learned so many lessons during this process that we could never report all of them. Prior to the competition, many of our team members had never been in a workshop, much less built a ROV. We learned many techniques that were pertinent to water-proofing, electronics, buoyancy, propulsion, as well as team work and much more.


Figure 32: Learning the Ropes

One of the more useful technical skills that we acquired was the ability to operate all shop tools effectively. Prior to entering the workshop and using any of the tools in it, each member of the team had to pass safety tests specific to all of the different tools with no questions answered incorrectly. With the tests done, each member of the team began to master the usage of the shop's tools during the construction phase of our ROV. These practical skills were, as expected, quite useful in the construction of our ROV. However, these skills will prove to be quite beneficial in other aspects of our lives as well. From future careers to future school courses to even jobs around the house these skills will prove to be valuable to all of the members of our team.

Not all aspects of this ROV project were quite so technical though, we also had to interact with people we did not know well in an often stressful and dynamic environment. We knew that successful completion of this enormous project would require effective and thorough teamwork. After much practice our team perfected our ability to recognize and utilize each others' strengths. The ability to recognize and utilize each others' strengths proved to be one of the most valuable interpersonal skills that we would acquire. This meant that each team member had their own specialization with the ROV. Whether it be Chris with the computer design or Alan with wiring, the ROV would not have been successfully completed without each and every teammate. After many months of dedicated hard work, our team learned many skills that were pertinent not only to ROVs but also to aspects of our future lives.

Reflections

Reflecting on the whole experience we are left only to think about our friend Denika Adams. The night prior to the Regional Competition our friend, and classmate, was tragically lost in a motor-vehicle accident. It was a very difficult time for our school and community. With Denika in our hearts we found strength and pressed on. We would like to dedicate our project to Denika. She will be remembered always.

Teamwork:

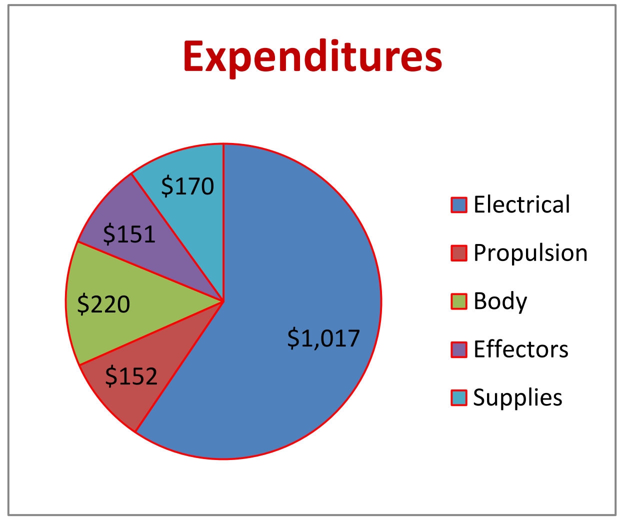
Figure 33: A Team Effort

The teamwork, determination, and dedication required to complete a ROV, such as "Pele", provides students with a valuable learning experience. To complete the project we needed each and every teammate to work to their potential on every aspect of the ROV, technical report, and the poster display. This was done by assigning specific jobs to be done by specific groups of teammates and by making a schedule of tasks. The schedule included tasks to be done, the scope of the tasks, and ideal completion times. Throughout the building process we acquired knowledge and practical skills from this unique and exciting project. As a team we worked hard to design and construct every aspect of "Pele" ourselves, especially the electrical components such as the tether, controller, and detachable auger mechanism. In the end we enjoyed a great extra-curricular activity which brought a group of different students with similar interests together. New friendships were formed. Innovative ideas were brought to the table. We learned co-operation, perseverance and competitiveness as well as a sense of accomplishment as a result of this rewarding experience.

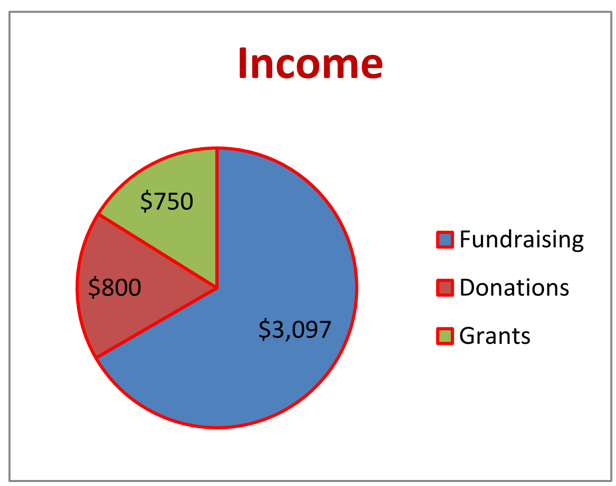
Front (L- R): Emily Hughes, Sarah Sullivan, Ri Guang Li, Meagan Perry, Megan Jacobs, Katie Hawkins
Back (L-R): Chad Baker, Garrett White, Chris Parsons, Nolan Porter, Josh Roul, Mark Pardy

Budget

Expenditures		
Electrical	Switches	$122.00
	Camera	$350.00
	Tether	$420.00
	Wire	$93.00
	Misc.	$32.00
	Sub-Total	**$1017.00**
Propulsion	Brass Hub	$20.00
	Bilge Pump	$90.00
	U - Brackets	$12.00
	Propellers	$30.00
	Sub-Total	**$152.00**
Body	Lexan	$200
	Deep Sea Buoy	$20.00
	Sub-Total	**$220.00**
Effectors	Thermistor	$34.00
	PVC pipes	$24.00
	Magnets	$20.00
	Hydrophone	$23.00
	Sheet Metal	$50.00
	Sub-Total	**$151.00**
Supplies	Tape	$15.00
	Epoxy	$15.00
	Misc.	$140.00
	Sub-Total	**$170.00**
Total		**$1590.00**



Income		
Fundraising	Cupcake Sales	$347.00
	Bottle Drives	$2200.00
	Car Wash	$550.00
	Sub-Total	**$3097.00**
Donations	Monetary	$500.00
	In-kind	$300.00
	Sub-Total	**$800.00**
Grant	Marine Start up	$750.00
	Sub-Total	**$750.00**
Total		**$4647.00**



Loihi Seamount

Figure 34: Hawaiian Islands and Loihi Seamount (Unknown, 2010)

Loihi Seamount is one of three active seafloor volcanoes, located about 30 kilometers off the southeast coast of the Hawaiian Islands. It lies on the region of Mauna Loa, the largest shield volcano on Earth. Loihi is the youngest volcano that sits over the Hawaii hotspot and began forming 400,000 years ago. Loihi rises more than 3000 meters above the seafloor and is expected to appear at the surface of the ocean.

This seamount generates frequent earthquake swarms, the most intense of which occurred in the summer of 1996. Over 4000 earthquakes from Loihi were detected which were more than any other recorded in Hawaiian history. After the 1996 eruptions a vent collapsed in on itself forming a depression and three craters, one of which is called Pele's Pit after the Hawaiian Fire Goddess. This inspired us to name our ROV "Pele" after the Goddess.

Our Mission and Parallels to Scientific Research

Scientists from the University of Hawaii have recently made many submersible dives to Loihi to study it in further detail. Similar to our mission, scientists have deployed recording instruments and used ROV's to gather as much information about the volcano as possible. Like us, these scientists are also researching many organisms such as crustaceans and a never before seen jelly-like organism that was found near Loihi in 1999, which is able to live in extreme temperature conditions. ROV's are also used to deploy equipment. The Hawaii-2 Observatory near Loihi was primarily established using 'Jason'; a ROV operated by WHOI's Deep Submergence Laboratory. "Jason" has been used specifically to set up a multisensor seismic-acoustic package very similar to the task required by our ROV "Pele". With some luck, maybe one day they can meet!

Figure 35: Crustaceans (Tunnelclif, 2006)

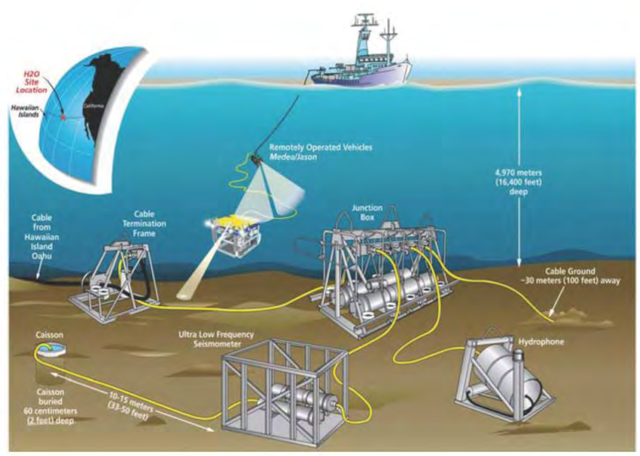


Figure 36: Hawaii-2 Observatory (MATE, 2010)

Acknowledgements

The Clarenville High School Robotics team would like to acknowledge and thank the many businesses and individuals who have helped with the building process and made this competition possible. We would like to thank MATE, the local businesses who donated supplies, Canadian Tire and Gosse's Iron Works. A special thanks to Pete Martin who aided in the construction of our tank. We are most grateful for the help and support of our parents. Most importantly we would like to express our sincere gratitude to our mentors Michael Spurrell, Carl Winter, and Bert Roberts. It is their direction, commitment, knowledge and guidance which made this whole experience possible.

Contributors[1]:

Paula Roberts	Canadian Tire
Peter Martin	ACOA
Paul Perry	Town of Clarenville
Gosse's Iron Works	Co-op
Town of Clarenville	Clarenville Lions Club
Newfoundland Power	North Atlantic Refining
Mercer's Marine	
Scotia Bank	

Note 1. These are contributors' as of May 20, 2010. An updated list will be posted at the competition.

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Appendix A: Flight Plan

Flight Plan	Time
Descend to mission site	30s
Collect sample of bacteria mat	1min
Return sample to surface	1min
Descend to vent site	30s
Retrieve vent spire	1min
Measure temperature at the three vent site	1min
Identify the rumbling site which is generating sound	1min
Remove pin holding HRH	1min
Remove HRH from the elevator	1min
Place HRH at the site which is rumbling	1min
Retrieve HRH connector from its holder	1min
Remove cap from HUGO junction box	30s
Place HRH connector into the port of HUGO	1min
Enter the cave	30s
Maneuver to back wall of the cave	30s
Collect 3 samples of crustaceans	1min
Maneuver out of the cave	30s
Return to surface with crustacean samples and vent spire	1min
Total	**15min**

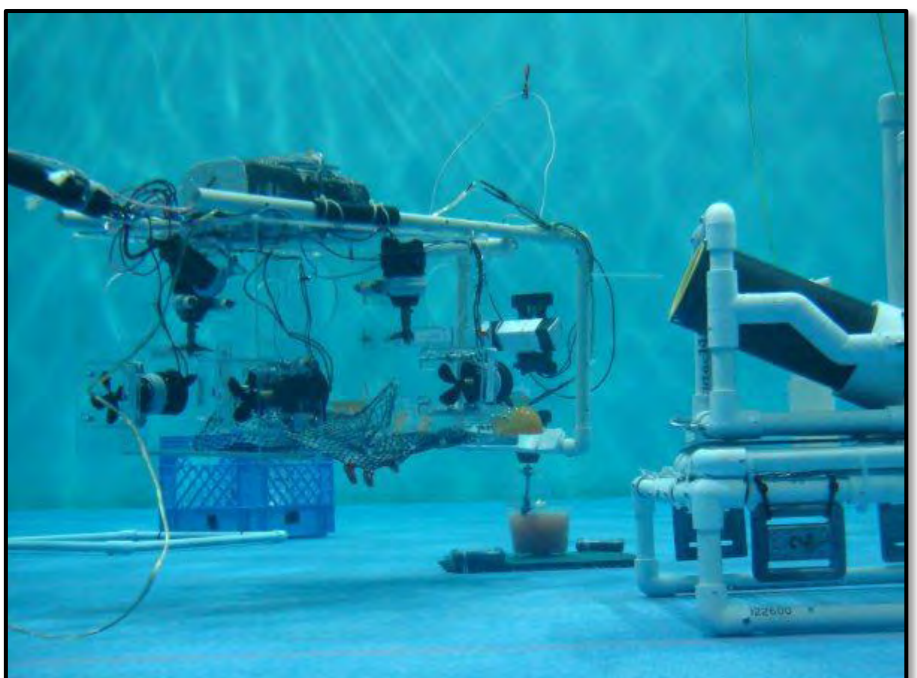
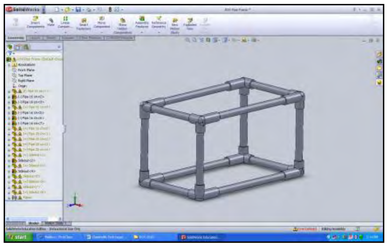


Figure 37: ROV Pele at the Regional Competition

Appendix B: Design Software Summary

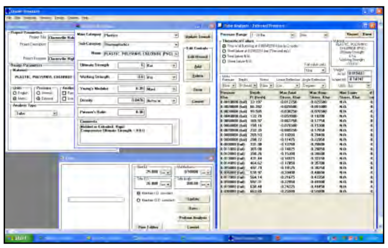
Throughout the course of the project we used a variety of programs and software to aid in the development of Pele. Some of these are listed below.

Solidworks 8



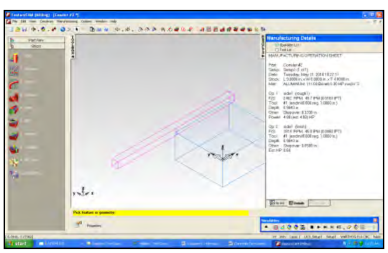
SolidWorks is a 3D mechanical CAD (computer-aided design) program developed by Dassault Systèmes SolidWorks Corp. It is very useful for designing ROV effectors since they can be see, tested, and altered without ever producing the part.

Under Pressure 4.5



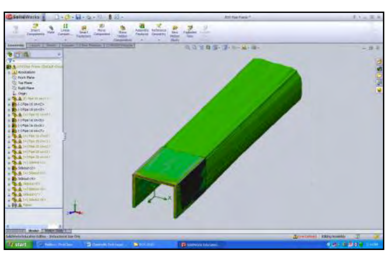
Under Pressure evaluates structural capabilities, deflections, and weights of common pressure vessel geometries such as cylindrical tubes, spheres, as well as hemispherical, conical, flat circular, and flat annular end enclosures. During the design of an ROV it can be used to test the maximum water depth of canisters used to hold electronics.

Feature Cam 2007



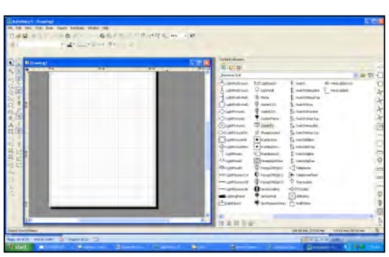
Feature CAM, developed by Delcam, is a suite of CAD/CAM software which automates machining and minimizes programming times for milling part. Feature Cam allowed us to directly machine parts created in Solidworks. This has a major implication since parts could be quickly machine without having to actually program the code.

COSMOS FlowWorks 8



FlowWorks is a fluid-flow simulation and thermal analysis program. With its analysis capabilities, you can simulate liquid and gas flow in real world conditions, run “what if” scenarios, and quickly analyze the effects. In the ROV world it can be a viable method for streamlining, buoyancy, frame, and effectors.

AutoSketch 9



AutoSketch 9 software provides a comprehensive set of CAD tools for creating precision drawings--from electrical details to floor plans, from conceptual sketches to product specifications. We used it during the construction of the ROV as a tool for creating electrical schematics.

Appendix C: Safety Checklists

Construction Safety Checklist

- ☐ Controller power switch is in off position
- ☐ ROV is disconnected from power source
- ☐ All personnel working on the ROV have proper qualifications for tools
- ☐ Team members are using safety glasses/ other appropriate safety equipment
- ☐ Propeller guards are securely fastened
- ☐ No corrosive materials or exposed wiring

Operational Safety Checklist

- ☐ Controller power switch is in off position
- ☐ Fuse is in place
- ☐ ROV is disconnected from power source
- ☐ Check ROV for hazards
- ☐ No exposed wiring
- ☐ Tether is neatly laid out
- ☐ No exposed wiring
- ☐ Ensure guards are securely fastened
- ☐ Check end effectors for damage
- ☐ Step away from ROV and connect to power supply
- ☐ Designated personnel to place ROV in water and release
- ☐ Turn on power

Appendix C: Team Spec. Sheet

Cougar Robotics

Clarenville High School
Newfoundland, Canada.

We travelled 9359 kilometers!

- We have competed in two Regional competitions, but this is our first trip to the International competition.

ROV PELE
Total cost: $1590.00
Primary material(s) used in construction: Acrylic
Approximate dimensions in metric units: 0.46m x 0.35m x0.30m.
Total mass in AIR: 5.8Kg
Safety features: Electrical connections are all watertight, 25 amp fuse, Emergency Shut-off.
Special features: (6) 12V Thrusters, LCA770c Camera, 15m 9-wire Tether.