Cougar Robotics Incorporated

Sub-sea Ingenuity

Clarenville Newfoundland, Canada

2011 MATE International ROV Competition

Technical Report

Featuring ROV: Horizon

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Abstract

At approximately 9:45 pm on April 20, 2010, the Deepwater Horizon drill rig exploded killing 11 workers. Two days later the Deepwater Horizon sank, leaving oil gushing out of the sea floor. This accident lead to the largest offshore oil spill in history.

Remotely Operated Vehicles (ROV's) played a critical role in stemming the flow of oil in this disaster and in monitoring the effects of the spill at depth. A ROV is a remotely operated unmanned submarine that can safely operate in deep water while performing various tasks. It is maneuvered by a "driver" on a surface ship.

Today there are in excess of 200 drilling rigs in the Gulf of Mexico and thousands more throughout the world's oceans. The use of an ROV as an effective tool in deepwater exploration was proven during the Deepwater Horizon Disaster. This year, the MATE ROV competition focuses on the role of ROVs in the deep water oil industry.

Our company has put countless hours into the planning and the construction of our ROV - The Horizon. We have named our ROV as a tribute to the lives lost in the Deepwater Horizon disaster. Looking to the future, the name Horizon also points to a new breed of engineer who will face the challenges of future deepwater oil exploration and oil production.

Figure 1: Deep Water Horizon Drilling Rig

Design Rationale

Cougar Robotics Incorporated made major attempts to construct the ROV from hand-crafted components. Very few parts on the ROV are 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 containers, ABS pipe and aluminum cans are some examples of simplistic objects that contributed to the overall design.

Throughout the project the company followed a five step design process (Figure 2). While developing components, we first determined exactly what was required, researched ideas, sketched solutions, constructed prototypes, and finally tested and evaluated the design.

Figure 2: Design Process

The function of the ROV has been optimized through the design and modifications which were made throughout the testing process. We strategically chose all systems, end effectors and tools, to maximize efficiency and maneuverability of the ROV Horizon. All components were designed and tested in SolidWorks prior to manufacturing.

The Frame

Two options were considered for the frame's material and design. The first option was a square frame constructed from 0.031m ID (1.25 inch) Polyvinyl chloride (PVC) pipe and fittings.

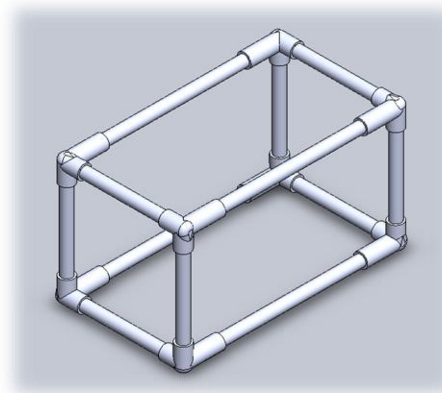


Figure 3: PVC Boxed Frame

The other option was a U- shaped frame contrived from 0.0047m thick polycarbonate resin thermoplastic.

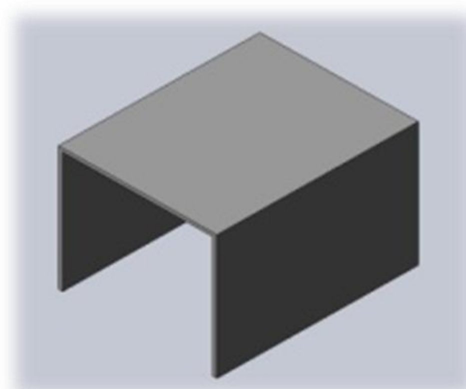


Figure 4: Lexan© U-shape Frame

Both frames were initially drafted in SolidWorks and tested using COSMOS FloWorks. The data has been recorded below.

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

COSMOS FloWorks enables engineers and designers to simulate complex and 3D fluid flow which provides 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 frames 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.

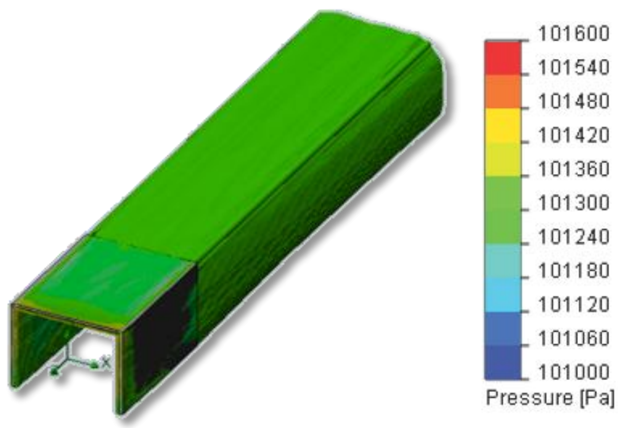


Figure 5: Drag Simulation Screen shot

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 $\mathbf{F_d}$ **(N)** is the drag force, **ρ** $\mathbf{(kg/m^3)}$ is the mass density of the fluid, **v (m/s)** is the speed of the object, $\mathbf{C_d}$ is the drag coefficient for the surface (Flat plate=0.1 and sphere=.47) and $\mathbf{A(m^2)}$ 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 - Calculation

Fresh water @ 20 °c

Velocity: 0.30 m/s

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

$F_d=(0.5)\ (999)(0.30^2)(0.01)(0.97)$

$F_d=0.44\ N$

After testing, the company decided 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 remolded and easily cut.

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

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 x 0.30m (L x W x H). The open-ended design was chosen as it was tested to provide minimal translational drag and sufficient space to easily mount thrusters, effectors and buoyancy.

Figure 6: Lexan© Frame

A further drag analysis was later conducted on the complete model, yielding a drag of -11.49N.

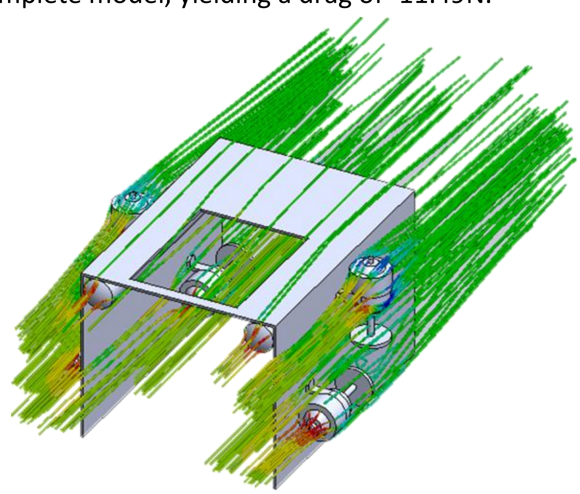


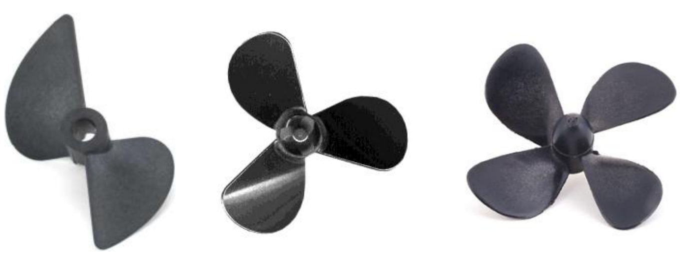
Figure 8: Complete Drag Test

Propulsion

ROV Horizon 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.

Figure 9: Bilge Pump & Thruster

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



2-blade 3mm - 50mm ***3-blade 4mm - 40mm*** ***4-blade 4mm - 40mm***

Figure 10: Propellers Tested

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.

Bollard Test Results and Measured Data (water@ 20°C)				
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

It was determined that a four-blade propeller provided considerably more torque than the others. An ammeter was also used to measure the current drawn by each thruster in and out of the water. It was 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.

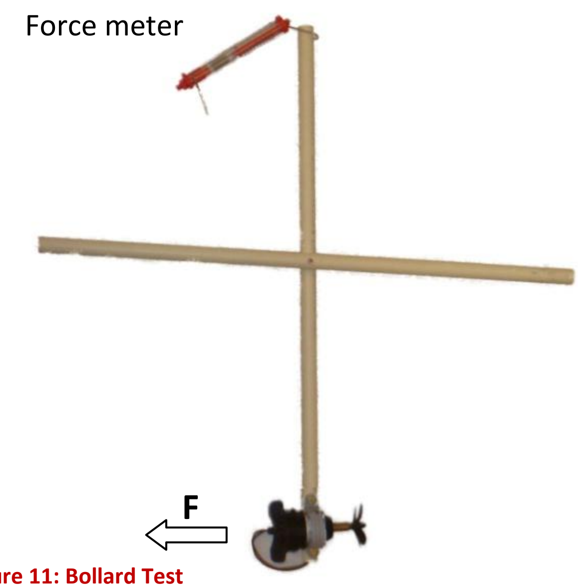


Figure 11: Bollard Test

From the data collected during the bollard test and the measured current used by each thruster, 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 current limit. In the end, six thrusters (2 for vertical translation, 2 for turning left, and 2 for turning right) were to be used.

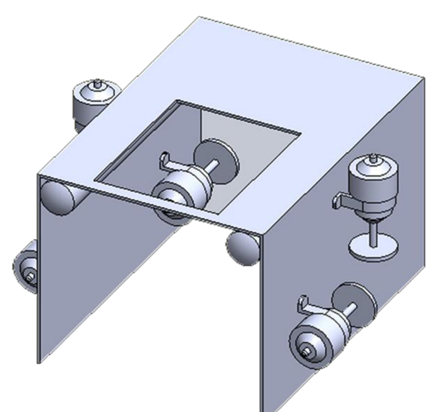


Figure 12: Thruster Placement

Placement of the thrusters is a very crucial aspect 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 below the vertical thrusters. 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.

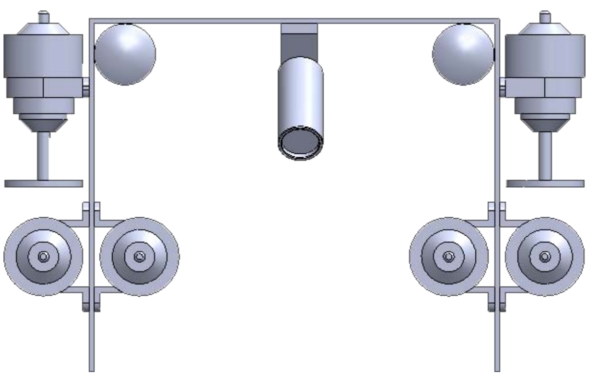


Figure 13: Thruster Placement – Cross Sectional

Electrical System: Fuse/Controller/Tether

ROV Horizon was powered by a 12v lead acid battery and protected by a 25 Amp blade fuse. The fuse was placed on the positive side of the power cable which leads into the controller. An ammeter was added to the controller to monitor the amount of current drawn by the system. In case of increased current flow due to a short circuit, overload, or device failure, the fuse will blow and protect both the operators and ROV from injury.

The control system for the ROV was thoroughly thought out and planned. When designing the control system the company chose a manual based system of momentary switches. This decision was solely based on simplicity and the possibility of troubleshooting in the event of a failure during competition.

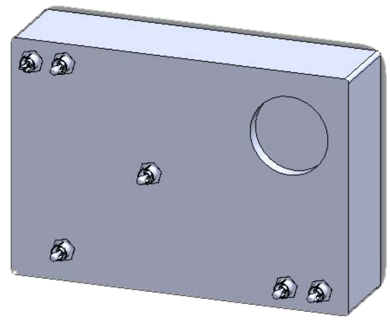


Figure 14: Solidworks - Initial Design.

The controller on the ROV consists of three two-way momentary switches to control ROV movement, a single dipole switch to shut down power and an ammeter to monitor current. There are also several single momentary switches available to control end effectors. The controller was initially designed in SolidWorks and re-sized so the pilot could easily access the switches improving on ergonomics.

Figure 15: Controller - Final Product

The Tether

The tether is the lifeline of any ROV. The tether for ROV Horizon measures 15 meters and was constructed from two positive buoyant tethers, twisted together to form the main tether. This provides the ROV with sufficient paths to transmit and receive signals.

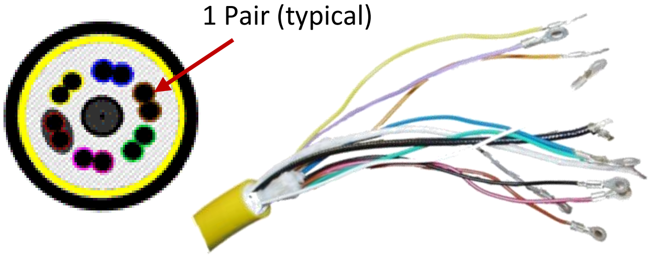


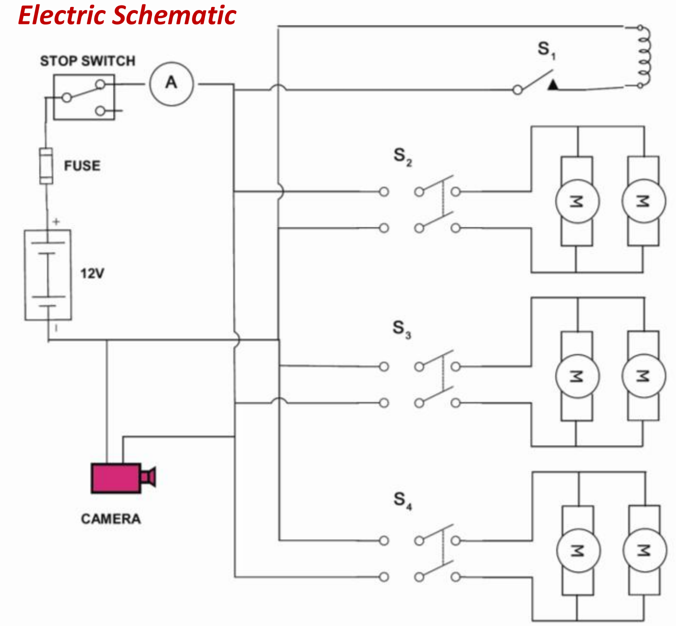
Figure 16: First Cable Tether – Cross Section

The larger tether is used for transmitting power to the motors and end effectors. It consists of eight pairs of 22G conductors, a video coaxial cable and a shield pair of 26G audio wires. The second cable carries signals for the sensors. It contains 6 pairs of 28G wires. Each cable is enclosed with buoyant filler and a polyurethane shell to provide waterproofing to a depth of 100 meters.

Tether Specification

	Tether 1	Tether 2
Mass	0.378 kg/m	0.125 kg/m
Tubing	2.223 cm OD	0.96 cm OD
Max Voltage	48V	48V

Electric Schematic



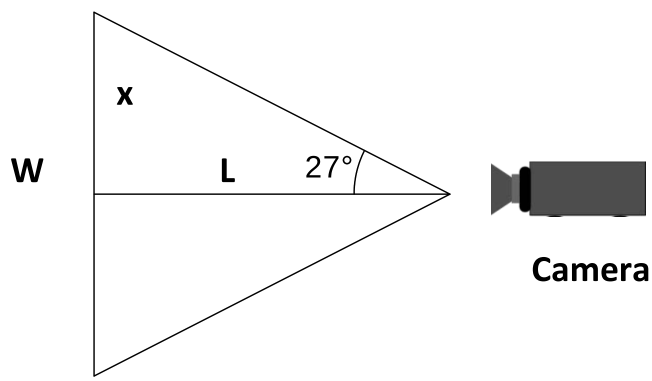
Camera

The camera is a LCA7700C underwater camera from Lights Camera 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. The camera was modified by disconnecting its external cable and connecting the camera directly to the ROV tether.

Figure 17: LCA7700C camera

Considering the 54 degree field of view simple trigonometry was used to define an equation for how far back the camera needed to be placed for optimal viewing. 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 and θ is the field of view angle divided by 2.

Figure 18: Camera Placement Calculation



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

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

$$L = \frac{x \cdot cos27}{sin27°}$$

$$L = x \cdot cot27°$$

Figure 19: 25A Blade Fuse

Ballast System

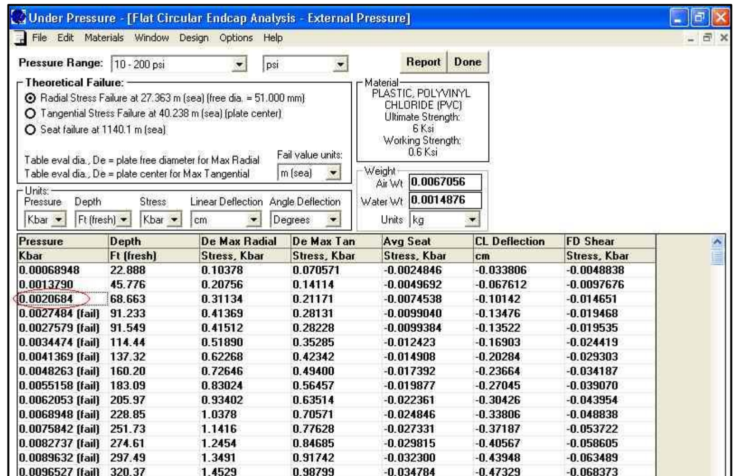
To control the vertical motion of the ROV, our company explored several possibilities. Initially, foam was considered for the buoyancy but it was found that the foam would compress and lose flotation at the depths the ROV would be operating at. Common Styrofoam, for example, yields 10% deformation at 100 kilopascals of pressure. This deformation would compromise the stability of the ROV. In the end, our company decided to use a hollow tube for floatation, and vertical thrusters to provide the necessary vertical translation.

The buoyancy was constructed from a 0.61m long, 0.006m OD section of ABS pipe and an end cap. The pipe was chosen because it would resist compression under extreme depths.

Figure 21: Buoyancy

There was much concern that the end cap could possibly collapse under pressure. To test this concern we used packaged software called Under Pressure 4.5, used as an engineering design tool to aid in the design of pressure housings and pressure vessels in the marine industry. The software evaluates structural capabilities, deflections and weights of common pressure vessels, also, 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 21 meters (69 feet) below sea level, which is 6m deeper than our tether allows.



Under Pressure - [Flat Circular Endcap Analysis - External Pressure]

File Edit Materials Window Design Options Help

Pressure Range: 10 - 200 psi | psi | Report | Done

Theoretical Failure:
- Radial Stress Failure at 27.363 m (sea) (free dia. = 51.000 mm)
- Tangential Stress Failure at 40.238 m (sea) (plate center)
- Seat failure at 1140.1 m (sea)

Table eval dia., De = plate free diameter for Max Radial
Table eval dia., De = plate center for Max Tangential

Fail value units: m (sea)

Material: PLASTIC, POLYVINYL CHLORIDE (PVC) Ultimate Strength: 6 Ksi Working Strength: 0.6 Ksi

Weight: Air Wt 0.0067056; Water Wt 0.0014876; Units kg

Units: Pressure Kbar; Depth Ft (fresh); Stress Kbar; Linear Deflection cm; Angle Deflection Degrees

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
0.00068948	22.888	0.10378	0.070571	-0.0024846	-0.033806	-0.0048838
0.0013790	45.776	0.20756	0.14114	-0.0049692	-0.067612	-0.0097676
0.0020684	68.663	0.31134	0.21171	-0.0074538	-0.10142	-0.014651
0.0027484 (fail)	91.233	0.41369	0.28131	-0.0099040	-0.13476	-0.019468
0.0027579 (fail)	91.549	0.41512	0.28228	-0.0099384	-0.13522	-0.019535
0.0034474 (fail)	114.44	0.51890	0.35285	-0.012423	-0.16903	-0.024419
0.0041369 (fail)	137.32	0.62268	0.42342	-0.014908	-0.20284	-0.029303
0.0048263 (fail)	160.20	0.72646	0.49400	-0.017392	-0.23664	-0.034187
0.0055158 (fail)	183.09	0.83024	0.56457	-0.019877	-0.27045	-0.039070
0.0062053 (fail)	205.97	0.93402	0.63514	-0.022361	-0.30426	-0.043954
0.0068948 (fail)	228.85	1.0378	0.70571	-0.024846	-0.33806	-0.048838
0.0075842 (fail)	251.73	1.1416	0.77628	-0.027331	-0.37187	-0.053722
0.0082737 (fail)	274.61	1.2454	0.84685	-0.029815	-0.40567	-0.058605
0.0089632 (fail)	297.49	1.3491	0.91742	-0.032300	-0.43948	-0.063489
0.0096527 (fail)	320.37	1.4529	0.98799	-0.034784	-0.47329	-0.068373

Figure 20: Under Pressure - Screen Shot
Fi

Since our ROV was totally dependent on its thrusters for vertical motion, it was important that the ROV remain stable (neutrally buoyant) 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.

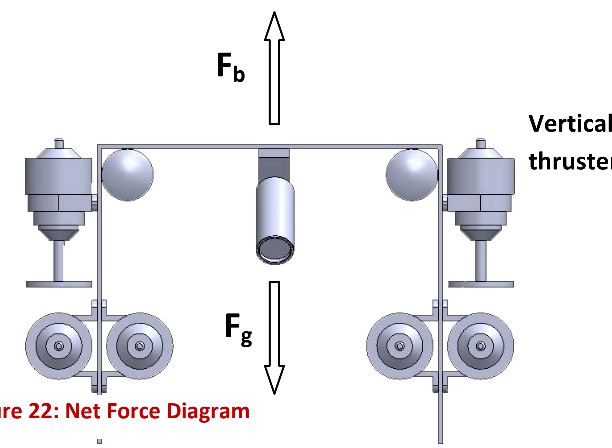


Figure 22: Net Force Diagram

To accomplish this state of neutral buoyancy, the gravitational force experienced by the ROV had to be equal to the buoyant force. Using Archimedes Principle, it was concluded that the weight of the water displaced by the ROV must equal the weight of the ROV. Next we determined the approximate volume of pipe needed to displace this amount of water. Knowing the mass of the ROV and the density of water allowed us the calulate and approximate the length of pipe needed to satisfy this requirement.

Sensors

ROV Horizon is equipped with a variety of custom designed sensors to enhance its performance and improve its functionality for the successful completion of its goals.

Since finding depth is major component of the competition, the company has fitted the ROV with three depth finders to offer system redundancy in the event of an equipment failure.

- The first instrument was constructed from a 500ml syringe. The tip was plugged, and a hole was strategically placed near the top of the syringe. As the ROV descends the water pressure forces the plunger to move. Through a series of test our engineering team has calibrated the movement to measure depth in meters.

Figure 24: Depth Gauge - Syringe

- The second depth gauge was custom built from a pressure transducer dismantled from a lab pressure sensor. The transducer consists of three wires, one of which reports a voltage to the surface. This voltage is measured topside (independent of the controller) using a multimeter and has been calibrated to report on the depth of the ROV.

Figure 25: Pressure Transducer

- The third, pressure gauge was extracted from a divers rig. It is an Uwatec, 330m digital bottom timer that is capable of reporting depth, temperature and dive rate.

Figure 26: Uwatec Depth Gauge

Technical specifications
Altitude range: unlimited
Depth range: 0-330 m (0-1080 ft)
Depth display resolution: up to 99 .9 m: 0 .1 m, >99 .9 m: 1 m, the resolution in feet is always 1 foot
Depth accuracy: 0 .1% ±0 .1 m (±0,4 ft)
Time measurement: quartz clock.
Temperature display resolution: 1 °C (1 °F)
Temperature accuracy: ±1 °C (±2 °F)
Operating temperature range: -10 °C to +50 °C

- In addition to these electrical sensors, we utilized a inclinometer that allows the operator to see if the ROV is off balance while transporting heavier objects during the mission.

Figure 27: Inclinometer

- Finally, as already mentioned, we have installed an ammeter on the controller to monitor the current used by the ROV. The ammeter measures from +30A to – 30A.

Figure 28: Ammeter Dial

To increase the ROV's versatility and make it marketable to a broader range of clients our company has included additional sensors at no charge. ☺

- To hear its surroundings, The ROV is equipped with a hydrophone which was constructed using a microphone, 0.025m OD 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.

  To identify noises, software called Audacity was used. It allows the user to both hear sound and view the audio frequencies recorded by the hydrophone.

Figure 29: Hydrophone

- The ROV is equipped with a temperature sensor constructed from a Positive Temperature Coefficient (PTC) thermistor. The thermistor is wired through the tether to a multi-meter at topside. In PTC type thermistors, changes in temperature are directly proportional to changes in electrical resistance. In this way, the thermistor converts the temperature into a measure of electrical resistance which is then in turn changed into a temperature reading by the multi-meter at topside (independent of the controller).

Figure 30: Thermistor

- The ROV is also equipped with a magnetic compass to aid navigation which has been placed within the camera's field of view. The company has determined that metal components and wiring on the ROV will slightly affect the reading. However, it could be used to provide the pilot with a fair estimate of direction.

Figure 31: Magnetic Compass

Features to Accomplish Missions (Payload Description)

The MATE ROV competition challenged our company to develop a specialized ROV for oil spill mitigation and to demonstrate the utility of these tools in an oil spill response training mission.

Teams will compete in one mission that consists of the following four distinct tasks:

Task #1: Remove the damaged riser pipe
Task #2: Cap the oil well
Task #3: Collect water samples and measure depth
Task #4: Collect biological samples

This year, our company chose to draw on its Newfoundland culture and designed end effectors to model traditional tools found in the Newfoundland fishery.

Figure 32: Newfoundland Fishery

The Jigger

Throughout the twentieth century, a squid jigger was a common tool of the inshore fishery. Adorned with as many as forty hooks the jigger was used to snag the abundant short-finned squid.

Figure 33: Squid Jigger

The company has designed a modified squid jigger to attach to the damaged riser pipe.

The jigger was made from a section of PVC pipe and 22 gauge tin sheeting. It will be used to attach a line to the riser pipe. When the ROV drives toward the U-bolt with the jigger, the jigger with the attached line passes through it. Once the jigger has passed through the U-bolt, the ROV will thrust backwards allowing the sides of the jigger to hook into the U-bolt. This will enable the deck crew to pull the damaged riser pipe to the surface without fear of dropping it.

Figure 34: Jigger

The Harpoon

From the sixteenth to the eighteenth century, Newfoundland fishermen such as the Basque Whalers preyed on bow head and other species of whales using small open boats and hand thrown harpoons.

Figure 35: Tradition Whaling Vessel

Just like the original, ROV Horizon's harpoon is the most versatile and deadliest of all end effectors.

Figure 36: Traditional Harpoon

It is constructed from 4mm diameter aluminum rod and consists of two 30mm barbs. It will be used for multiple tasks. First it will be used to transport the jigger to the riser pipe. Then it will be used to pierce the Velcro loop and detach it from the riser. Finally, it will be used to transport the well head cover to the well head.

Figure 37: Harpoon

The Prong

Until its banishment in the early 1980's, the fishing prong could be found on every fishing vessel throughout rural Newfoundland. The tool would be used to unload the day's catch.

Figure 38: Traditional Fish Prong

ROV Horizon's prong is made out of a 3mm thick sheet of Lexan© and has been cut and bent upwards on both sides to form a fork-like shape. This will allow the ROV to remove the hose-line from the top kill manifold and transport it to the wellhead.

Figure 39: Prong

The Bailer

Often constructed from an empty plastic container, it was used to remove bilge water from the hull of an open fishing boat.

Figure 40: Traditional Boat Bailer

The bailer is used to collect a water sample from the sample container and was custom built from a 12V windshield washer pump and vinyl tubing. The pilot is able to collect a water sample by inserting the inlet tube into a sample container. Once in position, a switch on the controller is triggered to start the pump. The sample is then contained in an attached collapsible intravenous bag and transported to the surface.

The Sculler

The final end effector is modeled after a sculling oar, once used by fishermen in a twisting motion to propel a boat through the water.

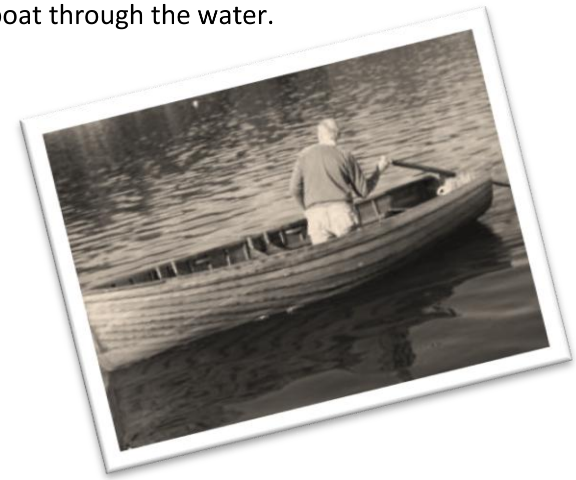


Figure 41: 'Sculling a Boat'

The sculler was made of a motor extracted from a bilge pump, an axle, and a section of perforated plastic. The tool is designed to propel the sample organisms into the belly of the ROV frame where they will remain until surfacing.

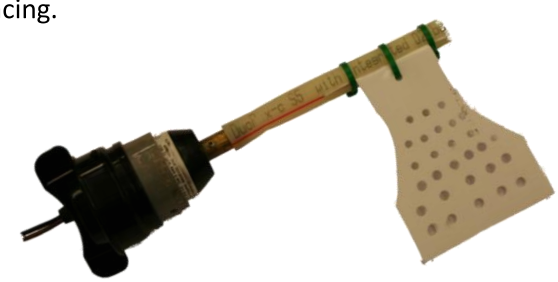


Figure 42: Sculler

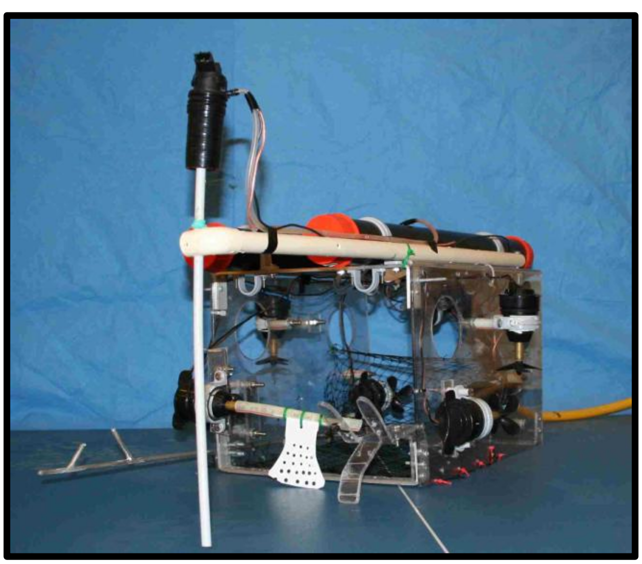


Figure 43: ROV with End Effectors

Challenges

Cougar Robotics Inc., has confronted and overcome many challenges in meeting the goals of this project. These challenges tested our company's abilities and forced us to become more innovative. Budget limitations posed a major challenge. To keep costs down, many of the parts on the ROV are recycled from last year's unit – parts that we had to modify to meet the needs of this year's competition. The company worked very diligently, brainstorming new end effector ideas, and dealing with issues that arose from the construction and testing of our new product within the time constraints that we faced.

Troubleshooting Techniques

In confronting the many challenges that faced our team during Horizon's construction, we adopted several trouble shooting techniques that proved to be very effective problem solvers. A main troubleshooting technique was trial and error experimentation. The company sketched possible solutions first and then experimented with the best ideas until an effective solution was found. One prominent example that is brought to mind is the problem we experienced with lines tangling around the propeller. As the ROV moved near a line it would often get drawn into the thruster. So, we used our troubleshooting technique to solve the problem. Ideas were suggested and tested. Eventually a wire mesh was added to the thrusters, encasing the propellers.

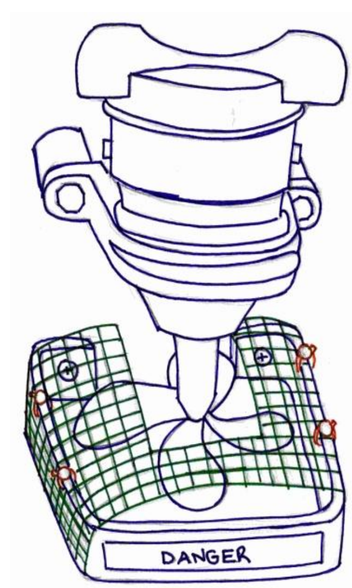


Figure 44: Sample Sketch

Future Improvement

Our company is very pleased with the final version of ROV Horizon. Based on the experience that we have had in our regional competition, we have identified improvements that could be made to improve the power of thrusters, to improve the design of the frame and to increase space to fit the end effectors.

The company has already considered strategies to improve the amount of space on Horizon. To accomplish this we would move end effectors to the sides, or to the top. We would also reduce the size of end effectors. These would be useful future improvements that would greatly enhance Horizon's abilities.

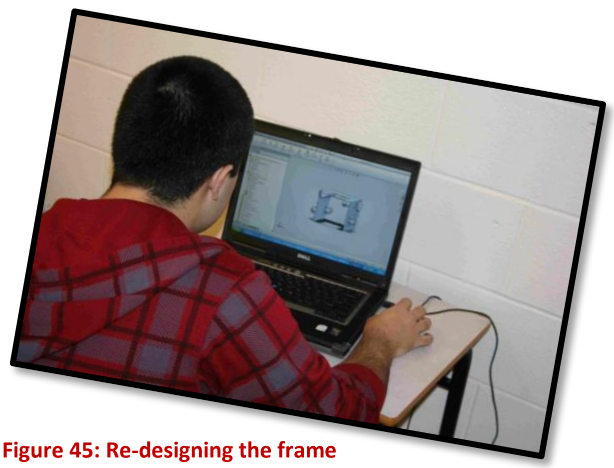


Figure 45: Re-designing the frame

Reflections

Coming together as a team to construct an ROV like Horizon has definitely been a very worthwhile and rewarding experience. Working together to solve problems and brainstorm new ideas has given our company members the chance to share knowledge with each other and to learn about the types of challenges and tasks that are presented to engineers, pilots and other people working in the ROV industry. One of our team members, Amy Short, says that "Our robotics team has come together to build great friendships and memories." We have definitely had a lot of fun during this process. We have made many new friends and we have enjoyed this whole experience. Our company is very proud of our accomplishments.

Team Work

The success of ROV "Horizon" would not have been possible without the strong teamwork that exists within our company. Constructing the Horizon ROV; developing and delivering the presentations, writing the technical report and designing and fabricating the poster board, required tremendous co-operation, coordination and trust between the team's members.

Cougar Robotics Inc. is a dedicated, enthusiastic and innovative company. Each of the members took on their respective tasks, brainstormed possible solutions and through an effective group problem solving method, developed solutions within a set schedule. This extra-curricular activity was more than a project, it was an experience, with new friendships developed in the process. The Company came up with innovative ideas as we learned to dedicate, co-operate and to persevere.

Lessons Learned

Throughout the construction of Horizon, our company learned many important life skills. Not only did we build a robot, we built an effective problem solving team. We came together to brainstorm ideas for frame design, end effector design, thruster design and many other aspects of Horizon's design. We cooperated in designing and building the key components of Horizon. We have all taken ownership, responsibility and pride in our design and in Horizon. Most of all, we've learned that a lot of hard work and dedication does pay off.

This year, the majority of our company is made up of new members and we have all learned a lot of new and valuable skills. Throughout the entire experience of building Horizon we have learned about the design process and the building process, along with acquiring skills in public speaking, presentation and working with computer programs.

Acknowledgements

Cougar Robotics Inc. would like to acknowledge the many businesses and individuals who have helped with the building process and made this competition possible. Thank you to MATE, the local businesses who donated supplies, Canadian Tire and Gosse's Iron Works. Special thanks to Pete Martin who aided in the construction of our test tank. We are also 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	The Wave Fitness Center
Peter Martin	ACOA
Gosse's Iron Works	Town of Clarenville
Town of Clarenville	Clarenville Lions Club
ESDNL	North Atlantic Refining
Pennecom Heavy Civil	Assoc. of Proff. Eng. of NL

Note 1. These are contributors' as of May 16, 2011. An updated list will be posted at the competition.

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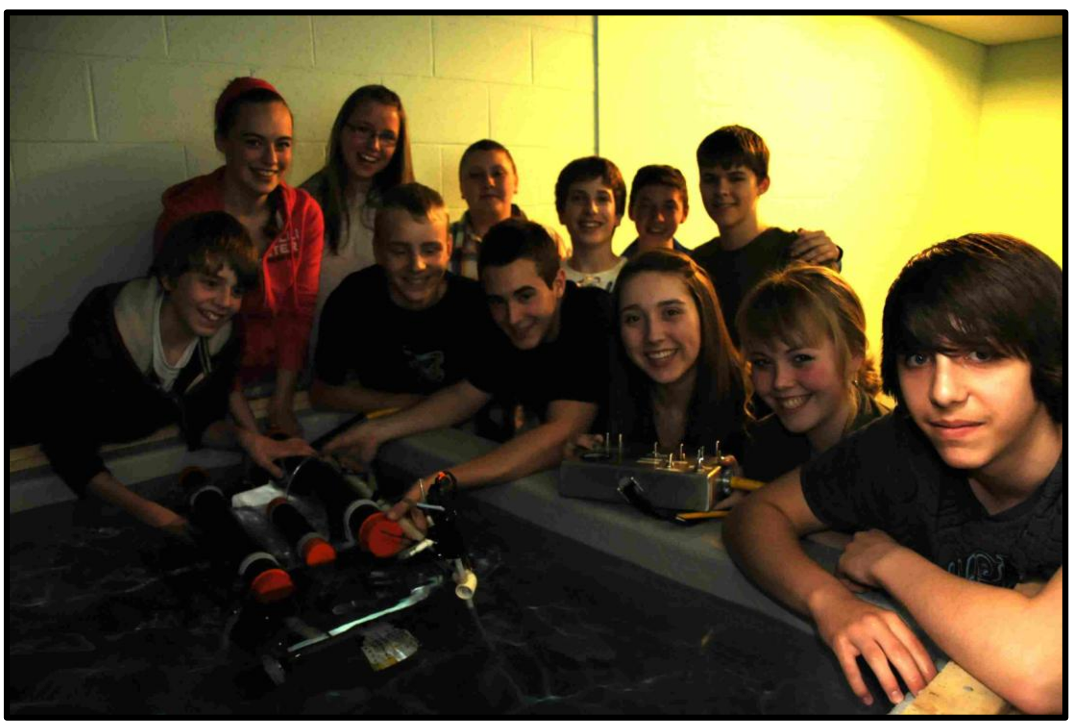
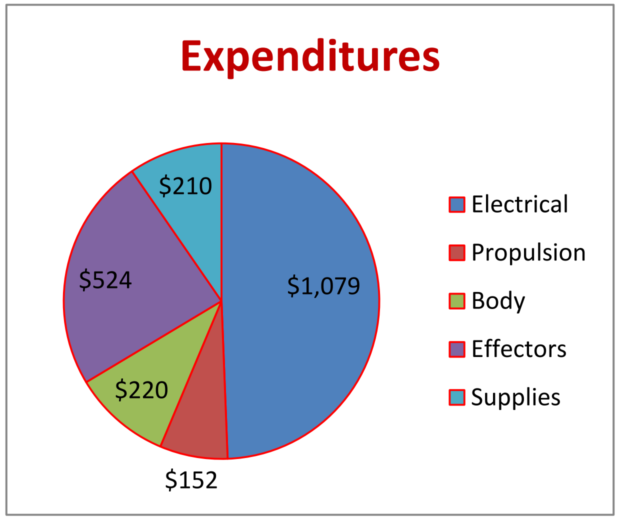


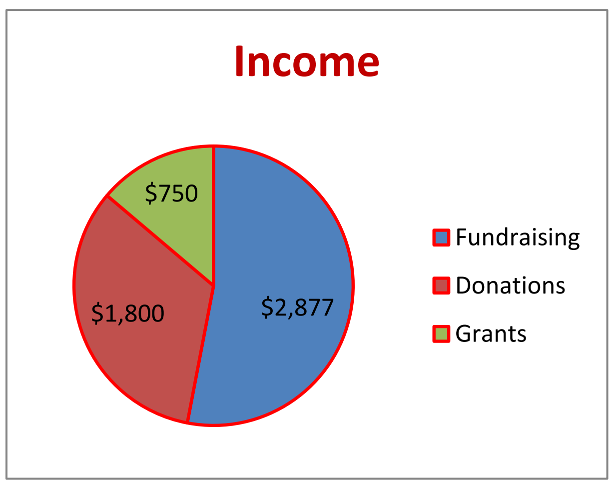
Figure 46: Cougar Robotics Incorporated

Budget (Cdn. Dollar)

Expenditures		
Electrical	Switches	$184.00
	Camera	$350.00
	Tether	$420.00
	Wire	$93.00
	Sensors	$380.00
	Sub-Total	**$1079.00**
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	Pressure Gauge	$350.00
	PVC pipes	$24.00
	Magnets	$20.00
	Lexan ©	$80.00
	Sheet Metal	$50.00
	Sub-Total	**$524.00**
Supplies	Tape	$15.00
	Epoxy	$15.00
	Misc.	$180.00
	Sub-Total	**$210.00**
Total		**$2185.00**



Income		
Fundraising	Cupcake Sales	$127.00
	Bottle Drives	$2200.00
	Car Wash	$550.00
	Sub-Total	**$2877.00**
Donations	Monetary	$1500.00
	In-kind	$300.00
	Sub-Total	**$1800.00**
Grant	Marine Start up	$750.00
	Sub-Total	**$750.00**
Total		**$5427.00**



Note: Many of the materials, we have reused from past years. The values indicated include the total amount need to construct Horizon.


Figure 47: Deep water Horizon. Apr. 20/10

Macondo Blowout

The Macondo Blowout disaster was the largest accidental marine oil spill in the history of the petroleum industry (London Telegraph, 2010). Oil continued to expel from the ocean floor from April 20th until July 15th in 2010. The spill started when the Deepwater Horizon oil rig was drilling an exploratory well. An uncontrolled release of Methane gas, commonly known as an oil gusher, had been released from the well. The gas vented up through the drill column where it ignited, causing an explosion. After burning for approximately 36 hours, the Deepwater Horizon sank.   An oil leak was discovered on April 22nd when a large oil slick began to form around the previous drill site.

The oil spill relief efforts were a series of trial and error attempts until July 15th when British Petroleum (BP) effectively completed the process of inserting a riser insertion pipe into the wide burst pipe. There was a stopper-like washer around the base of the tube that plugged the end of the riser and diverted the flow into the insertion tube.   On September 19^{th}, 2010, 5 months after the spill had began, BP announced that the relief well process was successfully completed and the United States government declared the well “effectively dead”.

Our Mission and Parallels to Scientific Research

Our project has mimicked the challenges faced by British Petroleum and ROV industries around the world. In many of our tasks we simulated the actions taken by BP to analyze and eliminate the effects of the gushing oil. Just like other underwater vehicles, such as gliders, which investigated the nature and depth of the spill, we too collected data during our mission.   During the spill, scientists used submersibles and ROV’s to collect samples of organisms for analysis. Our ROV Horizon also had to collect different types of organisms and return them as samples to the surface.

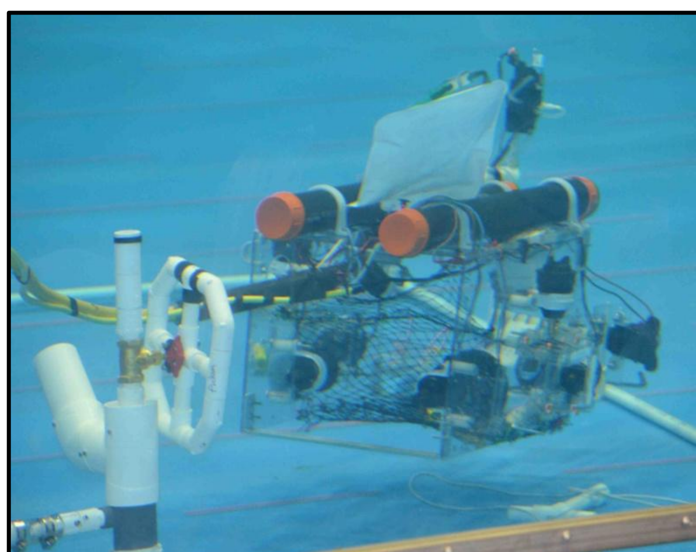


Figure 48: Horizon capping the Well

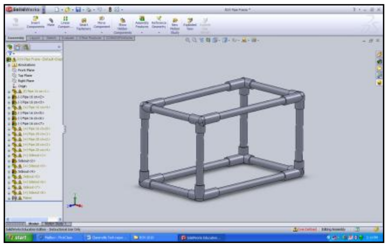
Appendix A: Flight Plan

Flight Plan	Time
Descend to mission site	1min
Transport and attaching a line to the u-bolt on the damaged riser pipe	30s
Simulate cutting the riser pipe by removing a velcro strip	30s
Lifting and moving the cut-off portion of the pipe from the work area	30s
Removing the hose line from the top kill manifold that rests on the seafloor	1min
Inserting the hose line into the port on the well head	1min
Turning the valve wheel from completely open to completely close, stopping the flow of oil	1min
Installing the cap on the well head	1min
Interpreting a graph to determine at which depth to sample	1min
Measuring depth at the sample site	1min
Collecting a water sample so that it is in possession of your ROV and no longer in the container	30s
Returning the water sample to the surface so that your team can retrieve the sample	1min
Returning >100ml of sample water to the surface	30s
Return to mission site	1min
Collect glass sponge	30s
Collect sea cucumber	30s
Collect chaceon crab	30s
Return to surface with one of each sample	1min
Total	**13:30**

Appendix B: Design Software Summary

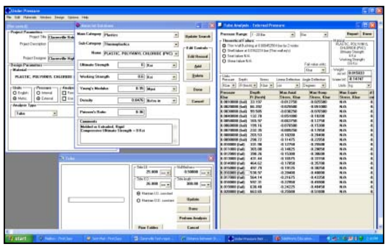
Throughout the course of the project we used a variety of programs and software to aid in the development of Horizon. Some of these are listed below.

Solidworks 8



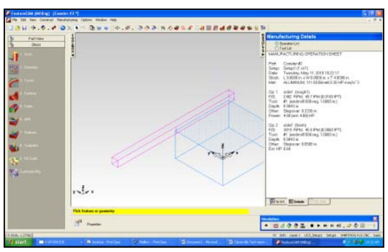
SolidWorks is a 3D mechanical CAD (computer-aided design) program developed by Dassault Systèmes SolidWorks Corp. It is very useful for designing ROV effectors since they can be seen, tested, and altered without ever producing the part.

Under Pressure 4.5



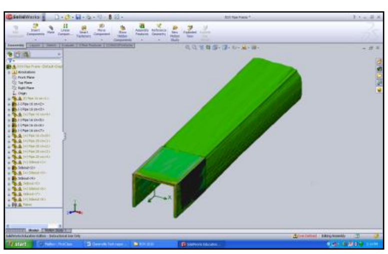
Under Pressure evaluates structural capabilities, deflections, and weights of common pressure vessel geometries such as cylindrical tubes, spheres, as well as hemispherical, conical, flat circular, and flat annular end enclosures. During the design of an ROV it can be used to test the maximum water depth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

Feature Cam 2007



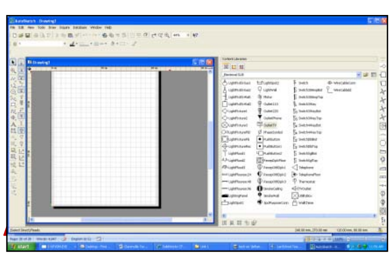
Feature CAM, developed by Delcam, is a suite of CAD/CAM software which automates machining and minimizes programming times for milling part. Feature Cam allowed us to directly machine parts created in Solidworks. This has a major implication since parts could be quickly machined without having to actually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

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 shop
- ◻ 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 (correct amperage)
- ◻ ROV is disconnected from power source
- ◻ Check ROV for hazards (loose bolts, cracks, buoyancy check)
- ◻ No exposed wiring
- ◻ Tether is neatly laid out
- ◻ No exposed wiring (complete resistance check)
- ◻ Ensure guards are securely fastened
- ◻ Check end effectors for damage
- ◻ Step away from ROV and connect to power supply
- ◻ Check all switches are working
- ◻ Designated personnel to place ROV in water and release
- ◻ Turn on power