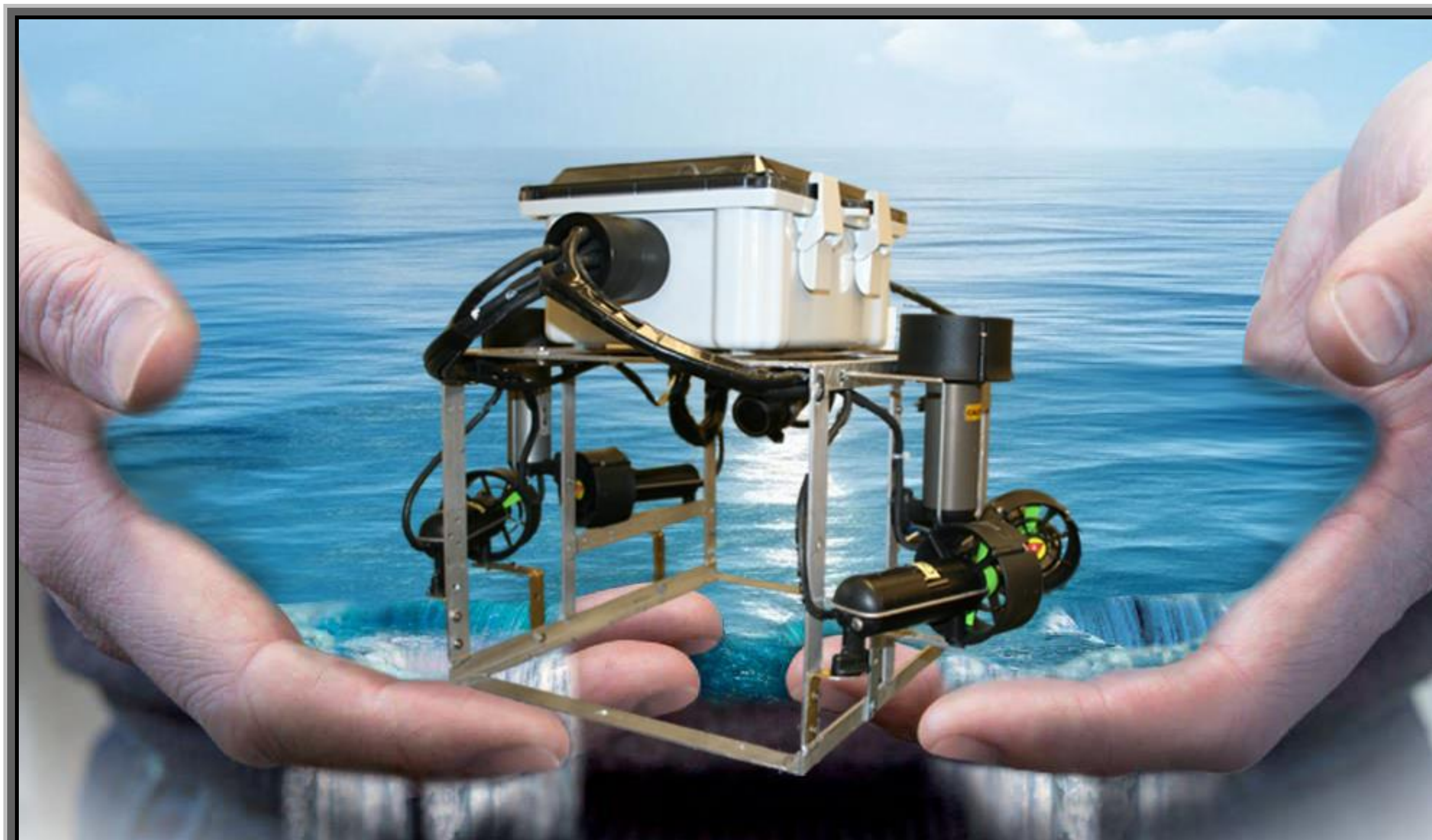

Clarenville High, Clarenville, NL, Canada

MATE International Technology Report 2015

Featuring ROV Erebus

COUGAR ROBOTICS INCORPORATED

Team Members:

Michaela Barnes *- Captain*

Courtney Clarke *- CEO*

Kyle Clarke *- Pilot*

Patrick Dove *– M2 Specialist*

Claire Sawler *- Marketing*

Brooke Snow *– M3 Specialist*

Andrew Sullivan *– M1 Specialist*

Mentors:

Bert Roberts

Michael Spurrell

Garry Walsh

Carl Winter

Chris Clarke

MATE

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Mate International Technology Report - 2015

Cougar Robotics Incorporated

Clarenville High School, Clarenville, NL, Canada
http://www.chs.k12.nf.ca/ROV.htm

Abstract

Cougar Robotics Incorporated from Clarenville, Newfoundland and Labrador, Canada has meticulously constructed an innovative and profitable ROV for the purpose of underwater exploration and conservancy. This report includes details on every aspect of Erebus including the frame, custom designed control system (consisting of an array of Phidget boards using visual basic programming), thruster positioning (creating enhanced maneuverability), neutrally buoyant tether (increased room for expansion), multiple cameras with a 360° view, and finally an adjustable buoyancy that provides for seamless attaching and detaching of various payloads or tools. A design process was implemented before construction of any tools and included a carefully developed troubleshooting technique to ensure that mission tasks would be accomplished efficaciously. Team members were divided into job specific tasks, based on varying skills and knowledge, to facilitate an efficient work environment that would meet scheduled milestones. Further to this, our report will reflect the teams challenges, lessons learned, collaborative processes, future ROV improvements, reflection on innovations, safety concerns, budget costs, acknowledgments, references, diagrams, and photos. Cougar Robotics Incorporated worked with pride, diligence, and innovation to construct Erebus to adapt to multiple situations and to produce successful completion of missions.

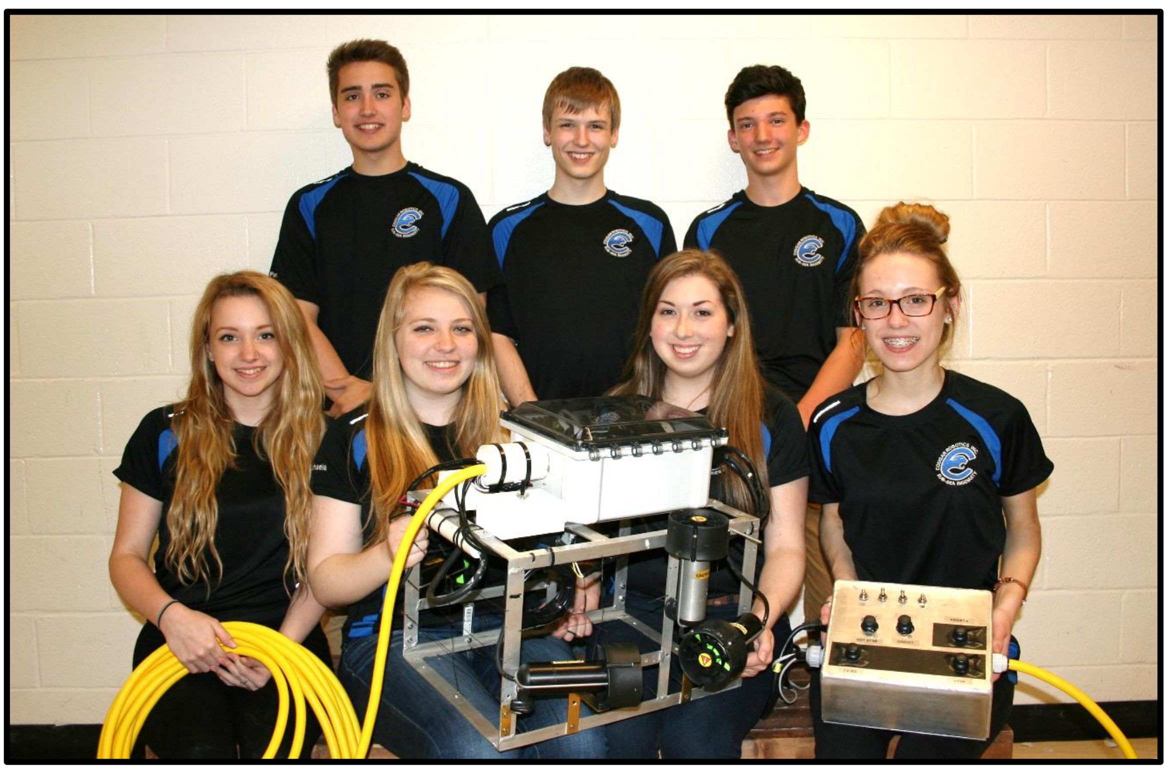


Figure 1: Team Cougar Robotics.

Front Row (L-R): Brooke Snow, Michaela Barnes, Claire Sawler, Courtney Clarke.
Back Row (L-R): Patrick Dove, Kyle Clarke, Andrew Sullivan

Introduction

Cougar Robotics Incorporated is a company specialized in the design and construction of ROV's (Remotely Operated Vehicles), originating from Clarenville High School in Clarenville Newfoundland and Labrador, Canada. Our company was tasked with the construction of an ROV to complete three distinct missions, all involving operations within polar conditions. When determining a name for our ROV we researched discoveries in Canada's Arctic and found information on Sir John Franklin's ship the *Erebus* which he sailed during his quest in 1845 to find the Northwest Passage to Asia. The *Erebus* was one of two Royal Navy ships on the expedition. Both ships were stuck in the ice, which resulted in the death of 129 crew members as well as Franklin. The reason for naming our ROV after one of Franklin's ships is that the discovery of *Erebus* is a monumental accomplishment for our country and the ROV community. As a company we felt that since ROV's were used in locating Sir John Franklin's ship that it would be fitting to name our ROV, *Erebus*, after the recently discovered ship in Canada's Arctic. This technical documentation will explain the reasoning behind the design of ROV *Erebus* along with the process in which the company used to perfect the final product. Cougar Robotics Incorporated has implemented a design process that guarantees a successful constructed ROV every time. This process was used in the design and construction of every component of ROV *Erebus*, such as the electrical and control system, frame, propulsion, ballast system, cameras and each of the payload tools. The company's success can also be attributed to the strict schedule followed by the team. Deadlines were set, and the team agreed to meet at least twice a week in order to ensure that the final product was perfectly produced. Each meeting began with a safety moment, announcements and the tasks at hand were discussed and distributed. Dedication and teamwork are a critical component in the construction of a successful ROV. This document will highlight the company's trouble shooting techniques throughout the construction of ROV *Erebus*. Cougar Robotics Incorporated faced many challenges and learned lessons that will aid in the design of future ROV's. The company is proud of the constructed ROV *Erebus* and is confident in its ability to complete the tasks presented by MATE. Furthermore, we present the technical documentation submitted by Cougar Robotics Incorporated of Clarenville High School.

Figure 2: ROV *Erebus*. (Isometric, Top, Left views)
Isometric (left), Top view (top right), Left view (left-bottom)

Design Rationale

The entire development and construction of ROV *Erebus* was guided by a 5-step Design Process to ensure that the ROV was designed as effectively and efficiently as possible. Every task, whether large or small, was subjected to the same procedure. Before tackling any problem, a clear concise description of the task or challenge was achieved. The company determined exactly what was required or needed. During the initial development stages, the team completed research and consulted with our mentors to find a viable solution. Prior to production, components were analyzed and tested using various design programs such as SolidWorks, Auto Sketch, Fritzing and Cosmos FloWorks. 3D assemblies of the ROV and effectors were created and used in tandem with COSMOS FloWorks to perform motion and drag tests. Finally, prototypes were constructed, tested and re-evaluated until an optimal solution was obtained.

Figure 3: Five Step Design Process

To facilitate the design process, the team adhered to a uniquely developed set of protocols which we appropriately named the 3Gs. The 3Gs is an acronym which stands for three goals: Minimal drag, Reduced mass, Durable materials and our philosophy of keeping it simple. During each production stage, the design team ensured that these 3 goals and philosophy were adhered to and strictly abided by.

3Gs

1) **G**oal-Minimal drag:

   Possibly the most important factor when designing an ROV is minimizing drag. During this year's mission, ROVs will have to maneuver and work in water current. Attempts were made to streamline each component and construct a frame which exhibited limited fluid resistance.

2) **G**oal-Reduced mass:

   Reducing the mass meant we would need less buoyancy in order to be neutrally buoyant, and also the ROV would be easier to maneuver in the water. A lighter ROV also has many benefits above the surface. Our company found that reducing the mass of ROV *Erebus* made it much easier for team members to work on and transport the ROV. Lightweight materials such as aluminum and acrylic were used in order to achieve this goal.

3) **G**oal-Durable materials:

   In order to create a strong, reliable ROV, we needed strong, reliable materials. It is important for an ROV to be able to withstand wear, pressure, and rough conditions while underwater. Our company developed an ROV that is capable of performing under these conditions by using durable materials such as stainless steel fasteners, 6061 grade aluminum, and buoyancy made from polymer microspheres.

4) **S**implicity:

   Our company strongly believes in finding the simplest way to complete any task. A simple outlook leads to thinking "outside the box" in order to find a quick and effective way of completing our missions. Keeping our tools simple decreases the probability of malfunction and makes troubleshooting much easier.

Although this will be the team's fifth appearance at the International competition, it will be the first appearance in the Explorer class. After winning the 2014 Ranger competition our team felt that we were ready to face the challeges associated with competing at the Explorer Class level. ROV *Erebus* has been completely built from the ground up. Every component, part, and system, has undergone a complete redevelopment and revolution. In the next few pages we describe these developments and explain how each component contributes to the success of ROV *Erebus*.

Control System

ROV *Erebus* is operated through a custom control system consisting of an array of Phidget boards and the Visual Basics programming language. Topside, a computer is connected via CAT 5 communication cable to the control box which then runs through our custom made tether, and USB to the 8/8/8. Using the Visual Basics program language we have written a custom ROV control program, used to configured an array of Phidget boards both topside and onboard the ROV to allow complete manipulation over the propulsion system and each end effector. Topside, our control box is a (20cmx28cmx10cm) welded aluminum box, containing four 6-start 2-way momentary switches left unused, and five miniature joystick sensors: three for movement and two for the control of end effectors. The miniature joystick sensor that has been selected has two axes and a pushbutton. Each axis, up/down and left/right has a potentiometer with a center value of approximately 500. When the joystick is moved from its center position, the value increases or decreases depending on the direction moved. Using our custom ROV control program, readings received from the joysticks enable us to encode sensitivity ranges for each potentiometer and the end effector or thruster they control, giving a range in power supplied when the joystick is moved.

Figure 4: Custom Control Box
Consists of a Phidget 8/8/8 board, Joysticks, and analogue switches.

Figure 5: Joystick
The miniature joystick has two axes and a pushbutton. Each axis, up/down and left/right, has a potentiometer with a center value. When you move the Joystick from its center position, the value will increase or decrease depending on the direction.

Inside the control box resides a Phidgets InterfaceKit 8/8/8 card, consisting of both analog inputs, digital inputs and digital outputs. The analog inputs on the 8/8/8 are used to measure continuous quantities such as temperature, and will be used for the momentary switches if necessary or sensors. The digital inputs have a Digital Input Hardware Filter to eliminate false triggering from electrical noise. They can be used to convey the state of devices such as push buttons, limit switches, relays, and logic levels. Because of this hardware, the digital inputs on the card are used for the miniature joysticks.

When the coded program is engaged, the input that is received from the sensors (potentiometers) in the control box is then transmitted by the Phidgets InterfaceKit 8/8/8 card to the custom ROV control program open on the laptop. The program interprets the message received from the 8/8/8 card, and will further send command through the Ethernet cable in the tether to onboard the ROV.

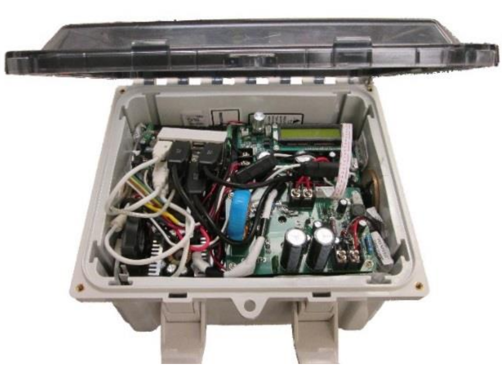


Figure 6: Onboard Electronics Box
The Custom electronic box consists of an array of Phidgets boards and DC-DC Convertors housed in a water tight Attabox.

Onboard the ROV is an array of Phidget boards, all vital for the efficiency of the computer based system designed. The PhidgetsSBC3 is a Single Board Computer with an integrated Phidgets InterfaceKit 8/8/8. The SBC3 is the first card inside of our watertight Attabox onboard the ROV; and it is wired to five motor controllers (for control over end effectors and propulsion units), is USB enabled (controlling three extra USB cameras) and most importantly, is wired from the tether, receiving output from the 8/8/8 and Visual Basics application. The integrated Phidgets InterfaceKit 8/8/8 allows us to connect devices to any of the 8 analog inputs, 8 digital inputs and 8 digital outputs. It provides a generic, convenient way to interface your PC and PhidgetSBC3 with a wide variety of devices and it operates exactly the same way as an external Phidget InterfaceKit 8/8/8.

With these available inputs, we are able to connect sensors when necessary, providing plenty of room for manipulation further on. The SBC3 is the link that allows the control over both propulsion and end effector units. It allows the transmission of output from the 8/8/8 card and the ROV control program, respectively, through the Ethernet to be passed on to the five motor controllers wired to the Phidgets SBC3: three in use for the total 6 thrusters, and two available for possible end effectors.

The custom ROV control program continually monitors the 8/8/8 card via the USB connection for any change in sensor values. This will continue until a change occurs. When the Phidgets InterfaceKit 8/8/8 relays a change in sensor values (ie. Potentiometer has moved from starting position), the ROV control program will find the sensitivity range that fits the reading, which will determine the percent of voltage sent to end effector or thruster. This command directive is further transmitted down the Ethernet cable portion of the tether. Once the command has reached the PhidgetSBC3, it continues to be transmitted to a motor controller and the desired end effector or thruster, therefore initiating movement.

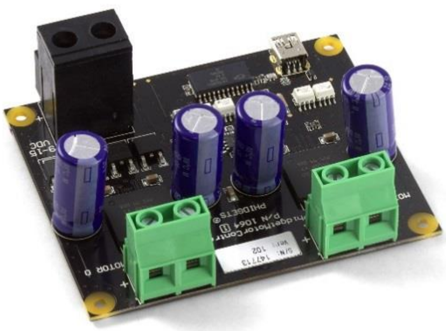


Figure 7: Phidget Motor Controller
Allows control of the angular velocity and acceleration of up to two high-current DC motors. Monitors surges and overheating in the API and connects to a USB port

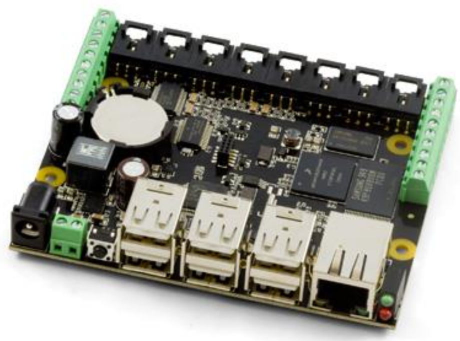


Figure 8: Phidget SBC3
The PhidgetSBC3 is a single board computer running Debian 7.0 with 128Mb DDR2 SDRAM, 1 GiB Flash, integrated 1018 and 6 USB 2.0 High Speed 480Mbits/s ports.

Figure 9: Phidget 8/8/8
A The Phidgets workhorse. Connect analog sensors, control switches, and check on push-buttons. One board handles up to 24 devices. 1018 with an on-board powered 6-port full-speed (12Mbit/s) USB hub.

Software Flow Chart

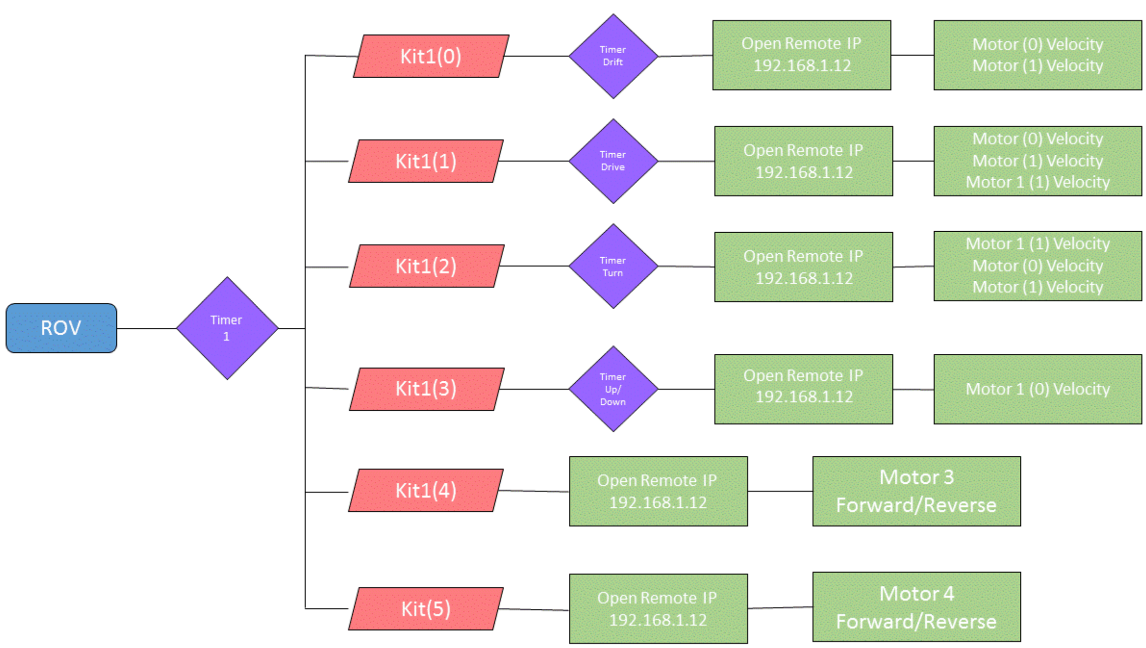


Figure 10: Software Flow Chart

Power Conversion

Onboard the ROV, inside the watertight Attabox is a DC 1200 watt programmable step down converter. 48 volts is being delivered to the ROV from topside and is only permitted to be converted onboard the ROV to the necessary output voltage. Our company selected the DX955y DC converter, which will be used to step down the provided input voltage of 48 volts to a safe output voltage of 19 volts for our ROV's six 19 volt BTD - 150 thrusters. Secondly, there is a smaller Buck Step-down DC converter in use, since our end effectors carry only 12 volts each. This second DC converter will be used to step down the new input voltage of 19 volts to 12 volts, accessible for any end effector.

Figure 11: *ZXY-6020S DC-DC convertor is 1200watt single output programmable switch power supply. The LED window shows the output voltage, current and power. The board is equipped with a TTL serial interface, to provide a serial communication.*

Tether

The tether is one of the most important features of an ROV because it is the communication link between topside and onboard the ROV. Our company has designed a unique tether to fit our ROV's needs with the assistance of LEONI Elocab Ltd. The tether has a nominal weight of 195 g/m and measures 19 meters in length. It consists of two 16 AWG wires to deliver power to the electronics box and a coaxial cable to carry video feed from the main camera. Two 20 AWG auxiliary wires are included for future expansion. An RJ-45 Ethernet cable consisting of four twisted pairs was also added to allow communication between the on board SBC3 and 8/8/8 card at topside. These cables are packed sturdily in a foam polyurethane shell measuring only 15.8mm in diameter, along with inside fillers to maintain its round form without collapsing due to water pressure. Our company's tether is neutrally buoyant, allowing for easy maneuverability and minimal drag.

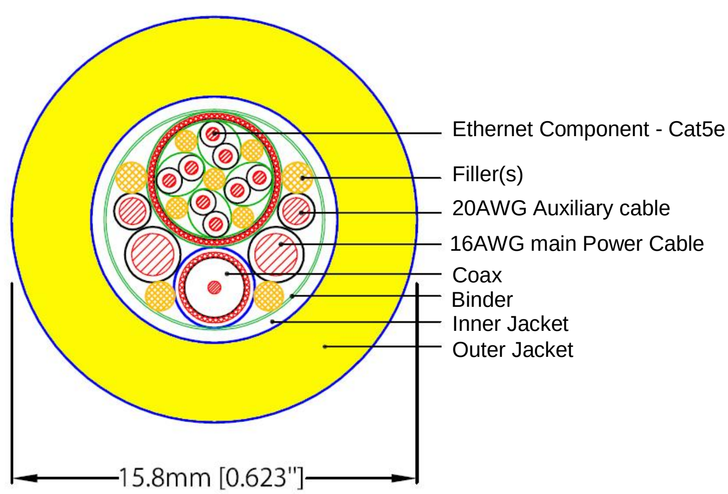


Figure 12. Tether

-Maximum Operating Voltage: 600VDC
-Operating Temperature: -20°C to 80°C
-Minimum bend radius: 2× cable diameter
-Cat 5e Impedance: 100 ohms ±10%
-RoHS Compliant
-Meets CE standard guidelines.

Figure: 13 Ethernet Cross-section - Cat 5e

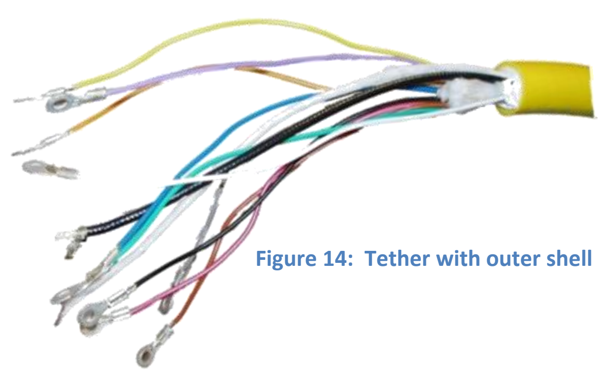


Figure 14: Tether with outer shell stripped.

Propulsion

An efficient propulsion system is a critical component in the design of a successful ROV. The thrusters allow the ROV to move fluently through the vertical and horizontal planes. After testing a number of commercial and homemade products, we decided to use the BTD-150 thrusters, available from Seabotix. These thrusters optimize the performance of our ROV by providing exceptional propulsion, speed and maneuverability. At an operating voltage of 19V and maximum operating current of 4.2A, these thrusters are well within the power limit of our ROV. Each thruster comes equipped with a shroud to direct water flow and to ensure no foreign objects will get caught in the propellers.

Figure 15: BTD-150 Seabotic Thruster
The thruster proved to be powerful, compact, lightweight, and efficient with a depth rating of 150m.

The positioning of the thrusters is crucial in providing stability and straight line motion to the ROV. In total, six thrusters were positioned around the ROV. Two vertical thrusters placed on either side of the ROV and align with the center of gravity to provide vertical translation. Four horizontal thrusters were positioned around the ROV at 20° angles - providing forward and backward translation, as well as the ability to turn or drift to sideways. The drift feature works by powering on the horizontal thrusters on one side of the ROV, in opposite directions. This causes the ROV to move smoothly in the horizontal plane, giving us the ability to maneuver the ROV precisely where it needs to be. Our company also developed a proportional control system, to better control the ROV when needing precise movements. Deflecting the joystick 1% to 80% of its full range allows the ROV to move at up to 30% of its full speed, while deflecting the joystick all the way allows to ROV to move at its top speed.

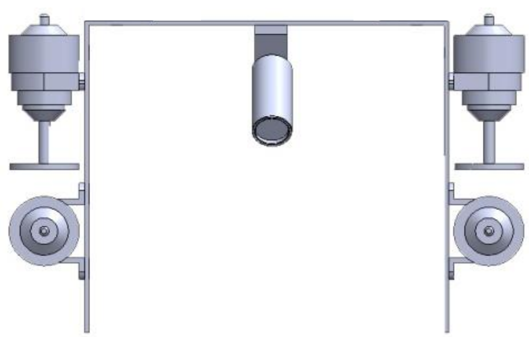


Figure 16: Thruster placement – SolidWorks Drawing
CAD drawings enabled us to visualize the ROV and perform drag analysis prior to construction.

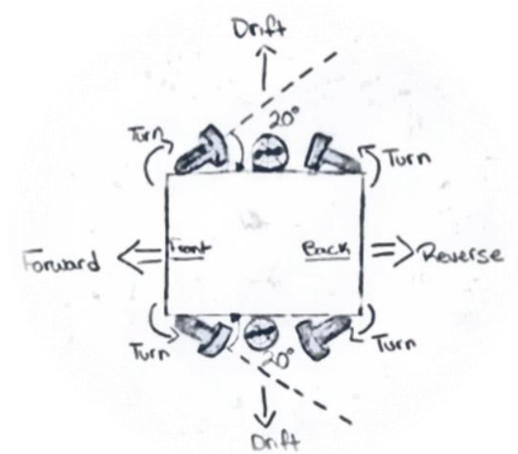


Figure 1t: Thruster Placement – Sketch
Six criticallt placed thrusters provide the ROV Erebus the ability to move forward reverse, up down and sideways.

Ballast System

For maximum control and efficiency, it is important for the ROV to be neutrally buoyant. Most of the buoyancy on the ROV is provided by the air in the electronics box (a waterproof box available from Attabox that houses the onboard computer and its components).

Since this year's mission requires the removal and placement of different tools the team developed an adjustable buoyancy system. A bolt on each corner of the ROV allows us to attach and remove buoyant discs to adjust the buoyancy of the ROV depending on the end effectors for each mission. These buoyancy discs were constructed from 6.0cm x 9.0cm pieces of Trelleborg TG-24 syntactic foam. This buoyancy is made up of hollow polymer microspheres that will not compress under the conditions of our missions.

Video Camera

ROV *Erebus* is equipped with four cameras. The frontal camera is directed at the tool bay and provides sufficient view of effectors. It is also the main camera used during the mission and offers an exceptional view. The camera is manufactured locally by SubC Control. SubC Control was chosen because they produce high quality products and were able to provide immediate assistance when needed. Angler model camera entails digital noise reduction, back light compensation, and highlight compensation which results in a clear, sharp image. The camera has an underwater view angle of 85 degrees and the ability to operate in low light conditions of 0.0001 Lux. It boasts a resolution of 1020 x 580 pixels, a sapphire lens, and the ability to operate at depths up to 500m.

Our ROV also uses 3 USB LED endoscope cameras that are plugged directly into the onboard computer. They feature a resolution of 640 x 480 pixels and in-water view angle of 54°. These cameras have 1m long waterproof cables and can be positioned to allow our pilot to see any of our end effectors, giving us a complete 360° view of our ROV and surroundings.

Figure 18: USB LED Endoscope.
There are three endoscope cameras on ROV Erebus. Each camera may repositioned to obtain necessary view.

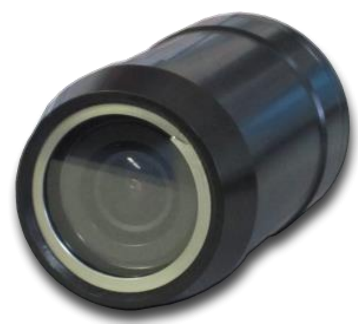
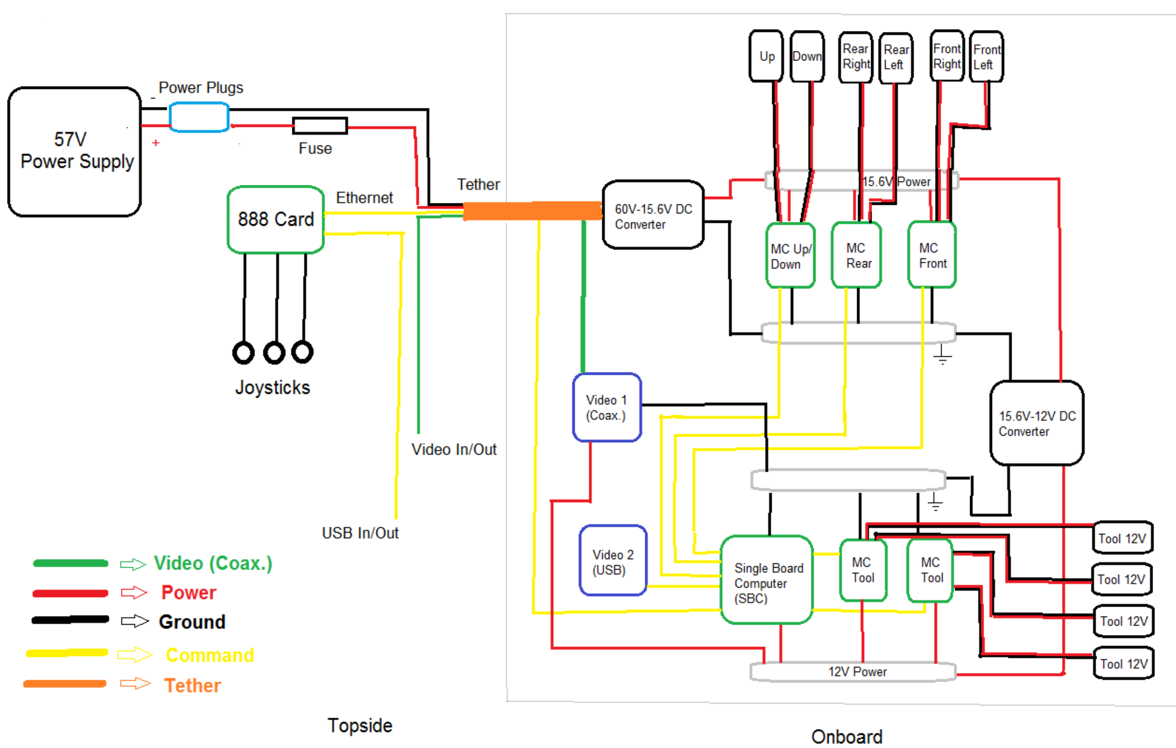


Figure 19: Angular Camera
The main camera was constructed by Sub C Control. This local company has worked closely with our team.

System Integration Diagram



Frame

The frame chosen was selected for its susceptibility to tool placement, but more importantly, its resistance to drag and reduced water flow. Before selecting the frame, all options were drafted in solidworks and underwent a fluid flow analysis using COSMO Flowworks. After testing, the company decided to construct the frame from aluminum flat bar. The box-shape frame measures 0.46m x 0.34m x 0.29m (L x W x H) and is an open on all sides. This spacious design provides sufficient space to easily mount thrusters, end effectors, and buoyancy and allows easy access to all mounted components for maintenance and troubleshooting. The aluminum flat bar design proved to be light weight, corrosion resistant, durable and malleable. As well it combines high tensile strength, hardness, and temperature resistance with low water absorption. Once the basic frame shape was chosen, buoyancy, thrusters, the camera and the waterproof Attabox were added.

Figure 20: Aluminium ROV Frame.
The aluminum rectangular-shape frame is open on all sides and provides sufficient space to easily mount thrusters, end effectors and buoyancy. In addition it combines high tensile strength, hardness, and is temperature resistant with low water absorption.

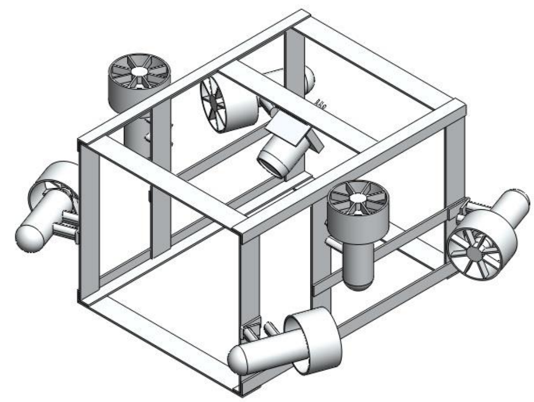


Figure 21: Isometric SolidWorks Drawing
Once the basic shape was chosen, a complete model including thrusters, buoyancy, and camera was drafted in SolidWorks. Further drag analysis was performed to see how fluid flow would be affected. The entire model yield a drag of -13.66N.

Features to Accomplish Missions (Payload Description)

Cougar Robotics developed a number of custom designed tools to complete the missions. These tools were created to be interchangeable and able to be quickly attached to the ROV using our unique plug and play system. All tools have a common attachment points and may attach to power using a multi wet connect system. The resultant changes in mass and a subsequent shift in the ROV's center of gravity can also be accommodated using the teams Trelleberg buoyancy system. After adding a tool, with a few minor adjustments, the team can quickly return the ROV back to a neutrally buoyancy state.

Phidget Oxidation - Reduction Potential (ORP) ADAPTER

To **test and measure the voltage of four specified points along the leg of an oil platform** the team has developed an electric field sensor from an ORP Adapter and BNC connector. Data is collected and fed to an Analog Input on a Phidget Interface board. If a reading is detected, the software indicates that the electrode is subject to galvanic corrosion. The ORP adapter has an input range of ± 2V DC, with 5mV DC resolution and ± 0.09 error in reading.

Figure 22: ORP Adapter
The Phidget ORP card is water proofed and connected to the SBC on board the ROV. Using a cable and BNC connector electromagnetic field readings are taken at the oil platform

Installing Gasket and Bolts

To **install a gasket and bolts on the pipeline** our team has invented by far the most creative and innovative tool we have ever seen. The multi-purpose tool is capable of transporting the entire setup and installing the gasket and bolts in one quick concise movement. The bolts are installed into the gasket at topside and held in place inside a pipe using an elastic band. Positioned behind the gasket is a spring loaded plunger. Once the gasket is installed over the pipe, a motor pulls the pin releasing the gasket and allowing the plunger to snap forward. This motion causes the gasket to sit nicely at the end of the pipe with the bolts installed!

Figure 23: Flange/ Bolt Tool

Pipe Retrieval

To **attach a lift line to the corroded pipe, and transport it to the surface**, our company developed a self-trigging clamping mechanism. The tool consists of a set of acrylic jaws held under pressure using an elastic band. Once the tool comes in contact with a length of pipe the trigger is activated allowing the jaws to snap shut, effectively gripping the pipe. The tool is then released from the ROV allowing the corroded section of pipe to be pulled to the surface using an attached length of nylon rope.

Figure 24: Jaws - Pipe retrieval tool

Hot Stab manipulator

To **insert/remove the hot stab into/from the wellhead** the company has constructed a tool from a 44.9cm x13.4cm sheet of Lexan, with three 19.3cm arms from one end of the sheet. Two of the arms were bent: one upward and one downward in order to comfortably carry the hot stab. To secure the hot stab, a 12.2cm x 1.1cm vertical slot was cut in the center of the Lexan. There is a 5.5cm Lexan arm controlled by a 12v DC motor that lowers to keep the hot stab in place, and rises to release the hot stab into the wellhead.

Figure25: Hot stab manipulator.

The Multi-tool

One of ROV *Erebus* simplest yet efficient tools is the multi-tool. The tool will be used **to recap the well head, transport the acoustics sensor, and position the water pump** in *Mission 3*. It is constructed from a section of aluminum flat bar and 6 cm bolts. One bolt acts as a barb keeping the payload in place and the other as a backstop to restrict the payload from sliding backward into the ROV.

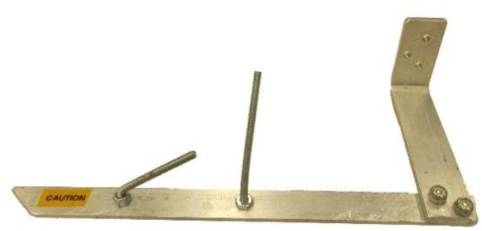


Figure26: Multi-tool

The Prong

This tool is used in *Missions 2 and 3* **for turning multiple valves**. It is constructed from an 11.5cm x 8.5cm aluminum rod with two prongs measuring 2.2cm in length. The aluminum rod is attached to a 12v DC motor which allows the rod to rotate. The prong is attached below our ROV, and once the ROV is positioned above the desired valve, the pilot will confirm that the prong is engaged with the valve and give the co-pilot directions to turns the switch, enabling the motor to rotate in the desired direction.

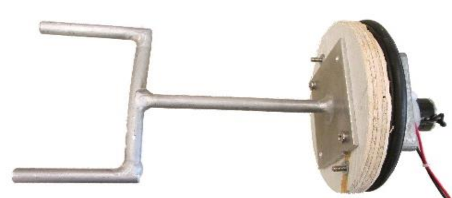


Figure 27: The Prong - Turning valves.

The Vacuum

To collect algae from underneath the ice our team designed a vacuum from a bilge pump and various pieces of ABS pipe. The tool is mounted on top of the ROV with the inlet pipe positioned vertically to capture the algae. Once retrieved, the algae cannot escape since it floats and is trapped in a holding bay constructed from a second vertical pipe. At the surface the cap of the holding bay is removed and the algae is retrieved. To aid with capturing the algae, one of the USB inspection cameras will be mounted on the top of the ROV and directed toward the inlet pipe for optimal viewing.

Figure 28: The Vacuum - Collects algae.

Measuring Tools

To measure various objects we have constructed a tool consisting of of a double-sided retractable tape measure. The tape is attached to an aluminum bar by a bearing removed from a dolly wheel. The bearing allows the tape to rotate when switching from horizontal to vertical measurements. The pilot flies the ROV directly toward the object catching it with an interchangeable ‘capture point’. Once a measurement is taken, the ROV reverses, allowing the tape to disengage and retract to its original position.

Capture points:

<u>The Cup:</u> will be used in *Mission 1* for measuring the **height** of the iceberg. This tool is constructed from a 10.2cm high polyurethane cup. This tool is attached directly inward on the front left side of the ROV. The keel of the iceberg sits in the cup and the ROV rises to take a measurement.

Figure 29: Cup measuring tool

<u>The Hoop:</u> To measure the **diameter** of the iceberg in *Mission 1*, we have developed “The Hoop”. It consists of an 11.5cm diameter ring used to catch the ends of the iceberg. The tape measure is attached to, aluminum bar by a 6cm high aluminum L bracket, keeping the tape stable and steady. The pilot flies the ROV directly under the iceberg, catching one of the four lettered posts with the ring. The ROV then continues to the opposite side where the measurement will then be recorded. Once recorded, the ROV lowers to detach from the iceberg and carry on with the mission.

Figure 30: Ring measuring tool

<u>The Hook:</u> is constructed from a wire hook and used to measure the **angled wellhead** in *Mission 3*. There is a ping-pong ball also fixed to the tip of this hook, so it will have the buoyancy to float upright. The hook catches the opening in the top of the well head. The ROV dives to take the vertical measurements and flies forward to measure the base.

Figure 31: Hook measuring tool

Troubleshooting Techniques

Throughout the entire project and fabrication of ROV *Erebus,* our company experienced many problems and faced numerous obstacles. When we encountered a problem we used a three-step troubleshooting technique that we developed and found to be very effective. We first identified the affected area; secondly, we selected a probable cause and determined a solution; and lastly, we tested the solution. When constructing our ROV, we tested the success of our components and the overall operation of the vehicle. After production, the ROV was vigorously tested in our homemade test tank. If problems were discovered we immediately put our three-step troubleshooting technique into action. Due to our troubleshooting procedure, we solved and avoided various malfunctions and were able to quickly deal with difficulties that arose.

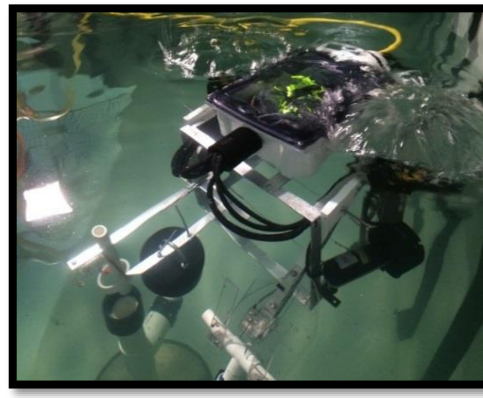


Figure 32: Testing ROV *Erebus* in our tank

Safety

Cougar Robotics' philosophy is "safety is our top priority". **ROV *Erebus* has been built to comply with competition safety requirements.** Our company followed proper safety protocol and procedures at all times when constructing and testing our ROV. We ensured that proper safety glasses were worn at all times, and all tools were handled properly. All members had to be trained in the responsible use of power tools. The floor and work areas were cleared of potential hazards before commencing work on the ROV. To protect the users and equipment, a 40A fuse was installed on the positive side of our control box, along with an emergency power on/off switch in the event of malfunction. Our company ensured that there were no bare wires left exposed on the ROV to reduce the chance of electric shock. In order to waterproof our onboard Phidgets, we used an airtight Attabox with a rubber seal, along with O-ring gaskets around other openings, to ensure that it will not leak. Silica gel packets were added to the inside of the Attabox in order to eliminate condensation that could short out our electronics. On ROV *Erebus* itself, there are no sharp objects that could potentially cause injury and our thrusters are shrouded and clearly marked with yellow caution labels to avoid tangling and injury. When piloting the ROV, we keep our tether in a neat coil to avoid any tangling and also eliminate a tripping hazard. Safety is of utmost importance during the construction process and the piloting of our ROV.

Figure 33: Courtney constructing end-effectors.

Challenges

When completing the requirements for MATE ROV's 2015 competition, Cougar Robotics Incorporated encountered various challenges of both a technical and a non-technical nature. One of the technical challenges faced was evident during the use and programming of our electronics box and control system. This year we replaced our Arduino based control board with Phidgets®. The Phidgets® system required us to completely redevelop our thinking and construct an entire electronic system. The task proved to be both challenging and worthwhile. A non-technical challenge was apparent when trying to schedule meeting times for our team. Building an ROV demands a major commitment. As high school students, many of our company members are actively involved in numerous school clubs and community events. Finding a common meeting time was nearly impossible. To overcome this challenge, we divided our team into various subcommittees which made scheduling of meetings much more manageable since it involved fewer people and fewer schedules to accommodate.

Lessons Learned

During the construction of ROV *Erebus* our company members have been exposed to a new way of thinking and working together as a team. Throughout this experience, we have acquired many useful skills which will benefit us individually and as a company in the future. A critical component in the creation of a successful ROV is company communication. We have learned the importance of giving precise instructions. Miscommunication ultimately slows down the production of the ROV and can be a safety hazard especially while operating the ROV. Effective communication guarantees that power checks are completed and malfunctions with electronics are prevented. While working as a team we came to understand the skill sets of all members ensuring everyone was contributing as much as possible. Assigning each member to a specific task helped us maintain focus. Throughout the year staying on task has proven difficult with team members' busy schedules. However, company members overcame conflicts guaranteeing that deadlines were met and the overall project was completed on time. On the technical side, we have decided to use six thrusters this year instead of four as in previous years. By adding two more thrusters, it upgraded the maneuverability of ROV *Erebus*. The extra thrusters enable the pilot to maneuver the ROV in ways it never could before, such as allowing the ROV to drift side to side creating precise movements while completing tasks. As a company we are constantly absorbing information, ensuring that we are progressive in the creation of the best ROV possible.

Future Improvements

Regardless of how much time is dedicated to the construction of an ROV, there will always be factors which can be improved in the years to come. Time is a crucial element which there never seems to be enough of. The planning stage and development process should begin earlier in following years. This will aid in the additional countless hours that were needed to fully construct and test the ROV. Fund-raising was a persistent challenge throughout the year. In years to come, the team should consider the fund-raising process itself, to avoid the unpleasant situations where desired ROV accessories could not be purchased. Accordingly, a HD camera and a 3D printer would be useful accessories for future missions. Participation in the EXPLORER class, made a HD camera increasingly necessary for competitiveness against exquisite university teams, an advantage we would aim for in the oncoming years. A 3D printer would prove to be useful in the planning and design stages. It is capable of creating efficient models for prototype testing. Finally, the learning experience from the Phidgets computer based system was phenomenal, and only leads to wonder what we can do next. In future years, we would like to enable more control of motor movement allowing the use of more than a single joystick at a time, meanwhile continuing to expand our knowledge on computer based systems.

Figure 34: Referee Gordon.
Gordon volunteers as referee at the Ranger competition.

Reflections

The feeling of pride summarizes our year with Cougar Robotics Incorporated. Working on our ROV has been a great success. Being a part of this project has allowed us to grow as individuals. Our strengths, creativity, and innovation have developed immensely. These attributes have translated into the creation of ROV *Erebus*, which is proficient and capable of completing each and every task presented in the missions. Competing in the Explorer class this year has provided us with a unique opportunity. As high school students we volunteered at the MATE Regional Ranger Class competition. It was a fantastic experience to have the opportunity to mentor our peers and view the competition from a different perspective.

Teamwork

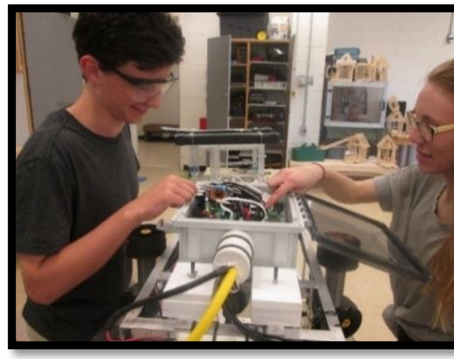


Figure 35: Working on the electronics box.

The teamwork and dedication required to design an ROV, provides students with a valuable learning experience. To complete this project, all members needed to work to their full potential; utilizing their skills on every aspect of the ROV, the technical report, the presentation, and the poster display. Throughout the building process, we acquired knowledge and practical skills from this unique and exciting project. We learned co-operation, perseverance, work ethic, competitiveness as well as a sense of accomplishment as a result of this rewarding experience.

Our team members have worked together as a group for a total of seven years. We first formed our team in middle school as seventh graders and competed in the local Scout competition. Later as sophomores, we competed in the local Ranger Class and after a number of close finishes, finally won the MATE 2014 International ROV competition in Alpena, MI. Through the years we have become close friends, some might even say family. After spending so much time together working on projects we have come to recognize our individual strengths and differences. We have taken advantage of inividual strengths and appointed members to manage tasks that he/she has excelled at. In the end, however, the creation of ROV *Erebus* and supporting documents has been a complete team effort. Nearly every component and piece has been deigned or constructed by our team. We have sought advice, opinions and guidance from our mentors, but the construction of ROV *Erebus* has been completed by the team. Below is a list of team members and a description of the task they were responsible for.

Michaela Barnes – Captain
Michaela is a go-getter… if there is a task to be done, she'll go find it. Michaela probably knows the missions and tasks better than anyone. Michaela was selected as our team captain and will be responsible for all operations on the pool deck during the competition.

Courtney Clarke - CEO
Courtney is a born leader and pays particular attention to detail when given a task. Her strengths are with public speaking and word processing. Courtney acted as CEO and is responsible for keeping the team focused, and for general management of the project.

Kyle Clarke – Pilot
Kyle is a technology genius and is a gamer at heart. Kyle took a lead role with the electronics on the ROV and was the main coder for our control system and developers of sensors and effectors. You will always recognize Kyle - he is the one with the soldering iron in his hands!

Patrick Dove – Mission 2 Specialist
Patrick is a trend setter and the motivation for our team. Patrick's strengths are with construction as he has proven to be mechanically inclined and capable of building just about anything.

Claire Sawler – Marketing
Claire has a special aptitude with publishing and design. Claire took a lead role on the technology report and poster design. During construction Claire was our main SolidWorks developer and was responsible for testing using FloWorks.

Brooke Snow – Mission 3 Specialist
Brooke is free spirited and thinks outside the box. She was a mission specialist and took a lead role with the frame design and planning the end effectors.

Andrew Sullivan – Mission 1 Specialist
Andrew is a 'jack of all trades'. He has superior spatial sense and a knack for problem solving. When something is not going right or not working the way it should be Andrew often solves the problem.

Project Management

Managing an entire project and the daily operations of team Cougar Robotics Incorporated is a monumental task. Immediately after our first meeting the team established a 5 step design process, a system of guidelines (The 3G's) and a schedule with completion dates. These three items have directed the entire project, guiding us with planning, organizing and building procedures. Below we have copied our schedule with timeline and completion dates.

November 1st
First meeting. Discussed frame design. Researched various materials and decided on aluminum for its durability. Created a frame design that had minimal drag, while also providing sufficient space for mounting various tools, thrusters, the camera, etc.

November 15th
Buoyancy placed on frame. We created a custom system of removable buoyancy in order to accommodate the multiple missions and varying tools.

December 1st
Thruster position discussed and six Seabotix BTD-150 thrusters are mounted onto the frame. Two vertical and four horizontal at an angle of 20o.

December 15th
Control system designed. A power adapter switch was installed to the side of the controller. Installed a phidget 8/8/8 card inside the controller to control these joysticks and switches.

January 1st
Tether designed. After much discussion and research, we decide that we will need a tether that consists of; two 16 AWG wires, a coaxial cable, two 20 AWG auxiliary wires, and an Ethernet cable.

January 15th
Electrical system designed. Researched possible options for waterproof electrical boxes. Decided to use a product called the Attabox instead of making a custom box, as it is safer and more secure. Phidget boards installed into the Attabox.

February 1st
Constructed props. Began brainstorming and constructing tools for mission one. Discussed the fastest, most efficient way possible we could complete each task. Sketches were made and prototypes were constructed.

February 15th
Finalized and perfected the mission one tools. Mounted the tools onto our practice robot and ran through the mission in our private tank. All the tools were tested and perfected.

March 1st
Began the Tech Report. Write ups for every section were distributed amongst members. Photos were taken and cropped, and diagrams and sketches were made. Each section was carefully edited and verified by other members to ensure a high quality product.

March 15th
The tools for mission two were brainstormed and discussed. Tools for completing tasks such as the hotstab and the installation of the flange were challenges. We drew up multiple prototypes and began construction.

April 1st
Construction of mission two tools complete. Began construction of mission three tools. The team brainstormed together, created prototypes and tested these in the private tank.

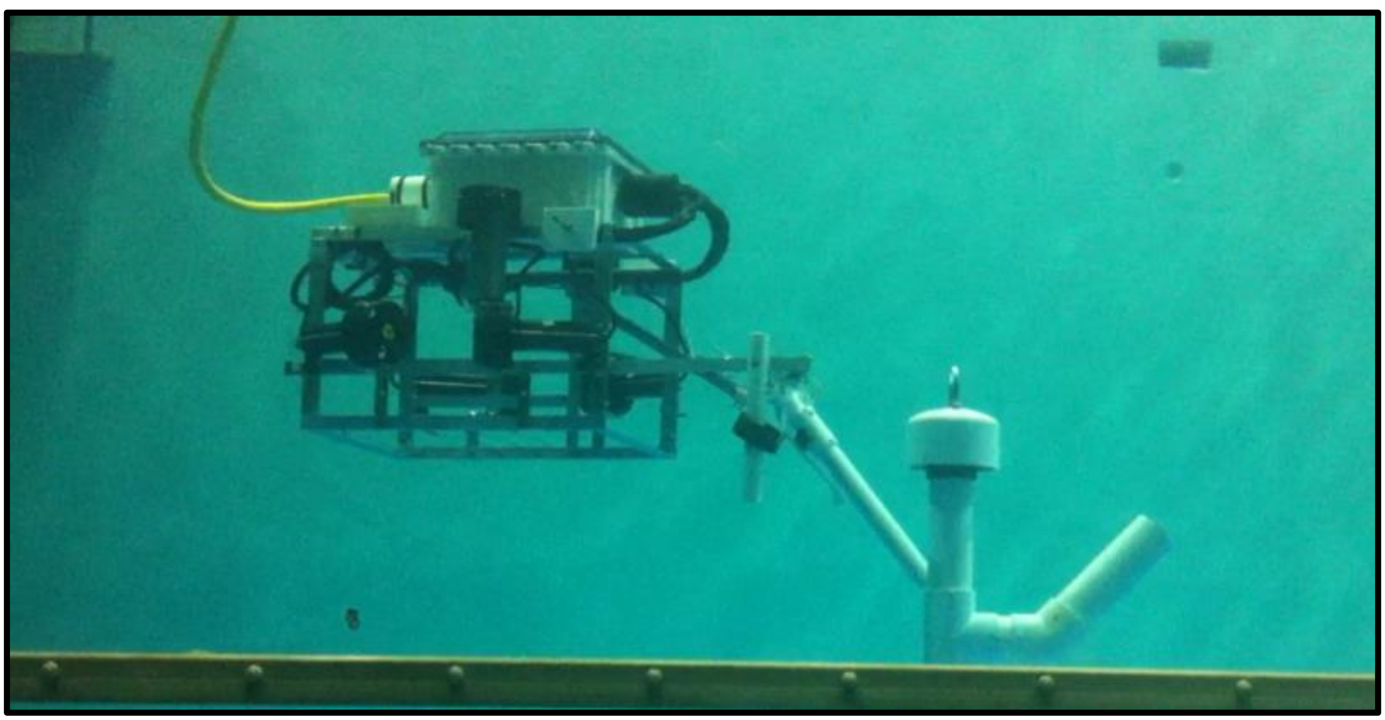
April 15th
Began preparation of speeches. Each member was given a speech topic. The team met together and began practicing and editing speeches.

May 1st
Preparation for poster board began. Write ups had to be distributed and each member contributed. Photos were taken and cropped, and then digitally put together on a poster board with a chosen background.

May 15th -
Tech Report finalized and edited. All details checked and every section reread for grammatical or technological mistakes.
All aspects of the project reviewed. Poster board and speeches edited and finalized. There is a tool for every task in the competition, and each of these tools has been tested and perfected. The control system and electrical systems are functioning, and the thrusters are providing significant power. The buoyancy system is neutral in every situation, no matter what tools. Now is the time to practice the missions and the speeches

Acknowledgments

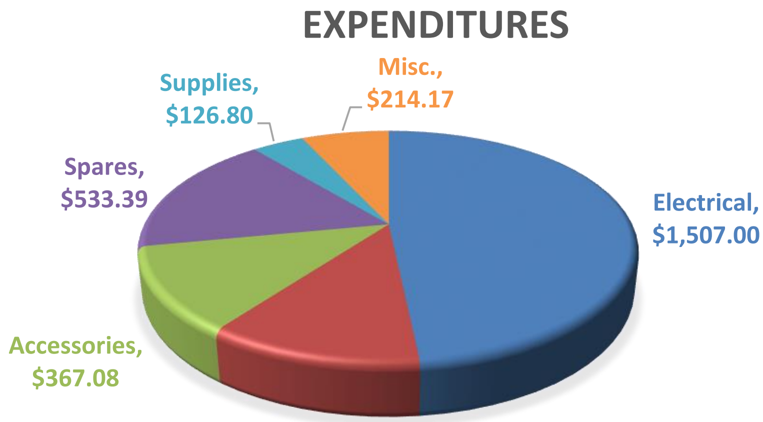
Cougar Robotics Incorporated would like to thank many people and companies for their support in this project. We would first like to acknowledge our local businesses Sub-C and Mike's Welding for their continued support and assistance. We would like to thank the companies Leoni, Trelleborg and Morrison Hershfield for their tremendous contributions. This team would also like to give thanks to our parents and our community, and specifically Vanda Dove. Their donations, efforts and time commitments were an essential factor in our success. A very special thank you to our mentors Mr. Michael Spurrell, Mr. Bert Roberts, Mr. Christopher Clarke, Mr. Carl Winter and Mr. Gary Walsh for providing us this amazing opportunity. It is their dedication, knowledge and determination that has guided us through this project. Finally we would like to thank MATE and the Marine Institute for hosting and organizing this event, and opening the door to the ROV industry for students all over the world



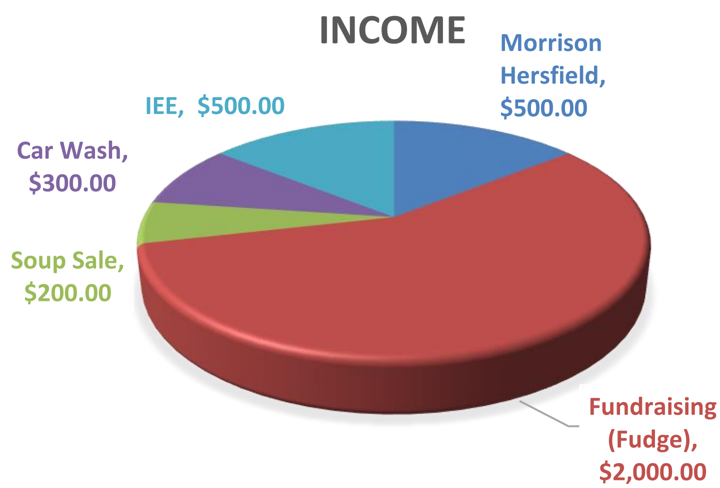
Budget

The budget for the construction of ROV *Erebus* was established early in the project once the team agreed on the concept for of the ROV. Expenditures were tracked against the budget for each category (i.e. electrical, propulsion, body, accessories, spares, supplies and misc.). There were key items that needed to be recycled from past projects to keep the cost below our budget. Having some items donated early in the project reduced the amount of fundraising. The ROV replacement cost is estimated at $8,436.25 of which $4,025.00 was cost incurred in previous years and $1,293.81 of donated items. The expenditure of $3,117.44 came in under the income. With the MATE 2015 International ROV Competition in Newfoundland this year, it drastically reduced what our budget may have been, since travel and accommodations is at a minimum.

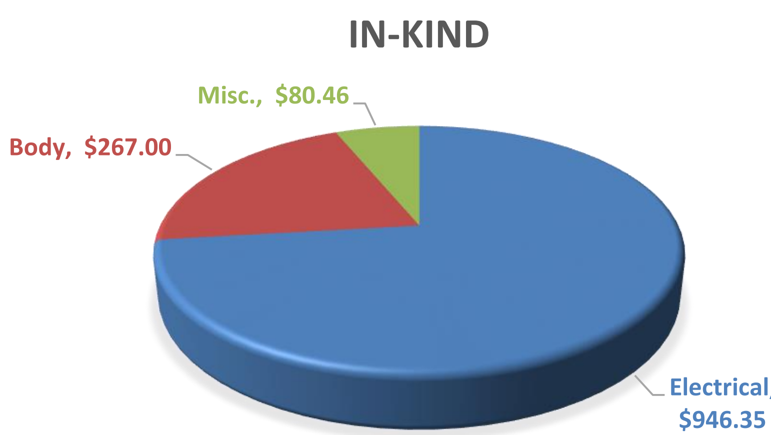
	Expenditures
Electrical	$ 1,507.00
Body	$ 369.00
Accessories	$ 367.08
Spares	$ 533.39
Supplies	$ 126.80
Misc.	$ 214.17



	Income
Morrison Hersfield	$ 500.00
Fundraising (Fudge)	$ 2,000.00
Allen Cup (Soup Sale)	$ 200.00
Car Wash	$ 300.00
IEE	$ 500.00
Total=	$ 3,500.00



	In-Kind
Electrical	$ 946.35
Body	$ 267.00
Misc.	$ 80.46



Budget Breakdown

	Expenditures	Recycled	In-Kind	Replacement Cost	Budget
Electrical					
Tether			$ 500.00		
100 W DC Convertor - 8A & 36V	$ 15.81				
1200 W DC Convertor - 20A & 60V	$ 117.52				
Phidgets	$ 936.60				
48V Power Supply			$ 446.35		
Four - 7 Position Terminal Blocks	$ 12.28				
Phidgets 888 - Ph Sensor & Current Sensor	$ 325.44				
RCA - USB Adaptor	$ 10.06				
Eight - 1ft USB Cable	$ 17.50				
Power Anderson Connectors	$ 62.54				
Gland Connector	$ 9.25				
Controller Box		$ 120.00			
Sub-Total =	**$ 1,507.00**	**$ 120.00**	**$ 946.35**	**$ 2,573.35**	**$ 2,000.00**
Propulsion					
BTD - 150 Thrusters		$ 3,675.00			
Propellers		$ 30.00			
Sub-Total =	**0**	**$ 3,705.00**	**$ -**	**$ 3,705.00**	**$ 1,000.00**
Body					
Trelleborg TG-24 Syntactic Foam			$ 150.00		
ROV Frame	$ 311.57				
Altabox - AH12106C			$ 117.00		
Thru-Hulls for Tether	$ 57.43				
Sub-Total =	**$ 369.00**	**$ -**	**$ 267.00**	**$ 636.00**	**$ 500.00**
Accessories					
12V Gear Motor c/w Wheel	$ 100.33				
Mini USB Camera	$ 12.75				
Phidget Ph Sensors	$ 30.00				
Mini Endoscope Camera	$ 63.75				
Flow Meter	$ 160.25				
Camera		$ 200.00			
Sub-Total =	**$ 367.08**	**$ 200.00**	**$ -**	**$ 567.08**	**$ 500.00**
Spares					
Spare 1200 Watt Power Supply (DC Convertor)	$ 106.61				
Spare 12V DC Convertor	$ 8.71				
Spare Phidgets	$ 418.07				
Sub-Total =	**$ 533.39**	**$ -**	**$ -**	**$ 533.39**	**$ 700.00**
Supplies					
Torch					
O-Rings / Nut for Thru-hull/ Tape	$ 28.94				
ape, Bazing Rod, Electrical Field Sensors & Motors	$ 97.86				
Sub-Total =	**$ 126.80**	**$ -**	**$ -**	**$ 126.80**	**$ 150.00**
Misc					
Photos for Spomsors	$ 22.06				
Team Registration	$ 117.85				
ABS Fittings for Props	$ 30.45				
Fittings for Props	$ 10.97				
Galvanized Strips	$ 4.51				
Bushing & Velcro	$ 12.07				
ABS End Cap			$ 8.46		
Putty	$ 16.26				
Servo Brackets			$ 72.00		
Sub-Total =	**$ 214.17**	**$ -**	**$ 80.46**	**$ 294.63**	**$ 150.00**
Total =	**$ 3,117.44**	**$ 4,025.00**	**$ 1,293.81**	**$ 8,436.25**	**$ 5,000.00**
Income					
Morrison Hersfield	$ 500.00				
Fundraising (Fudge)	$ 2,000.00				
Allen Cup (Soup Sale)	$ 200.00				
Car Wash	$ 300.00				
IEE	$ 500.00				
Sub-Total =	**$ 3,500.00**				
Variance =	**$ 382.56**				

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 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
- ☐ 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

Photo Credits

Figure 1: *Team Cougar Robotics*, Page 2. C.Sawler, May 2015.

Figure 2: *ROV Erebus*, Page 3. M.Barnes, April 2015.

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Figure 6: *Electronics Box,* Page 5. K.Clarke, May 2015

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Figure 30: *Ring measuring tool,* Page 12. A.Sullivan, January 2015.

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Figure 33: *Courtney constructing end-effectors,* Page 13. K.Clarke, May 2015.

Figure 34: *Referee Gordon,* Page 14. M.Spurrell, May 2015.

Figure 35: *Working on the electronics box,* Page 15. K.Clarke, March 2015.

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