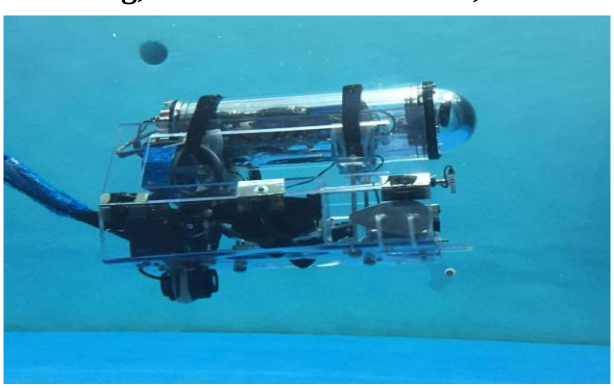
Mount Pearl Senior High School

Mount Pearl, Newfoundland Labrador, Canada

Husky Explorer

Name	Roles	Grade	Career Goal
Andrew Pye	Captain (Pilot)	12	Instrumentation
Alex Hayes	First Officer (Co-Pilot)	11	Mechanical Engineer
Sean Purchase	Chief Executive Officer	12	Instrumentation
Ryan Hayes	Chief of Engineering	12	Mechanical Engineer
Khafre Pike	Chief Operating Officer	12	Aerospace Engineer
Mary Pike	Vice President of Marketing	11	Software Technician
Jessica Hynes	Marketing Representative	12	Social Worker
Brady Chaulk - Goodyear	Marketing Representative	12	Film Director
Carley Froggatt	Marketing Representative	12	Addictions Counselor
Connor Hynes	Chief Financial officer	11	Naval Engineer
Mitchell Tuck	Financial Assistant	10	Naval Engineer
Daniel Drodge	Safety Officer	12	Marine Engineer
Aloysius Ducey	Vice President of Production	10	Pharmacist
Kyle Curtis	Engineer	12	Marine Engineer
Kyle Edison	Engineer	12	Mechanical Engineer
Kevin Verge	Engineer	12	Marine Engineer
Tyler Purchase	Engineer	12	Combat Engineer
Zachary Anstey	Engineer	12	Marine Engineer

Teacher Mentors: Mr. Paul King, Mr. Cameron Williams, Ms. Kaitlin Quinlan, Mr. Jacob Brown



TLB 1: Flying in Marine Institute Flume Tank.

Abstract

Husky Explorer specializes in the design and construction of underwater Remotely Operated Vehicles (ROVs). For our latest project, we have designed an underwater ROV, The Lunch Box One (TLB1), to compete in the 2016 Marine Advanced Technology Education Center (MATE) International ROV Competition that takes place June 23rd to 25th at the National Aeronautics and Space Administration's (NASA) Neutral Buoyancy lab in Houston, Texas. The ROV is equipped to perform tasks associated with sub-sea equipment recovery, forensic fingerprinting, deep water coral study, turning rigs into reefs, and even interplanetary exploration to one of Jupiter's moons, Europa.

Figure 1: Husky Explorer Logo (Credit: Khafre Pike)

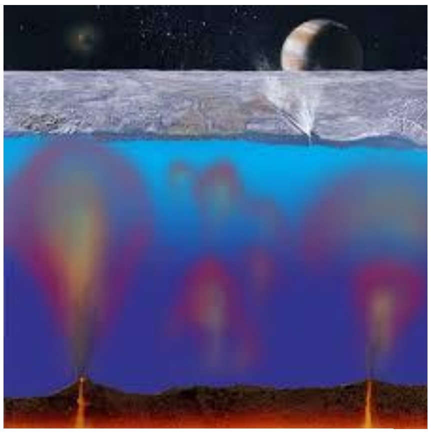


Figure 2: An artist's rendition of Europa's surface. Note the volcanic activity caused by tidal flexing making a liquid ocean possible. (Credit: americaspace.com)

Our ROV is equipped with several specialized tools, which have been designed to be small and versatile to overcome some of this year's challenges, such as: a small temperature sensor, a pneumatic claw, and a multipurpose hook.

Husky Explorer of Mount Pearl, Newfoundland and Labrador, Canada has prepared this report which outlines the company mission, project management details, design rationale, challenges, safety protocol, troubleshooting techniques, future improvements, financial report, references, and acknowledgements.

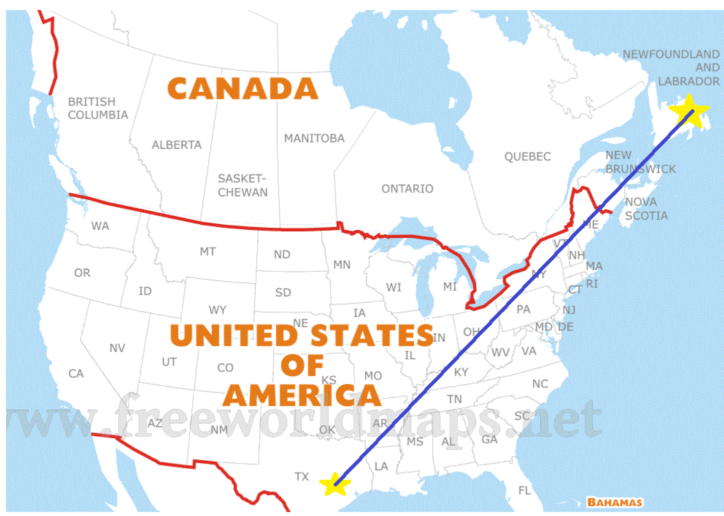


Figure 3: The distance between Mount Pearl and Houston is 5300km. (Credit: freeworldmaps.net)

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Company Mission

Minimizing the environmental impact of oil extraction is one of the top priorities for companies involved in the offshore in the Gulf of Mexico. One way to minimize environmental impact is to turn old, unused sub-sea equipment into coral reefs. Through this initiative, oil equipment and platforms are torn down and sunk (once all poisonous and/or dangerous equipment is removed) and left for nature to reclaim it, thus, creating an artificial reef. Research supports that these reefs can aid the underwater ecosystem:

> "Scientific studies at UC Santa Barbara conclude that the underwater platform structures have evolved into economically and ecologically valuable ecosystems. In some locations, reused platforms provide sanctuary to some heavily-fished species and enables said species to safely reproduce." (Rigs to Reefs, 2016).

Figure 4: Galileo & several planetary bodies (Credit: famousscientists.org)

Outer space exploration has been a fascinating source of interest for the majority of human history. Prior to the advent of reliable rocket technology, space was explored by remote observation; initially with the unaided eye and then with the telescope. Nowadays, rockets are a reliable means to explore space. Many missions to the Moon and Mars have been achieved, now exploration of one of Jupiter's moons, Europa, is necessary. The possibility of a liquid ocean on Europa (possibly the only other ocean besides Terra in the Sol Solar System) brings the strongest known possibility for extraterrestrial life, a topic that is often debated within the scientific community. The ocean is thought to be created due to tidal heating on Europa:

> "Because Europa's orbit is slightly stretched out from circular, or elliptical, its distance from Jupiter varies, creating tides that stretch and relax its surface. The tides occur because Jupiter's gravity is just slightly stronger on the near side of the moon than on the far side, and the magnitude of this difference changes as Europa orbits. The linear fractures across its surface result from the tides energy to the moon's icy shell. If Europa's ocean exists, the tides might also create volcanic or hydrothermal activity on the seafloor, supplying nutrients that could make the ocean suitable for living things" (Dunford, 2016).

In consideration of these challenges, Husky Explorer's newest model, TLB1, is designed to be agile, robust, and manoeuvrable. It is capable of conducting scientific exploration in extreme interstellar environments, inspecting, maintaining, and repairing offshore oilfield pipeline and production platforms, and the recovery of mission critical equipment.

Project Management

Husky Explorer is an ROV company consisting of 18 members. At the initial meeting, February 2, 2016, the team identified time management and prudent financial planning as key aspects for success. To this end, the team identified the strengths and interests of all the team members. Team members were then organized into three departments based on their individual strengths, The Board of Directors, Production, and Marketing. The latter two departments consist of smaller divisions (Electrical, Production and, Marketing, Safety, Financial, respectively) each with a team leader who reported to the Board of Directors. (See Appendix A for visual breakdown of staff member roles)

Upon reviewing the MATE competition manual, daily planning sessions were held to identify possible solutions to accomplish the mission tasks. Using a shared Google document, all members recorded brainstorming ideas and possible development plans. Large group meetings were held on a bi-weekly basis where ideas were debated and decisions were shared, as well, the Board of Directors held meetings when appropriate. A six step design protocol (see figure 5) was followed to help keep the project on track. This design protocol was an important instrument to help organize ideas, develop solutions, and allow all members a voice in decision making. The team had to resolve a variety of problems, including: frame design, buoyancy, propulsion, and tool options. By continuously modifying and improving ideas, we successfully arrived at our current design rationale and vehicle systems within budget. Routinely, the Board of Directors would confer with each department to troubleshoot any issues and provide motivation to accomplish their varied tasks.

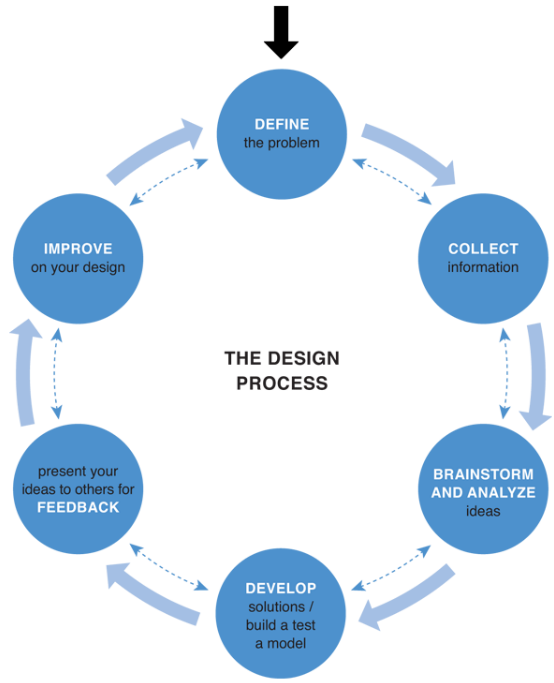

Figure 5: The Design Process (Credit: discoverdesign.org)

Budget

A large portion of project management involves managing human and financial resources. Through cost analysis, an estimated budget of $2000 was conceived. We required six new motors and controllers ($1200), electronic supplies ($600), and frame and tool materials ($200) which brought us to the $2000 total. Due to the estimated budget, it was clear that support from financial sponsors and in-kind donations would be necessary. Financial sponsorship was attained from MATE, Provincial Airlines, and Rutter Inc. In-kind donations of equipment and supplies were

Figure 6: Project Costing (Credit: bizitc.com)

gifted to the team by H&F Electrical and Mount Pearl Senior High. By researching and comparing equipment prices on-line we were able to purchase the necessary equipment within budget. In an effort to control resources, all purchases went through an approval process with the Board of Directors to ensure the project stayed on budget. A table outlining our project costing is located in Appendix C.

Once we earned the right to compete at the International ROV Competition in Houston, Texas following the Regional ROV Competition, we needed to build a travel budget for the team. We contacted Travel Professionals International (TPI) to compile the costs for flights and accommodations in Houston. For the 20 member team (fifteen students and five mentors) flights and insurance costs were $1045.39 each, for a total of $20 907.80. Accommodations cost $149.86 per night for eight rooms booked for five nights for a total of $5994.40. We have budgeted $1000 for ground transportation to events while in Houston. Our total approximate travel budget is $27 902.20. In order to accumulate funds for the trip, we have contacted members of the local business community to sponsor the Husky Explorer team and also endeavoured to raise funds through a gift card basket raffle.

Design Rationale and Vehicle Systems

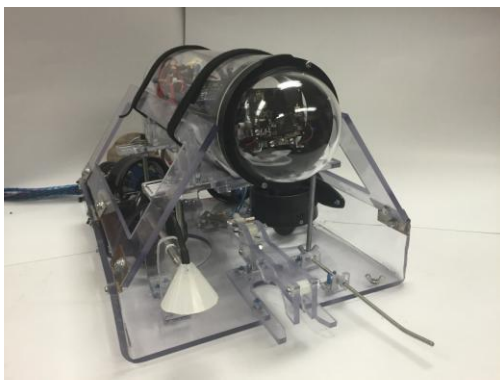
Figure 7: TLB1 (Credit: Mary Pike)

The design of our ROV and subsequent vehicle systems was dictated, in part, by the mission specifications provided by the 2016 MATE competition. The ROV had to be small so it could fit through a 48 cm diameter hole and light (less than 11 kg) to alleviate excessive costs in sending it to Europa. It needed sensors to measure the temperature of water emerging from a vent and determine the thickness of the ice and depth of the ocean. It needed to be agile to be able to connect an Environmental Sample Processor (ESP) to a power and communications hub. The camera on board needed to be sharp enough for the pilot to read the serial numbers on mission-critical equipment. The camera also needed to be able to take still photographs of two coral colonies and evaluate those photographs to determine whether the coral colonies are growing, stable, or decreasing in size. It needed a gripper claw to collect two samples of oil from the sea floor, collect two samples of a coral species, and return all these samples to the surface. We also needed a tool to attach a flange to the top of a decommissioned wellhead, install a wellhead cap to the top of the flange, and secure both the flange and the wellhead cap with bolts.

In developing an ROV to meet these mission tasks, eight main components were considered: frame design, buoyancy, propulsion, tools, tether, electronics, control, and cameras. In order for the ROV to function properly all components needed to work effectively together. Therefore, detailed research, planning, and decisions were a necessity.

Frame

We had three materials to choose from for our frame's design; these options included ½ inch PVC, angled aluminum, and 6.4 mm acrylic. After considering our options we decided to use the acrylic because it is durable, lightweight. As well, it was readily available in large quantities since our school had used this material for temporary windows and donated them to our team once they were no longer in use. Once we decided on this material we set out to find the winning design for our ROV.

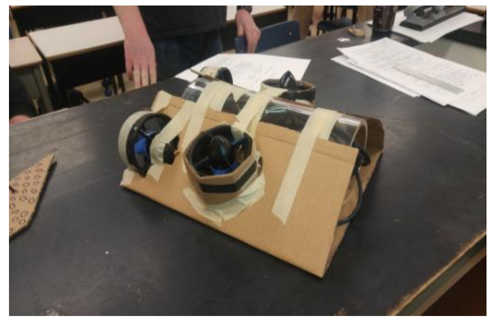

Figure 8: A cardboard mock-up of a potential design (Credit: Sean Purchase)

We made several iterations for our frame before deciding on the final design; we created mock-ups of each design in cardboard. The first design was the largest cube one could make that would fit comfortably through the 48 cm diameter hole and it used all six of our motors. This design was rejected because the use of all six motors took up too much space on the frame. The next cardboard mock-up was slightly smaller and only used four motors. While this design was better than the first, the team was not completely satisfied and questions arose about where to place tools. During a brain-storming session, a team member folded up the sides of the cardboard creating a triangular design (shown in figure 8). This design was well received; however the center of buoyancy was projected to be too low. The ideas from this triangular design and the previous two designed came together to create the final design of TLB1. Our frame's angled sides are mounted on hinges and can open up to allow for easy access of all components inside the frame, which is very handy when work or maintenance needs to be done on the ROV. This 'lunch box' design feature was so novel it gave our ROV the name The Lunch Box One (TLB1).

The frame was custom designed in-house using SolidWorks. This design was then programmed in Mastercam and cut using a Computer Numerical Control (CNC) machine in our technology lab. This new design is based around our Main Control Pod (MCP) which houses all the on-board electronics. This MCP is a newly implemented component, which had to be properly fitted into the frame. TLB1 is made of a single base and two hinged side plates . The completed dimensions of the ROV are 30 cm x 36 cm x 25 cm. The base plate of our ROV was bent using a heat bender making the sides 7 cm high. Inside the frame two MCP stands, made using 15cm treaded bolts and two repurposed eaves trough ice dams, support the MCP. The MCP is held down with Velcro straps to allow for easy removal when needed.

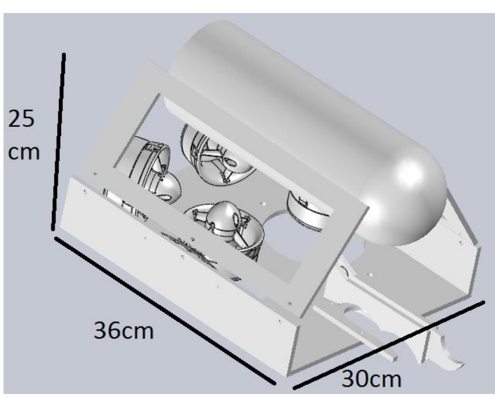

Figure 9: CAD mechanical drawing of TLB1.

Propulsion System

Figure 10: A T100 Blue Robotics Thruster (Credit: Blue Robotics)

An efficient propulsion system is crucial to completing the mission tasks. Two possible thruster systems were researched: a 12 V Blue Robotics T-100 thruster and a 12 V Mayfair 500GPH bilge pump. After a careful cost and performance analysis, it was determined that the Blue Robotics T-100 thruster was the superior choice because it provided more thrust (2.36 kgf) and the cost ($119 per unit) fit into our budget. Four of these motors are being used on the ROV, two mounted vertically and two horizontally. Two motors are mounted at the back of the frame, vectored at 20 degrees, to provide a tighter turning radius. The two motors which provide the vertical movements are mounted in the center of the ROV to allow it to rise and fall without being pitched.

Pneumatic System

The ROV contains a pneumatic system (fluid diagram and picture shown below) which is used to power our main tool, the "Gripper". This system contains a 150 ml reservoir (20 cm x 4 cm) attached to an air compressor and regulated to 40 psi. This system is controlled by a main shut valve which is connected to 4.0 x 2.5 mm tubing to a 40 psi pressure release valve that then goes to our single pneumatic solenoid. The VEX 5V Pneumatic solenoid is controlled and powered by the GPIO pins on the Raspberry Pi 2 Model B. From here, we use Python 3 to send signals to the solenoid when a button is pressed on the main driving joystick. A Graphical-User-Interface (GUI) displays the "Gripper" position on screen.

Figure 11: Pneumatic system inside vehicle cockpit using VEX components. (Credit: Sean Purchase)

The operation of the claw depends on the air pressure applied to the piston. When the compressed air is directed into the front of the cylinder, it applies pressure to the piston causing it to retract (length = 15.6 cm). Similarly, when the compressed air is directed into the back of the cylinder it pushes against the piston causing it to extend (length= 21 cm). With a 10 mm cylinder bore (diameter) and a 689 kN/m² (100 psi) internal pressure the maximum force of 54 N (12 lbs.) can be applied by the pistons. A sample fluid diagram can be found on the next page.

Sample calculation:
(Cross Sectional Area of Cylinder) x (Internal Air Pressure) = Force
pi x (5 mm ^2) x 689 kN/m² = 54 N or **21.6 N at 276 kN/m² (40 psi)**

Reservoir Specifications: **Cylinder Specifications:**

Length	(20 cm)	Length	Dbl.- Compressed - 15.6 cm / Extended - 21.0 cm.
Diameter	(4 cm)	Stroke	(5.08 cm)
Cylinder	Wall (3.2 mm)	Cylinder Bore	(10 mm)
Weight	(308 g)	Weight	(20 g)
Volume	(150 ml)	Maximum Pressure	(0.7 MPa)
Cylinder Strokes	45 Strokes from 100 psi to 25 psi	Maximum Output Force	(54 N @100 psi) (22 N @ 40 psi)

Figure 12: Reservoir and Cylinder Specifications. (Credit: Vex Robotics)

Fluid Diagram

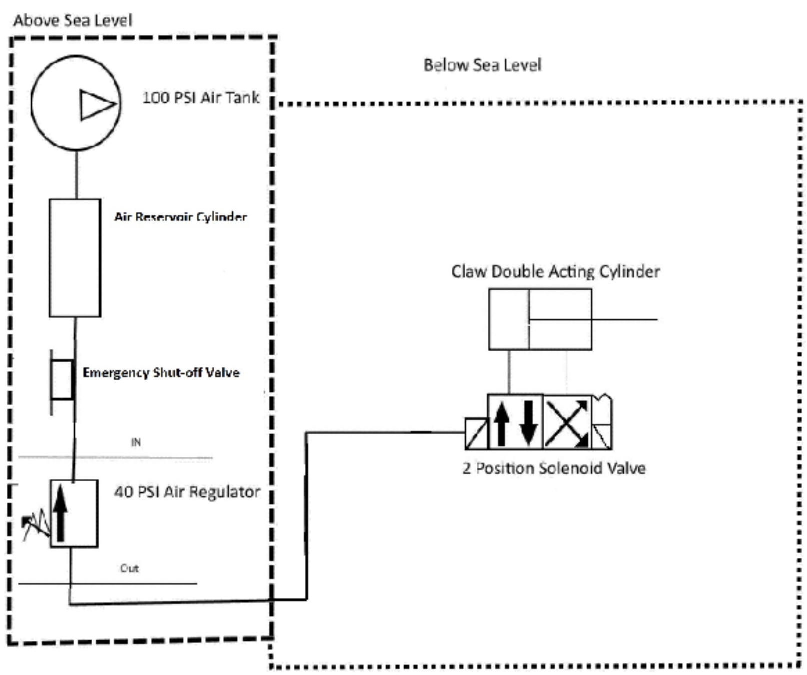

Figure 13: Fluid diagram. (Credit: Khafre Pike)

Tools

This year's unique missions required our team to develop new approaches to complete demanded tasks. As a result, all of our tools are original designs that we either hand-crafted or purchased and modified. The size of our ROV is much smaller than last year's because the vehicle needed to be able to perform multiple tasks on the planet Earth and also travel to Jupiter's moon, Europa, inside of a rocket. The design for each tool underwent extensive prototyping by providing detailed drawings, modeling using cheap materials (such as cardboard), and testing these models before fabricating the final product.

Our ROV was tested at our school in our indoor testing pool (1.83 m x 1.83 m x 0.91 m) and at the Mount Pearl Summit Centre. We have developed the following tools to accomplish this year's mission: pneumatic claw, hook, and a temperature sensor.

A pneumatic claw ("Gripper") was created from a combination of three pieces of acrylic. One is attached to the bottom on the ROV for support and the two other pieces join to form the claw arm. A piston controls the up and down movement of the arm. The team decided on a claw design that opens and closes vertically, rather than one that moves horizontally, after looking carefully at the missions. Our design makes it easy to retrieve oil samples, collect coral samples, and connect the bolts to the flange. There are grooves placed on our claw's arm that were measured specifically to retrieve 1 inch PVC. With those grooves, our "Gripper" can hold two oil samples securely in place at a time.

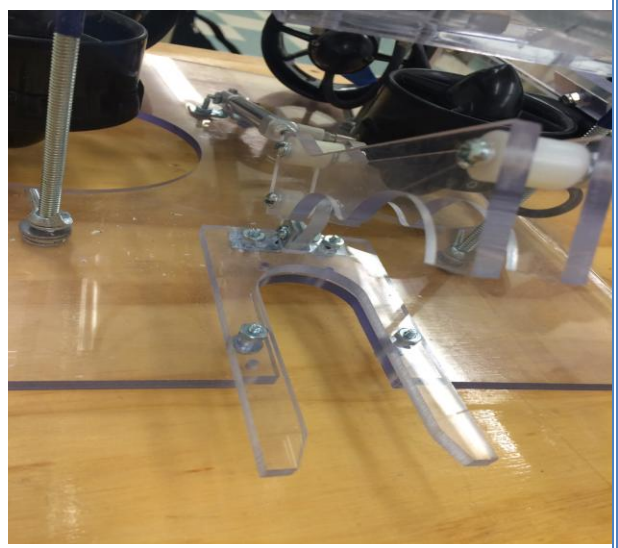

Figure 14: "The Gripper" (Credit: Mary Pike)

A hook was made from a threaded rod with a slight bend at the tip. We created this for the inner space mission of Rigs to Reef. This hook design also allows the ROV to pick up the flange cap easily. We also created the hook to be used to flip over CubeSats allowing us to read their serial numbers and locate the specific four we need to retrieve. The hook had some rough edges and a sharp point on the end, so heat shrink was placed over it for safety reasons.

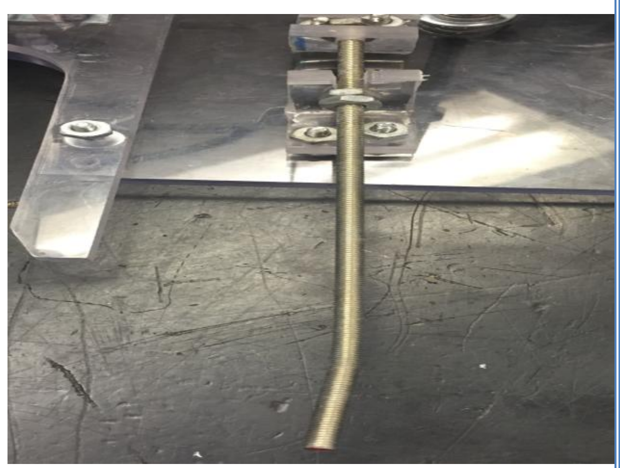

Figure 15: Threaded rod hook (Credit: Ryan Hayes)

A DS18B20 High Temp Waterproof Digital Temperature Sensor was installed to the bottom of the frame. We utilized the temperature sensor to complete the outer space Europa mission of measuring the venting fluid under the ice of Jupiter's moon Europa. The placement of the sensor allows the pilot to easily land on top of the vent and collect the temperature.

Figure 16: DS18B20 Temp sensor (Credit: Robot Shop)

The ROV has minimal tools to make it as versatile, small, and light as possible because the cost to transport anything to space is quite high; we wanted no excess mass. With only three tools the ROV will be able to do all mission tasks.

Tether

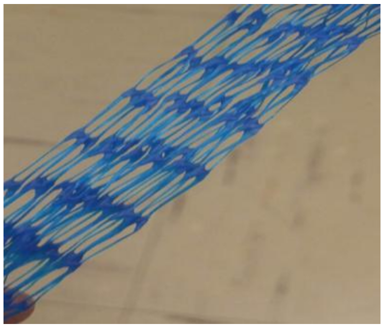

Figure 17: Bait mesh. (Credit: Sean Purchase)

The 14.7 m neutrally buoyant tether connects the top-side power and electrical components to the ROV motors and tools. It consists of one pair 12 AWG insulated wires used for our power supply that is run in to the power distribution block located inside the MCP, and two category six wires which are connected to two IOGEAR USB range extenders in the control box into our Arduino Uno and Logitech C170 Webcam located inside the MCP. In addition, it has two coaxial cables for video and a pair of pneumatics lines. The pneumatics lines power the gripper and the video lines connect the onboard cameras to the televisions on deck. This custom made tether is wrapped in bait mesh to protect all wiring and keep the wires together. Finally, the tether can be neatly wrapped on the ROV in order to save space & fit inside the 48 cm size restriction.

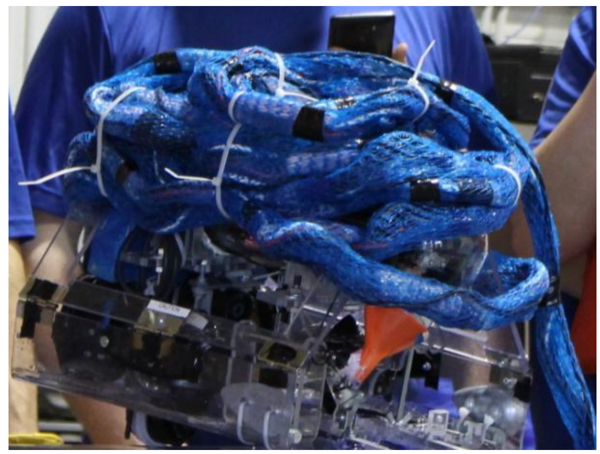

Figure 18: The tether neatly bundled on top of TLB1. (Credit: Aloysius Ducey)

Electronics and Control Systems

Hardware

The control system consists of a combination of off-the-shelf components and custom hardware, all enclosed in a Pelican Protector 1600 case, measuring 62 cm by 49 cm x 22 cm. Putting all of our surface controls in this pelican case, or Main Vehicle Cockpit (MVP), allows us to setup and teardown the control system with minimal time and space. The control

Figure 19: Pelican cases that hold our control and ROV system. (Credit: Sean Purchase)

electronics are centralized into one box where all we need to do is open the lid, connect the tether from the ROV through a strain relief, and press a power button. The ROV itself is stored and transported inside another Pelican case, allowing our vehicle to deployed & stored again very quickly and effectively. This is very time and space efficient and a major improvement from previous systems, where cable clutter and setup time were two very limiting problems.

Each member of Husky Explorer had an opportunity to contribute their ideas towards the design of the control system and each member had the opportunity to operate the ROV. There were several different decisions to make concerning the design and development of our control scheme and electrical system for this year's ROV.

Incorporating experience from previous contracts, we felt that a digital and software based system would be worth developing, moving our company away from analog electronics and control systems. The computer system includes a Raspberry Pi Model 2 B for our main computer, which then connects to two Logitech Attack 3 USB joysticks, a keyboard, mouse, multiple displays (one of which is hard mounted inside a pelican case along with the rest of our controls), a VEX 5v pneumatic solenoid, and two IOGEAR USB range extenders. The Raspberry Pi runs our custom control program in Python 3, sending digital signals through the USB extender, then through category 6 cable in the tether, to the opposite end of the USB extender. One USB extender is then connected into an Arduino Uno which takes the digital signals and translates them into analog signals our electronics can use. The other extender is designated strictly as a data line for the Logitech C170 Webcam inside the MCP. We used two separate lines in order to cut down on video latency & make the system more reliable. Through testing, we found that our computer would not recognize both the Arduino Uno & Logitech C170 when attached to the same line through a USB hub. Along with our 12V pair for power, the communications cable goes through a cable penetrator from Blue Robotics. The 12V pair connects to a distribution block, which in turn, provides power to a 12V bus for our thrusters and a 5V bus through a 7805 5V regulator to provide power to onboard electronics including the Arduino Uno, the IOGEAR USB range extender, two servos for a modified Charmed Labs pan and tilt mechanism, and the logic components of 4 BlueESC 30A Electronic Speed Controllers. A full systems integration diagram can be found in Appendix B.

Figure 20: Logitech Attack 3 Joystick (Credit: Sean Purchase)

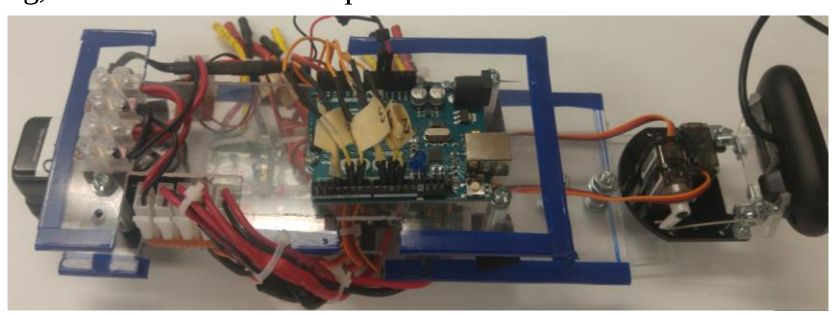

Figure 21: The electronics portion of our main control pod. (Credit: Khafre Pike)

Controls

To control the ROV, we use two Logitech Attack 3 Joysticks, as well as a USB keyboard connected to our Raspberry Pi. We have designed the ROV controls to be intuitive, which make it easy to learn to operate. One joystick controls the flight of the vehicle and sends signals to our Python 3 program which are then sent down the tether to control the thrusters. If the pilot pushes forward on the joystick the vehicle will move forward and if the pilot pushes backward then the vehicle will move backward, etc. The joystick and the ROV will move in sync. The other joystick is used to control the repositionable camera, allowing us to move the ROV and the camera independent from one another.

Software

This year, we designed a program from scratch in Python 3 for our control system. We used a variety of different libraries including Pygame to pull input from USB joysticks, and nanpy, which allows us to use the Arduino Uno as a slave device with our Raspberry Pi in order to control the onboard electronics. We designed our software to function the way we wanted it but also to be tidy in order to aid with troubleshooting, if necessary. The program includes a Graphical User Interface to tell us exactly what position and direction the thrusters are moving, as well as relaying data from our sensors.

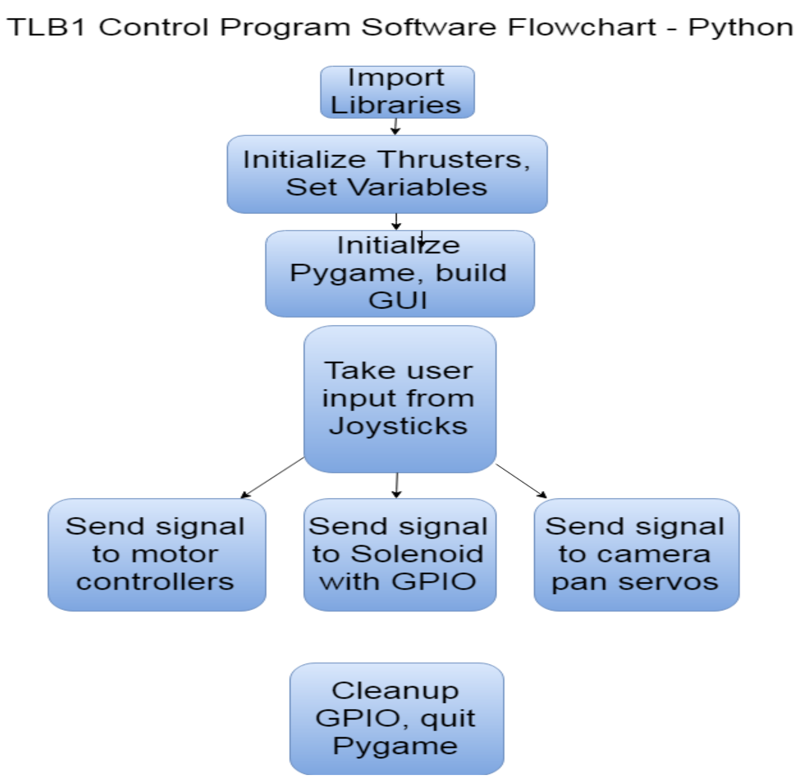

Figure 22: Software flowchart explaining our control software. (Credit: Sean Purchase)

Video System

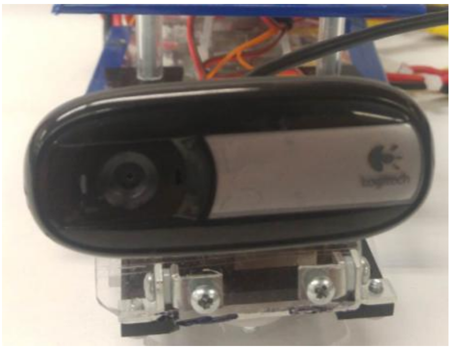

Figure 23: Logitech C170 on pan and tilt mechanism. (Credit: Sean Purchase)

This year, our ROV uses three cameras; a new variable position camera inside our main control pod that can take still pictures and record video, and two fixed view cameras, which were reused from previous contracts since they were reliable and provide great viewing angles. Each camera is designated an independent display to allow us to see multiple views at once. The two fixed view cameras, Speco Technologies CVC620WP, are used to view tools, and are waterproof to 18 m. These cameras contain a 3.6 mm lens which provides a 92° viewing angle under water. One camera is mounted toward the back of the frame on the underside of the mounts for our control pod. This view is used to navigate the ROV and operate tools. Another fixed view camera is mounted on the underside of our frame using a plastic conduit strap. This view is used to navigate and position oil samples into our main gripper. The third camera, a Logitech C170 USB Webcam, is mounted inside of our main control pod on a modified pan and tilt mechanism from Charmed Labs. This mechanism uses two GS-9018 Micro Servos which are connected to our Arduino Uno inside the tube; allowing us to control the camera inside the dome with a Logitech Attack 3 Joystick. The ability to position this camera is vital to our control scheme and it a huge improvement from previous years cameras. It allows us to leave the vehicle stationary and move the camera to take pictures of coral samples via a keyboard connected to our Raspberry Pi. The up arrow is pressed on the keyboard and it automatically captures what the camera sees, saving it for later review. The cameras are strategically positioned to drive and see tools.

Figure 24: Speco Technologies CVC620WP. We have two of these on our ROV. (Credit: Sean Purchase)

Buoyancy

The buoyancy system of any ROV can be achieved using a variety of materials. This year our ROV was designed around the Main Control Pod, which has an its own inherent buoyancy, and we postulated that once the ROV was assembled it would be neutrally buoyant. Through testing we found that with just the MCP aiding buoyancy the ROV would slowly fall while in the water. The back of the ROV was slightly heavier because of the two rear mounted thrusters, so high density

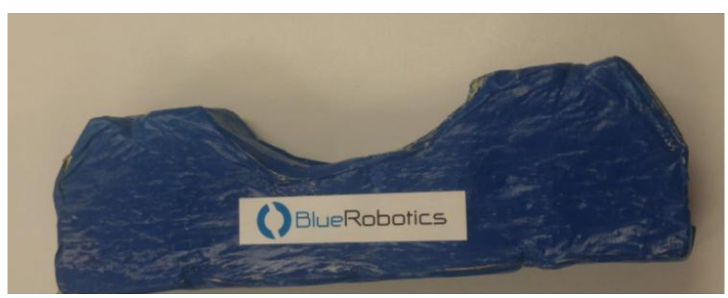

Figure 25: High Density Foam wrapped in tape & painted provides counterbalance. (Credit: Sean Purchase)

foam was placed there to try and bring the ROV to neutral buoyancy. After trial and error with different sizes of foam we got it sitting neutral in the pool.

Once the ROV's buoyancy was solved the buoyancy of the custom in-house tether was tackled. While stretching the tether out in a pool, high density foam was placed at 30 cm intervals to make it neutrally buoyant. This was necessary so that it does not weigh down the rear of the ROV and it make difficult to pilot. During testing it was found that when driving forward the front of the ROV would fly upward slightly. To fix this, 325 g of mass was added to the front and the issue was corrected. The pilot and co-pilot tested the manoeuvrability of the ROV until they were satisfied with its performance. This trial and error method was successful since the ROV drives quite well. The completed ROV is fully functional and capable of completing all missions.

Safety

The safety of our company's members is our number one priority. At the beginning of the year our safety team developed a safety checklist (Appendix D) that we regularly reviewed with our members before each meeting to ensure safety while at work on the ROV.

Figure 26: A 25A fuse inside fuse holder on positive lead. (Credit: Daniel Drodge)

During the construction, each member received instruction on the use of new equipment and tools. To prevent accidents while using tools that were a potential hazard, long hair was always pulled back and tied up, long sleeves were rolled up, and safety glasses were worn. Supervision is always a priority. No members were permitted to operate equipment without a mentor present. As well, members were encouraged to ask questions and practice a safe workplace.

Figure 27: A conduit strain relief is used to secure cables coming from the tether. (Credit: Daniel Drodge)

While working on electrical components of the ROV we ensured that each connecting wire was soldered and shrink wrapped to prevent damage to electrical items. Furthermore, a 25 amp fuse was added on the positive side of the circuit to prevent damage to the electrical components of the ROV and to protect our teammates from any injuries which may be sustained from working with the electrical items. Every corner or sharp edge of the ROV was filed down to prevent injury. Each bolt end was covered in heat shrink so it did not create a sharp point. Safety is of utmost importance for our team and we wanted to build an ROV that was user friendly in its operating capacities and its safe features.

From the beginning, we made sure to be safe while working with electrical equipment and components by wearing safety glasses and incorporating a safety protocol into each aspect of our work on the vehicle. Each time before we powered up the vehicle we completed a checklist; we ensured all connections were reliable and no wires were crossed, we made sure to check fuses, and we requested that all technicians near the ROV kept their bodies, extremities, hair, and clothes, far away from the ROV while under operation and maintenance of the electrical system. The tether was also secured to the frame using a strain relief to prevent damage to the electrical system. Finally, when we visited the pool to practice the missions, all teammates near the water were wearing their Personal Floatation Devices (PFDs) under the supervision of a lifeguard present. As well, we ensured that the tether was kept neat to prevent tripping and that our teammates were wearing gloves to protect them from any potential sharp edges that could potentially harm them. Our safety department worked with all team members to ensure that the procedures required for the design, the building, and the use of the ROV followed all safety protocols.


Figure 28: Members of Husky Explorer shown wearing PFDs were close to the water. (Credit: Aloysius Ducey)

Troubleshooting Techniques

Throughout the completion of the ROV the team faced many challenges. For example, the frame was a brief struggle and we had to design it multiple times due to placements of holes on the original frame having to line up with the mounts for thrusters and tools. We also had trouble with one of our tools, the gripper. Originally, the top part of the gripper was straight. We re-evaluated upon realizing we were required to pick up two oil samples and if the top was straight once we went for a second sample the first one would fall out. To fix this we made two semi-circle cuts in the gripper to allow one oil sample to be locked in place while we are picking up the second. Although we struggled with two of these situations we used a troubleshooting process to guide us to a solution. The troubleshooting process often involves the process of elimination, where a technician will follow a set of steps in order to determine the problem or resolve the problem.

Our team used a simple three-step approach to troubleshooting:

1. Isolate the cause by eliminating possible problems.
2. Correct the cause of the problem.
3. Verify that the problem has been corrected.

This process proved to be very effective during the construction and development of the ROV. Once the ROV was completed it was tested at our indoor testing facility and then several practice sessions were held at the local pool, the Mount Pearl Summit Centre. It was through vigorous testing and troubleshooting that our ROV, and our on deck team, became as effective as possible.

Challenges

Technical

While working on the ROV we faced many technical challenges, but the largest technical problem was definitely the programming. This was a whole new experience for the majority of team members, so we began at square one and had to learn how to code simple programs with Python 3. The more we learned the programming language the less daunting the task of programming our ROV became. We began to understand the programming aspect and eventually our ROV was programmed to function how we intended.

Another challenge we experienced was the struggle with using SolidWorks. The software is challenging to use at first, but once we had a handle on it we were able to design several components of our ROV was ease. Trying to decide the shape of the ROV, the size, and where we would be placing everything involved a lot of brainstorming and discussion. Fabricating the cardboard mock-ups became very helpful as it enabled us to determine what shape would be beneficial for the mission task, as well as the best location for our tools.

A critical issue was experienced during a practice trial with the ROV. The sealed MCP, which holds the electronics, formed condensation on the inside when it was submerged in cold water. This posed a serious danger to the on-board electronics. A quick brainstorm session revealed several possible solutions. One involved using an absorbent feminine hygiene pads inside the MCP, top and bottom, to absorb the water. This was a quick fix for the regional competition, but not a completely reliable one. For the international competition, the MCP will be vacuum sealed so that no moist air will present to cause condensation.

Non-Technical

Husky Explorer is composed of a large 18 member team and this played an important role in the process of building our ROV this year. Having such a large team has many benefits, but it can also create the need for additional management and conflict resolution. With so many members, we faced difficulty with having multiple people working on the same task at the same time and sometimes this resulted in little to no progress. To resolve this problem, the CEO assisted in dividing the team into smaller groups, based on each individual member’s interests and strengths. Each group was assigned a specific role to play for the fabrication of the ROV or the management of the company. We made sure to keep all written documents, including brain storming, design proposals, and modifications in the team’s Google drive to allow the inclusion of all team members. Moreover, we kept a large checklist on the whiteboard in the lab, helping to ensure that all tasks were completed, eliminating the possibility that a team member would begin a task that had already been completed by someone else.

Lessons Learned

Technical

One technical lesson that we have learned is the importance of planning the size of our vehicle in advance with all our equipment attached to the ROV. Initially, when we began planning the size of the ROV, we knew it had to fit through a 48 cm diameter hole. Considering the difficulty we had with the large frame last year, we decided to build one much smaller, initially 36 cm x 30 cm x 10 cm. However, we quickly realized that when the tools, such as our claw and hook, were mounted to the front it extended the length of the ROV, and it no longer fit through the 48 cm diameter hole. Through this error, we learned the importance of planning and thinking through thoroughly each facet of the ROV design before making any final decisions. Fortunately, we were able to adjust the hook and claw to fit through the hole without much difficulty.

Interpersonal

One interpersonal lesson we have learned throughout this process is how difficult it is to assign roles for a large company with 18 members. From the very beginning, it was clear that with so many people each person would need to fulfil a different role and responsibility within the group. However, everyone worked at different rates, so it became difficult to divvy up tasks so that everyone was productive. Therefore, as time progressed, several members had no job to complete, so they were unproductive. Due to this issue, it was decided that in the future, we would determine who works faster, and make sure that we left enough work for those members to do in order to have a company with a constant productivity level.

Future Improvements

Although this was a successful year, one of the major future improvements our team would like to make would be time management. Every year we start about the same time (December), and every year we are stuck last minute trying to make minor adjustments. If we allowed ourselves to start sooner and use our time effectively to complete these minor adjustments earlier rather than last minute we would have more time for practicing the manoeuvrability and control of our ROV. Other future improvements would be sticking more closely to a detailed timeline. This would help us to plan for short term goals and allow us to allocate extra time to needed tasks.

Reflections

As a team we have accomplished a great deal throughout the process of designing and manufacturing our ROV. We began with nothing but a mission and our minds, and finished with a product that brings us great pride. As soon as the competition manual was released we began brainstorming our ideas. With these ideas in our heads, we split off into smaller groups where we were able to accomplish the construction of each of our designated tools and components. By working separately in teams and cohesively together, we were able to build and modify all the necessary components of the ROV, creating a sense of accomplishment when the project came together, with each team member seeing their portion having aided in the completion of the mission tasks on competition day.

The MATE competition has given us an opportunity to learn and accomplish tasks we might not have thought possible. You can learn a lot in the classroom but this competition allows for hands on experience approaching a variety of real world problems that allowed us to use our own ideas and designs to solve them. This gives us a real sense of accomplishment when we can all watch our own ROV in action.

Acknowledgements

The Husky Explorer staff is extremely grateful for our amazing mentors Mr. Paul King and Mr. Cameron Williams, who have guided us and helped us through the process of completing this project. We would also like to thank Mr. Gonzo Bennett for his guidance in using SolidWorks and the CNC Mill to design and fabricate the frame. A special thank you goes to Mr. Jacob Brown and Ms. Kaitlin Quinlan for helping us learn how to program our ROV using Python. We are also grateful for our sponsors, Marine Institute, MATE, Mount Pearl Senior High School, Provincial Airlines, and Rutter Inc. Thank you to H&F Electrical for the donation of the components in our tether. Without the aforementioned individuals, this ROV would still be a drawing on paper.

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Appendix

Appendix A: Company Breakdown

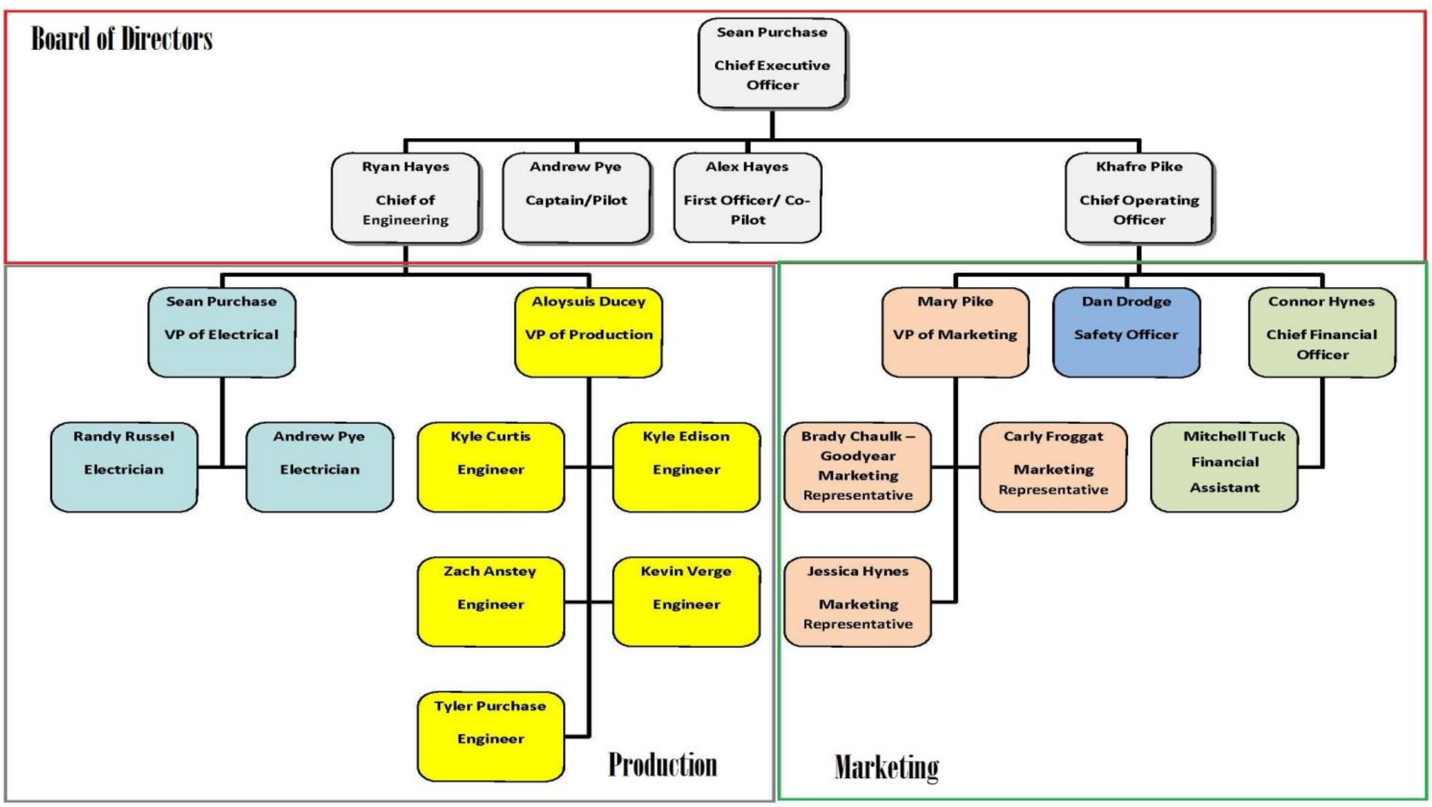

Figure 29: Organizational structure of Husky Explorer (Credit: Khafre Pike)

Appendix B: System Integration Diagram

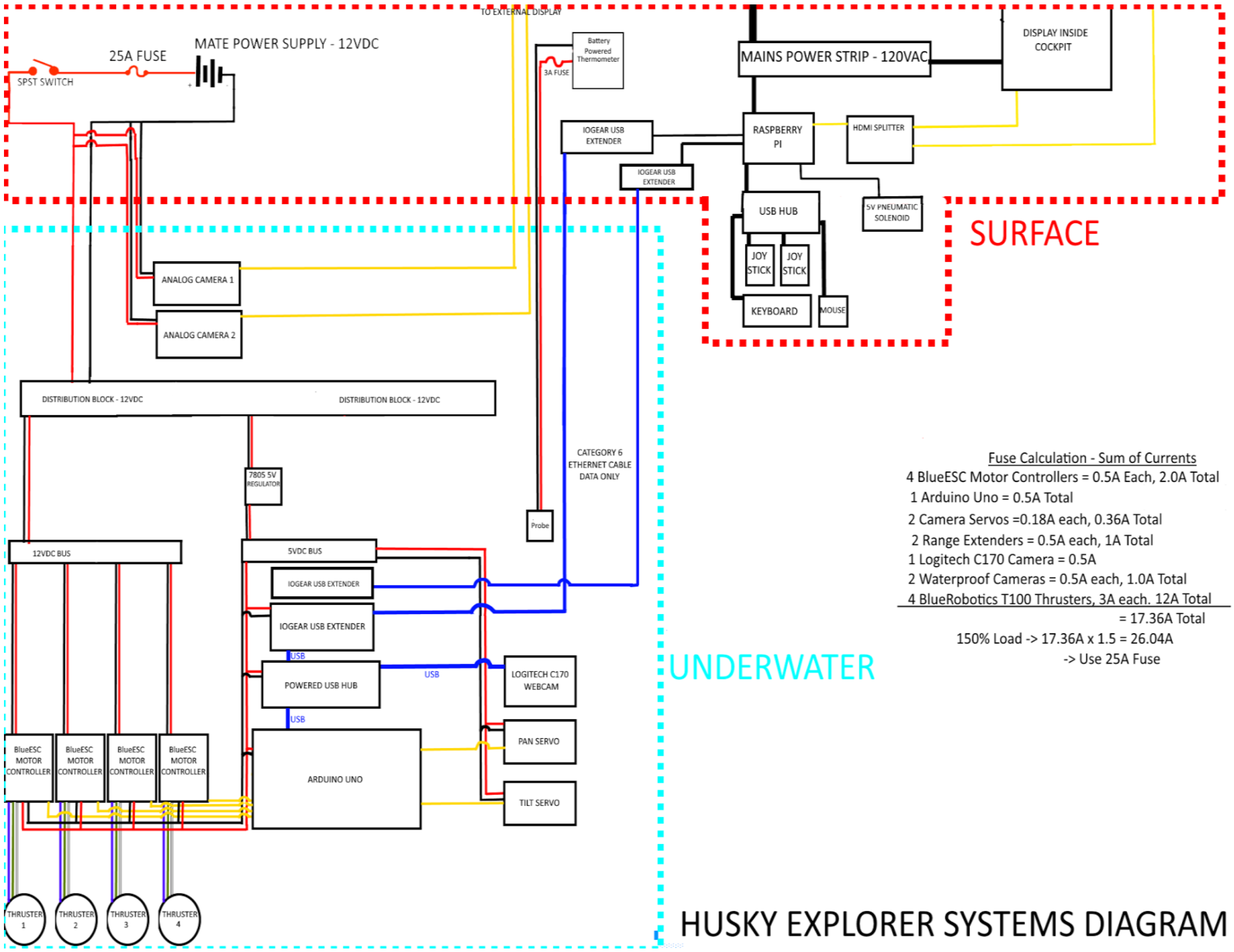

Figure 30: Systems Integration Diagram - This diagram shows all components of the vehicle's control and electronics system. Components are labeled as surface or as underwater. A fuse calculation is also shown. (Credit: Sean Purchase)

Appendix C: Project Costing (Canadian Dollar)

ROV Budget

Quantity purchased	Product	Cost	Quantity	Product	Cost
1	Acrylic End Cap with Holes- 4 in	$32.11	1	Waterproof digital temperature sensor	$9.32
1	Cable Penetrator Bolt for 6mm Cable	$40.14	1	Pan/tilt kit for pixy CMUcam5 image sensor	$44.11
1	Cable Penetrator Blank Bolt (No Hole)	$10.70	1	Pixy CMUcam5 image sensor	$95.11
1	Cast Acrylic Tube - 11.75” L - 4”	$72.25	1	Humidity and temperature sensor	$13.45
2	O-Ring Flange - 4 in	$77.60	1	6 DOF gyro, accelerometer IMU	$13.38
1	Clear Acrylic End Cap - 4 in	$21.41	1	Barometric pressure/temperature/altitude sensor	$13.45
6	Speed controller for electric motor	$133.79	1	Dome end cap (4” series)	$78.92
6	Electric motor for underwater use	$583.35	2	O-ring flange (4” series)	$77.58
1	Velcro wrap	$8.99	3	Spare o-ring set (4” series)	$12.04
1	Ties and cables 7.5”	$3.99	1	Vacuum plug	$10.70
1	USB 2.0 boostlinQ	$99.17	1	End cap with 10 holes (4” series)	$32.10
1	Raspberry pi 2 ultimate kit	$94.95	1	Canakit starter kit for Arduino	$42.95
				Total Purchased:	**$1874.96**
Donation Type	Company	Amount/Equipment Donated	Donation Type	Company	Amount/Equipment Donated
Monetary	Provincial Airlines	$1000	Service	The Print & Sign Shop- Poster board	$130.00 (CMV)
Monetary	MATE	$750	Hardware	ESL - Bait Mesh	$200.00(CMV)
Monetary	Rutter Inc	$200	Hardware	H and F Electrical - Wire	$100.00(CMV)
Reused	Mount Pearl Senior High- Cameras	$600 (CMV)	Hardware	Mount Pearl Senior High- Used Pelican Cases	$500.00(CMV)
			Hardware	Mount Pearl Senior High - Acrylic	$200.00(CMV)
				Total Donated:	**$3680.00**

Travel Budget

Quantity Purchased	Product	Cost
20	Flights	$20707.80
8	Hotel	$5994.40
1	Ground Transportation	$1000.00
	Total Purchased:	**$27902.20**
Donation Type	Company	Amount
Grant	Government NL	$20000.00
Ticket Sales/Bottle Drives/Recycling	Husky Explorer	$6200.00
	Total Donated:	**$26200.00**
	Subtotal Purchased (ROV)	**-$1874.96**
	Subtotal Purchased (Travel)	**-$27902.20**
	Subtotal Donated (ROV)	**$3680.00**
	Subtotal Donated (Travel)	**$26200.00**
	Total:	**$102.84**

Figure 31: Budget (Credit: Connor Hynes)

Appendix D: Safety Checklist

Safety Procedures during construction include:

- ❏ Safety a priority in discussions, displays and actions.
- ❏ No loose clothing.
- ❏ Long hair tied up.
- ❏ Closed toe footwear.
- ❏ Safety glasses at all times since multiple activities occurring in shop.
- ❏ Appropriate behavior: no running or horsing around.
- ❏ Safe materials handling: long or heavy stock moved by 2+ people; use trolleys.
- ❏ Instruction and apprenticing for all shop equipment usage (power tools, heating, etc.)
- ❏ Hazardous or toxic chemicals removed from lab permanently.
- ❏ The team is educated on all tools being used.

Pre-Mission Checklist:

- ❏ Deck Crew put on PFDs.
- ❏ Wear Safety Glasses.
- ❏ Remove loose clothing.
- ❏ Tie up long hair.
- ❏ Place ROV in secure location on deck.
- ❏ Unwrap tether and extend along the pool deck.
- ❏ Prepare to launch ROV.
- ❏ Place small TVs control box and panel in suitable location.
- ❏ Use Banana Plugs to connect to main power supply.
- ❏ Connect Video cameras to Control Panel power supply.
- ❏ Connect video cameras to TVs.
- ❏ Turn on Main Power switch.
- ❏ Commence pre-mission check on systems: Cameras, Tools and Thrusters.

Appendix E: Husky Explorer Team Picture

Front row (left to right): Kaitlin Quinlan (Alumni Mentor) Jessica Hynes, Kevin Verge, Mitchell Tuck, Zach Anstey, Connor Hynes.
Back Row (left to right): Cameron Williams (Teacher Mentor), Jacob Brown (Mentor), Aloysius Ducey, Ryan Hayes, Alex Hayes, Kyle Edison, Kyle Curtis, Mary Pike, Daniel Drodge, Khafre Pike, Andrew Pye, Sean Purchase, Paul King (Teacher Mentor).

Missing: Carley Froggatt, Brady Chaulk-Goodyear, and Tyler Purchase.

Appendix F: Schedule

Below is the schedule that was employed to keep our company on task. The schedule was divided into two sections: the month and what we wanted to complete in said month. The green bars signify being on time, while the yellow bars signify running behind schedule, the red bars signify being over schedule, the black bars signify completed tasks and the peach bars signify a task not yet started.

Month / Day	Tasks to complete			
February	Decide Frame Design	Learn Programming	Cut Frame	
2				
4				
9				
11				
16				
18				
23				
25				
March	Poster board	Programming	Props	Fix Frame
1				
3				
8				
10				
15				
17				
22				
24				
30				
April	Poster Board	Programming	Tools	Finalize Frame
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
18				
19				
20				
21				
22				
25				
26				
27				
28				
29				
May	Sales Presentation	ROV Practice	Regional Comp. Prep	
2				
3				
4				
5				
6				
7	Compete	Compete	Compete	
8	Compete	Compete	Compete	