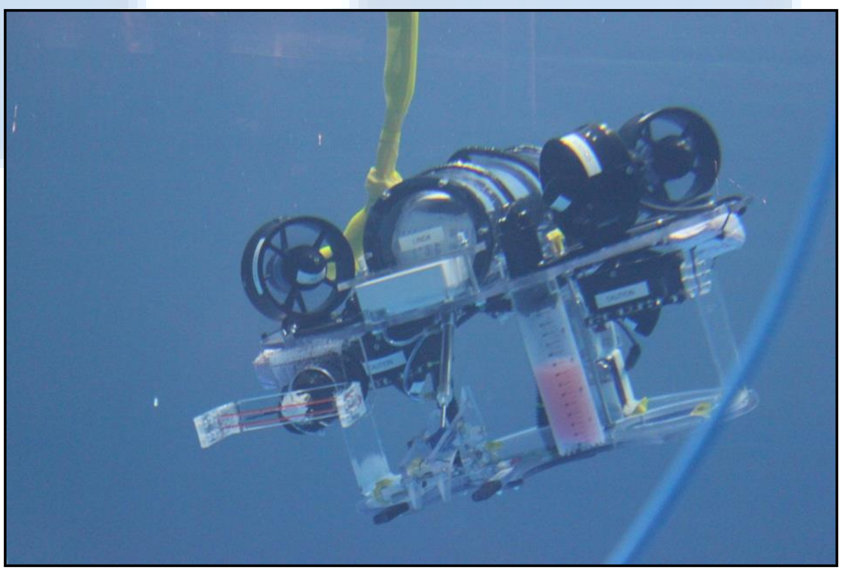
# Mount Pearl Senior High School

## Mount Pearl, Newfoundland Labrador, Canada

# *Husky Explorer*

| Name | Roles | Grade | Career Goal |
|---|---|---|---|
| **Alex Hayes** | CEO/Captain (Pilot) | 12 | Mechanical Engineer |
| **Rod Fowler** | Software Engineer (Co-Pilot) | 11 | Software Engineer |
| **Raquel Morgan** | Chief Operating Officer | 12 | Obstetrician |
| **Aloysius Ducey** | Vice President of Marketing | 11 | Pharmacist |
| **Connor Hynes** | Chief Financial Officer | 12 | Naval Engineer |
| **Mitchell Tuck** | Safety Officer | 11 | Naval Engineer |
| **Matt Martin** | Chief of Engineering | 12 | Police Officer |
| **Cole Morecombe** | Vice President of Electrical | 11 | Astrophysicist |
| **Randy Russell** | Vice President of Production | 11 | Agriculturist |

**Teacher Mentors: Mr. Paul King, Mr. Gonzo Bennett, and Mr. Sean Purchase**



ROVer: Flying in Marine Institute Flume Tank. (Credit: Raquel Morgan)

# Abstract


Husky Explorer specializes in the design and construction of underwater Remotely Operated Vehicles (ROVs). For our latest project, we have designed a brand new underwater vehicle, ROVer (**R**emotely **O**perated **V**ehicle **E**astern **R**egion), to compete in the 2017 Marine Advanced Technology Education (MATE) Center's International ROV Competition, June 23$^{rd}$ - 25$^{th}$, at Long Beach, California, USA.

Figure 1: Husky Explorer Logo (Credit: Mitchell Tuck)

ROVer is designed to perform tasks associated with constructing an Hyperloop system, regular maintenance on the port's light and water show, identifying and collecting samples of contaminated sediments, remediating the contaminated area, and identifying the contents of cargo containers that have fallen off vessels into the harbor. In completing these tasks our ROV will be able to expedite the delivery of goods and streamline commerce, guarantee uninterrupted entertainment, and ensure the health and safety of people and the port.

Figure 2: The Port of Long Beach California vessel being unloaded by numerous cranes. (Credit: http://www.joc.com)

ROVer is equipped with several specialized tools which have been designed to accomplish this year's challenges. These include: a sediment extractor, a pneumatic clamp, a valve spinner, an electromagnet, clam collector and a Raman Spectrometer.


Figure 3: The distance between Mount Pearl, Newfoundland and Labrador and Long Beach, California is 7,128km (4429 miles). (Credit: Alex Hayes)

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

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# Safety

The safety of our company's employees is our number one priority. At the beginning of the year, before any work was started, our safety team designed a checklist of safety procedures (Appendix A) to be distributed and followed each meeting by all employees to ensure a safe environment while working on the ROV.

During ROV construction, employees were properly educated on how to operate tools which may be hazardous in the workshop. No members were permitted to operate equipment without a mentor present. As well, members were encouraged to ask any questions they might have to ensure a safe workplace.

When working with electrical components of the ROV, each connection was soldered and shrink wrapped to prevent damage to electronics. Furthermore, a 25 A fuse is located on the positive end of the circuit to prevent damage to the electrical components of the ROV and to protect our employees from any injuries which may be sustained from electrical malfunctions.

Figure 4: A 25A fuse inside fuse holder on positive lead. (Credit: Mitchell Tuck)

Every exposed edge on the ROV frame was filed and rounded to prevent any cuts or scrapes when handling the ROV. Every exposed bolt end was covered with heat shrink to cover any sharp points and all spinning/moving parts. Any edges which may have sharp points are indicated with caution labels. Safety is of utmost importance for our company. Our ROV is user friendly in operation and maintenance.

From the beginning, we made sure to have a safe workplace when working on the ROV. Every time we powered up the ROV we completed a checklist; we ensured all connections were reliable and that no wires were crossed, we made sure to check all fuses, and ensured all technicians operating on or near the vehicle were at a safe distance from the ROV while under operation and while completing maintenance of the electrical system. The tether is secured by strain reliefs on both points of connection to prevent damage to the electrical system.

Finally, when our company visited the pool to practice missions, all employees working near the water were wearing Personal Flotation Devices (PFDs) and were under the supervision of an on-duty lifeguard. As well, the tether was neatly organized away from congested areas to prevent tripping. Employees managing the tether wore gloves to prevent from cuts and scrapes that may occur from sharp extrusions on the tether. Our safety department worked with all employees to ensure that procedures used in the design, building and operation of the ROV followed all safety protocols.

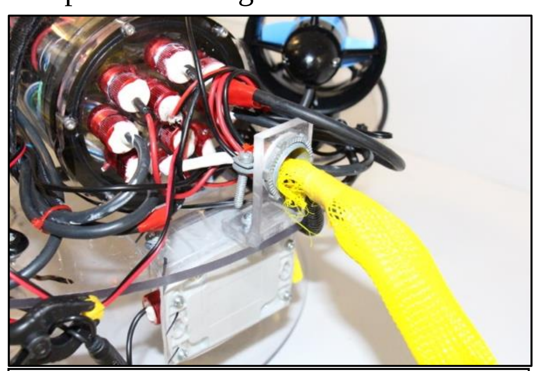

Figure 5: A conduit strain relief is used to secure cables coming from the tether. (Credit: Raquel Morgan)

# Company Mission

Around the world, busy seaports like the Port of Long Beach are experiencing vessel traffic contributing to the prevalence of accidents and pollution. Due to this traffic, vessels wait in line for several days continuously spewing smog into the air. This eventually leads to an increase of pollutants in the air which negatively affects the health and safety of neighboring areas. It is the economic issue of "cargo surges from big ships and the extraordinary randomness of container discharges and truck visits to marine terminals that will be the longer-lasting problems for ports" (Long Beach CEO, 2017). Programs like the Green Ship Incentive Program and the Green Flag Incentive Program have been put in place to increase the air quality and reduce the pollutants that are emitted from the vessels: "Since 2005, the Port has cut diesel particulates by 81 percent. In addition, nitrogen oxides were down 54 percent and sulfur oxides were down 88 percent over the same period. These results, from data collected through 2012, represent six straight years of improving air quality in the harbor area" (Air Quality, 2017). Although these measures are in place, it is still not enough to completely diminish the pollutants and safety problems caused in previous years.

Husky Explorer has recently been requested, by the Port of Long Beach, to help with the reduction of pollution and extraction of harmful contaminated sediments within the ocean. Our ROV can locate contaminated cargo containers that have fallen off vessels, determine the level of risk of the containers, and retrieve contaminated sediment samples for analysis. With these capabilities, our ROV will be able to ensure the health and safety of the port and people in surrounding areas.

Figure 6: A vessel delivering hundreds of cargo containers to the Port of Long Beach, California. (Credit: http://www.polb.com/about/bigshipready.asp)

Our ROV is also capable of constructing and maintaining an Hyperloop commerce system that will be efficient in delivering goods and will help businesses, as well as consumers in the community, to save money. In addition, the new system would reduce the number of cranes and other heavy equipment located in the port and completely diminish the number of vessels coming in as they will be no longer needed with the Hyperloop system in place. It is said that this new system "is a new way to move people and things at airline speeds for the price of a bus ticket. It is a new mode of transportation that will change the way we live" (Hyperloop One, 2017). The community will therefore flourish due to the cost-effective system that will be put in place and maintained by our ROV. The reduction of the heavy machinery along the port will increase the space that could be used for entertainment purposes. This relates back to our last mission which is to maintain the entertainment aspects of the Port of Long Beach.

Lastly, the ROV will be able to maintain entertainment systems like the light and water shows put off at the port nightly. The entertainment aspect of the port generates a lot of money from tourists, which thereby enables the port to invest money in additional forms of entertainment. The ROV will be able to maintain, repair, and replace the underwater fountains that play a big role in running the light and water show with specialized tools created to perform such tasks. The

ROV is designed to ensure “the approximately 19,000 square-foot projection screen, [of which] nearly 1,200 fountains shoot water 200 feet into the air,” is functioning successfully (World of Color, 2017).

With the challenges in mind, Husky Explorer’s newest model is designed to be versatile, robust, and maneuverable. It can complete the mission tasks with our specially designed tools including the clamp, the agar extractor, the valve spinner, electromagnet, clam collector and  Raman spectrometer. These tools will aid in the construction of the Hyperloop system, light and water show maintenance, extraction of contaminated sediments, and in identifying harmful cargo containers.

# Project Management

Husky Explorer is an ROV company consisting of nine members. At the initial meeting on August 1st, 2016, the team identified that time management and prudent financial planning were key aspects for success. To this end, the team identified the interests, strengths, and weaknesses 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, Marketing, Safety, and Financial respectively. Each of the team leaders in the latter two departments report to the Board of Directors. (See Appendix B for a visual breakdown of staff members)

Upon reviewing the MATE 2017 Competition Manual, resources, procedures, and protocols were managed to ensure all mission objectives were met. Planning sessions were held to identify possible solutions and solve any operational problems. Five consecutive Friday meetings, following our initial meeting, were then held to design and evaluate this year's frame. Beginning on September 8th, team meetings were held twice a week for two hours. Then, on January 3rd , we increased team meetings to five days a week, 2 hours per day to prepare for the regional competition. In these planning sessions, ideas were debated and decisions were made by the Board of Directors.

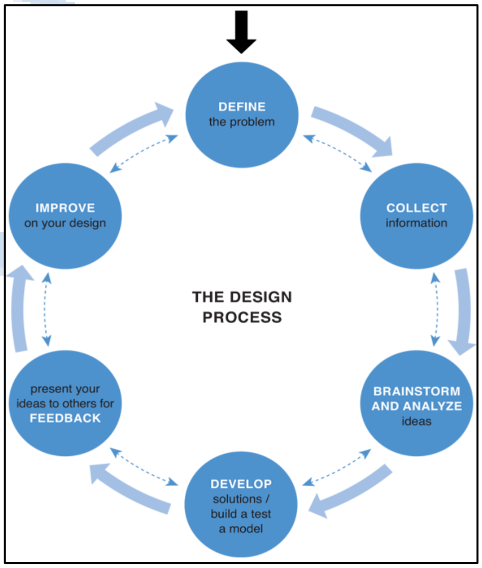


Figure 7: Our design process we followed to keep on track. (Credit: discoverdesign.org)

A six-step design protocol 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 an opinion in the final decisions made for our project. Informative posters of the RANGER Class Preview Product Demonstration were made to ensure the team members knew all the aspects of this year’s mission tasks allowing them to design and build tools appropriately. These posters were then placed in our meeting classroom so the relaying of information was easily accessible.

Throughout this process, the team had to resolve a variety of problems regarding buoyancy, propulsion, and tool options. By continuously modifying and improving ideas, we successfully arrived at our current and final design rationale and vehicle systems while managing to stay within our budget. Routinely, the Board of Directors would confer with each department to troubleshoot any issues and provide motivation to our fellow teammates to accomplish their varied tasks.

# Budget

A large portion of the project management is the human and financial resources. Through cost analysis, an estimated budget of $2500 was developed, which would be used to buy electronic supplies and materials. Due to the estimated budget, it was clear that support from financial sponsors and in-kind donations would be necessary. Financial sponsorship ($800) was received from Marine Institute. In-kind donation of equipment and supplies was given to us by our school Mount Pearl Senior High. By researching and comparing equipment prices online we purchased the equipment that was needed for this year within budget. To control spending, all purchases went through an approval process with the Board of Directors. A table outlining our project costing is in Appendix E.

Figure 8: Project Costing. (Credit: biztic.com)

Following the Regional ROV Competition at the Marine Institute, we built a travel budget for the team. We contacted Travel Professionals International (TPI) to compile the costs for flights and accommodations in Long Beach. For the 12-member team (nine students and three mentors) flights and insurance costs were $1040.00 each, for a total of $12483.00. Accommodations cost $239.93 per night for five rooms booked for nights for a total of $9597.00. We have budgeted $2500 for ground transportation to events while in Long Beach. Our total approximate travel budget is $28780.00. To accumulate funds for the trip, we have contacted members of the local business community to sponsor the Husky Explorer team and endeavored to raise funds through a gift card basket raffle.

# Design Rationale and Vehicle Systems

The design of our ROV and subsequent vehicle systems was dictated, in part, by the mission specifications provided by the 2017 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 meet the stringent size and weight restrictions. It needed special tools to manipulate items and complete ROV tasks. It needed to be agile to collect samples of contaminated sediment, use a simulated Raman spectrometer to identify if the sediment was contaminated, and return all these samples to the surface. The cameras on board needed to have a high resolution so that the pilot could locate cargo containers, identify if the contents were high risk, and be able to determine the direction and distance from the highest-risk container to the other three containers. It also needed a tool to install rebar reinforcement rods into a baseplate, transport and position a hose for pouring concrete, to place a cap over the contaminated area, and to disconnect and reconnect a power cable on the platform. We also needed a valve spinner to turn the valve to stop and restore the flow of water. An additional tool

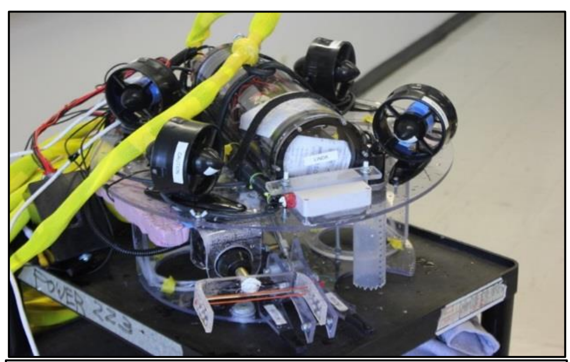

Figure 9: Our ROV, ROVer. (Credit: Raquel Morgan)

was needed for attaching a buoy marker to the U-bolt on the container with the highest-risk cargo and for the removing of old fountains and the installing of new ones.

In developing an ROV to complete every mission task, eight main components were considered: frame design, buoyancy, propulsion, tools, tether, electronics, control, and cameras. For the ROV to function properly all components needed to work effectively together. Therefore, detailed research, planning, and careful decisions were a necessity to complete the contract required by MATE.

# Frame

Three frame design options were considered for this years ROV: PVC pipe, angled aluminum, and acrylic. After considering all strengths and challenges for each material, a decision matrix was developed to narrow our choice. A 0.64 cm clear, transparent acrylic was chosen since it is durable, machinable and lightweight. This acrylic was also readily available because our school had used this material for a few temporary windows while under renovation, and donated them to our team once they were no longer of use to them. ROVer, Husky Explorer's newest product, was designed with the competition's restrictions in mind. During the design process of the ROV, the frame, tools, propulsion, and camera views were all considered. This included forward planning to troubleshoot how our tasks could be completed efficiently, how tools and cameras would be mounted, and how all systems would interconnect while not interfering with one another. With this planning in our minds, our company consulted with members from past years' products to discover past products' faults. We sought to abolish past faults and create a new ROV which outperforms anything of the past. The frame, being the main structure, is crucial to the success of the ROV. Our group decided we needed to focus on agility, maneuverability, and camera view.


Figure 10: A mock-up of our potential design. (Credit: Raquel Morgan)

First, we brainstormed a design and shape that would best accomplish our goal while adhering to MATE's size restrictions. Our chosen circular design allows for a maximum amount of usable surface area based on the 48 cm in diameter restriction. A modular design allows for ROVer to be easily serviced. In case of damage, a section can be easily replaced instead of replacing the entire structure. After choosing a design our group created a cardboard mock-up, which we used to visualize our ideas and plan for tools based on the mission tasks. Adhering to our design principle our company transitioned to corrugated plastic. We finalized our size and created a 47cm in diameter circle (top plate) and 36 cm in diameter (bottom plate) which was support by 2 mounting brackets and 6 mm threaded rod. A mounting system for our Main Control Pod (MCP) was designed: the simplistic idea of a rectangular slot accompanied by 4 slits and lightweight Velcro straps was chosen instead of a bracket system chosen in past years. This second model in our design process utilized stronger material allowing our company to dry fit thrusters and find the ideal vector (45 degrees) for our vertical thrusters based space.

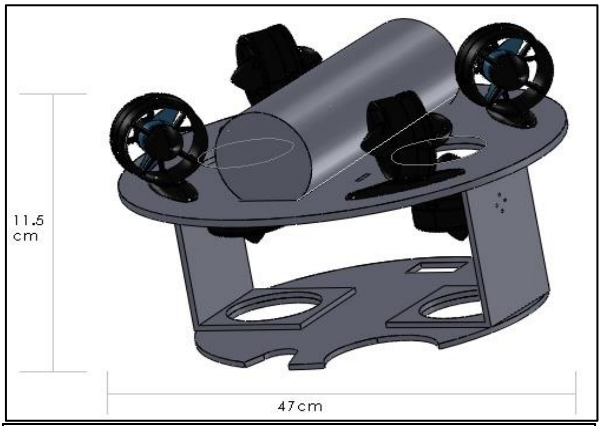

Figure 11: A CAD mechanical drawing of ROVer. (Credit: Alex Hayes)

Using SolidWorks, a CAD design was created. All the necessary holes and mounts were cut in the acrylic with the school's Computer Numerical Control (CNC) machine leaving us with three main structural pieces, two circular plates (47cm and 36 cm in diameter), and two vertical brackets measuring (16 cm in diameter). This design creates an overall height of approximately 20 cm and a maximum diameter of 47 cm (frame only).

# Propulsion System

Figure 12: 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. The ROV is equipped with six of these motors, four mounted horizontally, and two mounted vertically. The T-100 thrusters are fitted with a clockwise and a counter clockwise propeller which provides counter torque. Four vectored motors are mounted at $45^0$ which provides a better turning radius and allows the ROV to move in all directions. Two T-100 thrusters are also mounted vertically on the frame supports to provide vertical movement. These thrusters are mounted lower in the center of the vehicle to maintain stability when moving up or down.

# Pneumatic System

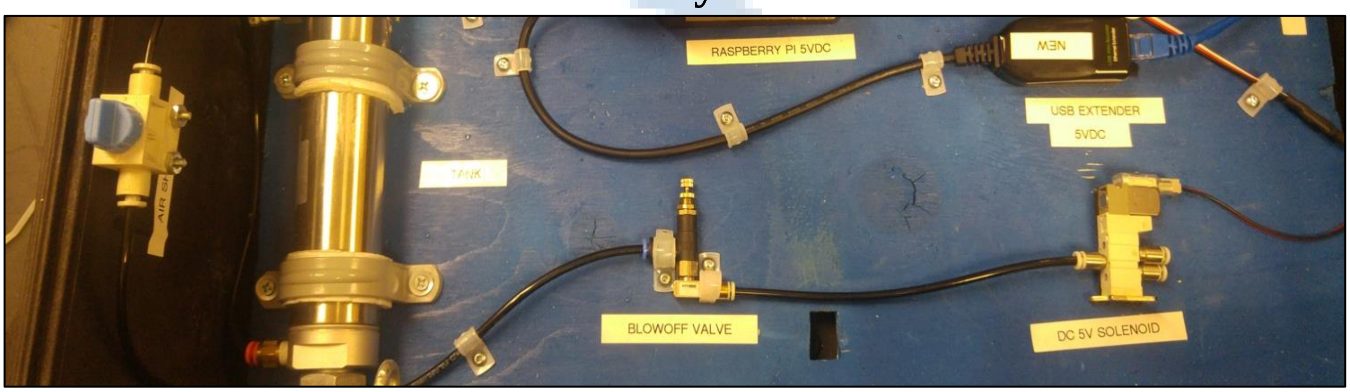

Figure 13: Pneumatic system inside vehicle cockpit using VEX components. (Credit: Raquel Morgan)

ROVer is equipped with a pneumatic system which is used to power a pneumatic clamp. The system consists of a 150-mL reservoir (20cm x 4cm) attached to an air compressor which is regulated at 40 psi. The reservoir feeds air through a main shut off switch, which then feeds to a 40-psi pressure release valve, then to a 5V pneumatic solenoid. The solenoid is controlled by GPIO pins on a Raspberry Pi 2 Model B which generates signals for the solenoid through a Python 3 program. When a button is pressed on the main driving joystick, the solenoid is actuated, thus opening or closing the clamp. 4.0 x 2.5mm tubing is used for all connections in the system, both inside the box and underwater and Teflon tape was used to ensure a reliable connection within fittings.  Each component of the pneumatic system is neatly labeled inside the main vehicle cockpit and the main shut off switch is easily accessible as an added safety precaution.

The operation of the clamp 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 $kN/m^2$ (100 psi) internal pressure the maximum force of 54 N (12 lbs.) can be applied by the pistons. A 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 $kN/m^2$ = 54 N or **21.6 N at 276 $kN/m^2$ (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)<br>(22 N @ 40 psi) |

Figure 14: Reservoir and Cylinder Specifications. (Credit: Vex Robotics)

## Fluid Diagram

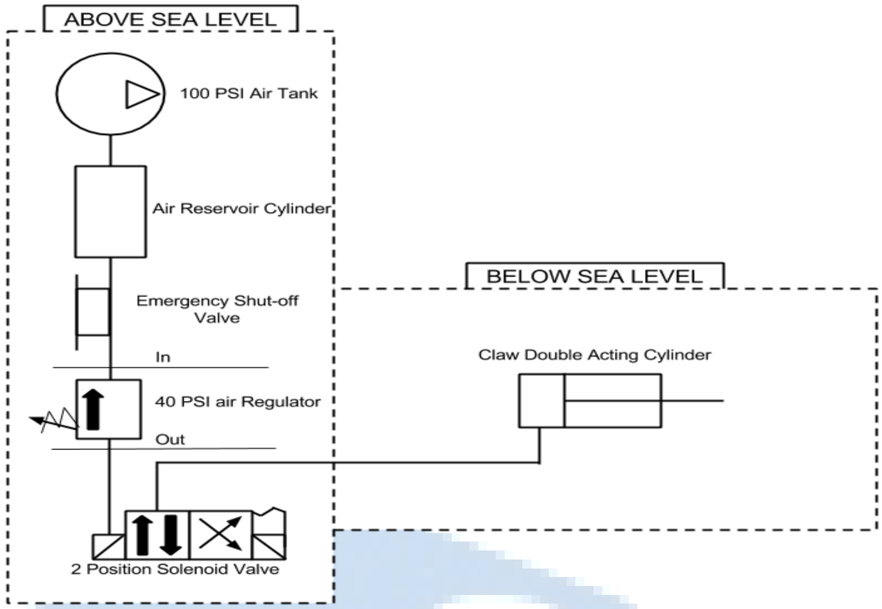


Figure 15: Fluid Diagram. (Credit: Randy Russell)

# Tools

ROVer consists of six unique tools: a pneumatic clamp, an agar extractor, a spectrometer, an electromagnet, a valve spinner, and a clam and beacon collector. An increase in the number of tools signifies a major improvement compared to last year's ROV, which only had three tools onboard. All the tools are new, hand-crafted and made specifically for this year's tasks. Through trial and error, prototyping and modifications, the ROV can perform every mission task. Due to the strict weight and size restrictions, the company chose to use components and parts that were small and light. Inexpensive, yet quality, parts were used, when possible, to cut down on our costs. Our tools were tested at our school in our indoor testing pool (1.83 m x 1.83 m x 0.91 m) and at Falck Safety Services in a 15 m pool used for offshore survival training.

The pneumatic clamp is the most versatile tool on the ROV because it can be used in many missions. It is made of clear, light weight acrylic and designed specifically to grab most objects. This tool is used to grab the rebar reinforcement rods in the Hyperloop construction mission, transport the fountain and power cable for the light and water show maintenance and the cap for Environmental cleanup. The clamp will open just enough to grab these objects and provide a large gripping force (22 N @ 40 psi) to hold them securely. The dual pneumatic piston is used instead of an electric or hydraulic system because of its low weight and low risk to the environment. In addition, air is easily compressible and provides buoyancy to the tether.

The agar extractor mounted on the left side of the ROV is used to extract 100 ml of sediment samples from the contaminated area in the environmental cleanup mission. This tool is made using a 140-ml plastic syringe and a bilge pump. The syringe is jagged on the end to ensure it breaks the surface tension. The bilge pump is used to provide reduced pressure in in the cylinder tube, like sucking on a straw to drink water, to help pull up the agar sample and keep it there.

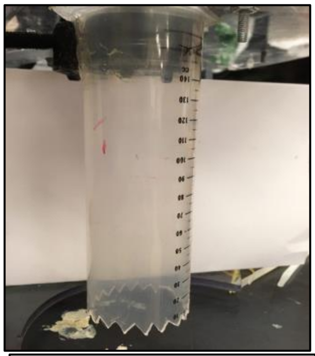

Figure 16: Our agar extractor made of a 140ml plastic syringe. (Credit: Raquel Morgan)

The spectrometer is used in the risk mitigation mission to illuminate agar samples to determine if they are contaminated. This tool is mounted on the vertical thrusters and uses a 420-nm blue LED to light up the front of the ROV. It also serves as a backup light source in low light conditions.

An electromagnet is also used in the same mission. This tool is mounted under front plate and can be used to activate the reed switches.  An electromagnet was chosen instead of a regular magnet because it can be toggled on and off to activate the switches whenever needed.

Figure 17: The electromagnet. (Credit: Raquel Morgan)

The valve spinner on the right side of the ROV is used to turn the water valve for light and water show maintenance. The valve spinner was the hardest tool to finalize due to difficulty providing enough power to spin the valve. The final design uses an acrylic rotator and a 5.0 A bilge pump which provides four times the torque (T=FrsinΘ) of the 2.0 A bilge pump we were originally using. This was tested in our indoor testing facility using a spring scale and ruler.

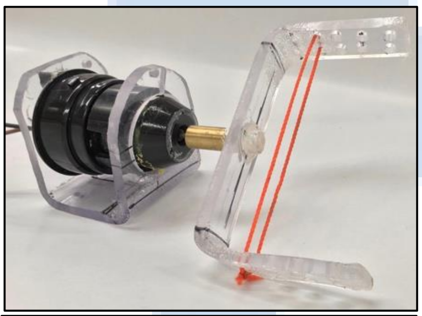

Figure 18: The valve spinner. (Credit: Raquel Morgan)

The last tool is the clam collector located on the bottom of our ROV. The clam collector was made using multiple rubber bands attached to a clear acrylic container. This tool is used to pick up clams in environmental cleanup by forcing itself down on the clams. The tool acts as a trap for the clams: the rubber bands stretch out for the clams to fit between them but the distance between the bands is too small for the clams to escape.

## Tether

Figure 19: The tether neatly wrapped around our ROV. (Credit: Raquel Morgan)

ROVer's tether measures 15.24 meters in length and has been made neutrally buoyant by placing pieces of high density foam approximately 25 cm apart down the length of the tether. It has been encased in a neon yellow Techno Flex sheath to keep the cables neatly bundled and add a layer of protection against cuts from cable ties for the employees operating the tether. The tether contains a pair of 12 gauge conductors which are used to provide 12V to the Main Control Pod (MCP) and T-100 thrusters, as well as two pairs of 18 gauge conductors which are used to provide 12V to the electromagnet, valve spinner, agar extractor, and Raman spectrometer. The tether also contains a CAT-6 ethernet cable for communications and three coaxial cables for three independent video signals. Finally, two 2.5 x 4.0 mm pneumatic lines have been added to the tether inside of plastic wire loom for additional protection. The tether wraps neatly around ROVer during storage (like a water hose) and transport, while still allowing the vehicle to meet a 48cm size restriction.

# Electronics and Control Systems

**Hardware**

Figure 20: Pelican cases that hold our control and ROV system. (Credit: Raquel Morgan)

The control system is a combination of off-the-shelf components as well as custom hardware, all of which is enclosed in a Pelican Protector 1600 case that measures 62 cm by 49 cm x 22 cm. Putting all 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 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 case, allowing our vehicle to deploy and be stored again very quickly and effectively. This is 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 for the design of the control system and each member had the opportunity to operate the ROV. There were several decisions to make concerning the design and development of our control scheme and electrical system for this year's ROV.

In previous years, the control system relied on analog switches which were cumbersome and awkward to operate. Incorporating experience from previous contracts, we felt that a digital and software based system would be worth developing. A software based control system has been designed this year to make ROVer more reliable and easier to operate.

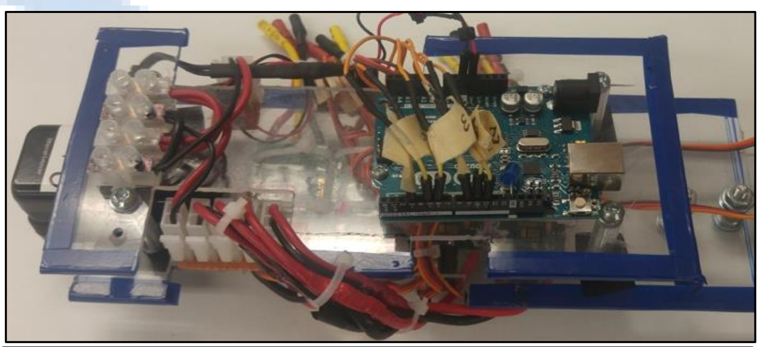
Figure 21: The electronics portion of our main control pod. (Credit: Alex Hayes)

The computer system consists a Raspberry Pi Model 2 B for our main computer. The Raspberry Pi Model 2 B was chosen because it was inexpensive and compact. The Raspberry Pi connects to a Logitech Attack 3 USB joystick, a keyboard, a mouse, a display, a VEX 5v pneumatic solenoid, and an IOGEAR USB range extender used for communication to ROVer. The Raspberry Pi runs our custom control program in Python 3, sending digital signals through the USB extender, then through CAT-6 ethernet cable in the tether to the other end of the USB extender inside the main control pod. This USB extender is connected to an Arduino Uno which takes the digital signals and translates them into analog signals our electronics can use. Along with the 12V pair, the communications cable travels through the potted cable penetrators from Blue Robotics into the back of the main control pod. Our 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, the logic components for our 6 Blue Robotics ESC 30A Electronic Speed Controllers. A full System Integration Diagram can be found in Appendix D.

**Controls**

To control the ROV, a Logitech Attack 3 Joystick is connected to our Raspberry Pi. We have designed the ROV controls to be intuitive, which make it easy to learn to operate. The joystick controls the flight of the vehicle and sends signals to our Python 3 program which are then sent down to 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. We also have a button on the joystick that allows the operator to toggle between sideways movement and spinning about the center of the vehicle. The intuitive control scheme allows the operator to focus on the tasks at hand is easier to learn than alternative control systems, such as, toggle switches. ROVer is by far the most capable and easy to operate product Husky Explorer has ever created.

Figure 22: Logitech Attack 3 Joystick. (Credit: Rod Fowler)

**Software**

This year, we designed a program 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 to control the onboard electronics. We designed our software to function in a way which allows us to move in all directions and control our pneumatics all while being responsive and easy to use. We designed the program to be tidy 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 and informing us of the ROV’s mode, all in easy to read clear text that allows the pilot to focus on the task at hand.

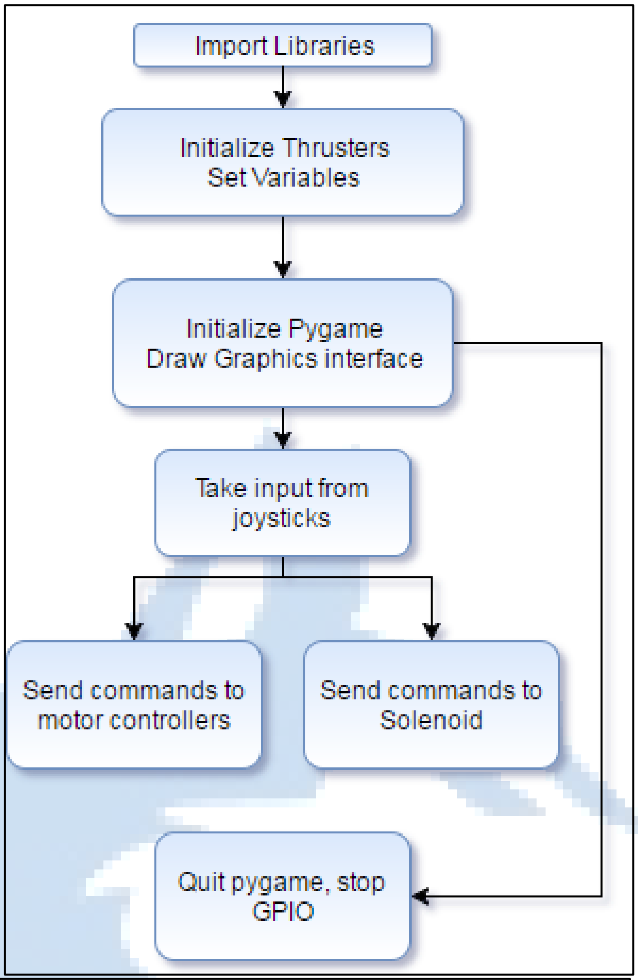


Figure 23: The software flowchart explaining our control software. (Credit: Rod Fowler)

# Video System

This year, ROVer uses three backup cameras instead of commercial ones because of their light weight, small size and large viewing angle. These new cameras are half the mass (450 g compared to 900 g), 10 times less expensive ($30 compared to the $300 CAD), and have a larger viewing angle (170° vs 90°) than the cameras we used last year. Each camera is designated an independent display which allow us to see multiple views at once, while also allowing the pilot to maneuver the ROV more effectively. This innovation allowed us to minimize our costs and reduce our size and weight. These cameras are versatile since they can be placed strategically around the ROV. Two cameras are placed on the rear to allow the pilot a clear view to drive and see all the tools. The third camera can be mounted anywhere on the ROV to allow the pilot a view of different tools during the mission. The cameras were waterproofed by placing them inside a GoPro case and using epoxy to seal the cable penetrator.

Figure 24: CarRover backup camera with a GoPro waterproof housing. (Credit: Raquel Morgan)

# Buoyancy

Our ROV was designed around the MCP, which is filled with air to act as the main source of our buoyancy. The MCP is inset in the middle providing a high center of buoyancy. We attempted to place the horizontal thrusters underneath the top plate to separate the centre of mass from the centre of buoyancy and increase the stability of the ROV. However, the driving view was compromised and the surface area for mounting tools was reduced. Therefore, we decided to put the horizontal thrusters on the top and lower the vertical ones to increase stability. After testing the ROV in water, we realized that a high-density foam was required near the front of the ROV to make it neutrally buoyant. This was determined by trial and error.

The Husky Rover team also designed a 15 m tether which required floatation. To make it neutrally buoyant small pieces of high density foam was added to the inside the tether cover every 25 cm. During testing, it was found that this was sufficient to support the tether. However, when driving forward the right side would sink down slightly. To fix this, high density foam was added to that side, and the issue was corrected. The pilot and co-pilot continued to test the maneuverability of the ROV until they were satisfied with its performance. The completed ROV is fully functional and capable of completing all mission tasks.

## Build vs Buy; New vs Used

For our company to operate efficiently, being cost effective in our building process was key. Our company made decisions based on which components would be smart to reuse from the past year, purchase new, build, or a combination of either. These choices were significant and played an important role in our ROV's performance and our budget. Our frame constructed from 6 mm acrylic was chosen as it is easy to mill on our school's CNC machine and there was also an abundance of this material from a past renovation. The entire ROV is 90% new. We chose to reuse some major mechanical components from past years' products such as thrusters, pneumatics systems, and electronics. We believe it was a wise decision to reuse these parts since they are very expensive to buy and these were still working well. Our company's ability to reuse these major components drastically reduced cost, allowing us to focus our funds on other areas of our project. Those funds which we saved allowed for the modification of our MCP providing us with space and programing for 6 thrusters compared to last year's 4. The money which was saved was used primarily to improve the camera design. We decided to abandon past camera systems since they were big and heavy. Instead, we chose to purchase the components and assemble a new camera system. We purchased a "CarRover" universal automotive rear view cameras ($24.01) and waterproof GoPro Hero session dive housings ($19.53). These cameras ($50) provided a superior 170 $^{0}$ viewing angle at a fraction of the cost, weight, and size. This was a major improvement

For the tether, we reused our previously successful 12 AWG main power wire to the MCP, ethernet cable and pneumatics line but added four new 18 gauge wires which provides power to our additional tools. The entire tether was then we wrapped in a new neon yellow braided Flexo PET. This highly visible wrap protects the sensitive cables from the elements and other hazards.

Four new tools were designed or redesigned for this year's mission: clamp, sediment (agar) extractor, valve spinner and collector. The clamp is reshaped to grip the rebar and cover handle. It is powered by a pneumatic system from a previous contract. The agar extractor is a new tool made from a syringe and a repurposed bilge pump. ROVer's valve spinner is a new "spin" on an old design, with a new fork and mounting bracket constructed from a lighter 6 mm acrylic. The "lobster pot" collector is utilized to collect clams and beacons. It is constructed from 6 mm acrylic and elastic bands. This static tool has proven reliable and effective and it cost $0 to build as our school provided the elastic bands and acrylic.

Husky Explorer prides itself in producing a new product for the MATE contract each year. While some parts are often reused or redesigned, it is essentially a new product with a new frame, hardware and tools. This production requires a dedicated staff who are willing to research, develop, prototype and collaborate. As a result, much time is often spent testing, trouble shooting and refining the product.

# Troubleshooting Techniques

Throughout the completion of the ROV, the team faced many challenges. When we encountered a problem, we used a troubleshooting technique that we developed and found to be very effective. 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.

When constructing our ROV, we tested the success of our components and the overall vehicle. Initially, the vehicle was completed, designed, and tested using SolidWorks. After production, the ROV was tested in our indoor testing facility and practice sessions were held at a pool used for basic survival training, at Falck Safety Services Canada (NL). It was through vigorous testing and troubleshooting that our ROV, and the on-deck team, became as effective as possible. If problems were discovered we immediately put our three-step troubleshooting technique into action. Due to our troubleshooting procedure, we believe we have not only solved and occasionally prevented problems, but we also were able to deal with any difficulties that arose quickly.

# Challenges

## Technical

While working on ROVer, we faced many technical challenges, but the largest technical problem proved to be the programming of our system. This was a whole new experience for most of our team members, as over half of our team consisted of first year members. Because of this, we began at square one and learned how to code simple programs with Python 3, a program that we just introduced last year. We began to understand the programming aspect and eventually our ROV was fully functional as 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 could design several components of our ROV, with ease. Trying to decide the shape of the ROV, the size, and where we would be mounting all our tools, involved a lot of brainstorming and discussion sessions. Fabricating the cardboard mock-ups became very helpful as it enabled us to determine what shape would be beneficial for all mission tasks, as well as, the best for mounting our tools and wrapping our tether.

The most potentially dangerous challenge faced was a moisture condensation issue inside the main control pod (MCP). The main control pod (MCP) houses all the electronics which become warm during operation. However, when submerged into cold water, condensation begins to form on the inside of the pod, thereby endangering the on-board electronics. Several solutions were researched including using an inert gas instead of air, placing the MCP under vacuum, and using absorbent silica pads. After careful consideration, using the absorbent pads proved to be cheaper, faster and a more practical means for reducing moisture in the MCP.

### Non-Technical

Husky Explorer is composed of a small nine-member team, in contrast to last year's 18-member team. This played an important role in the process of designing and building our ROV this year. Having such a small team proved to have many benefits, but it also created the need for additional management and conflict resolution. With fewer members, we faced the difficulty inconsistent attendance, which therefore resulted in little progress. To resolve this problem, the COO assisted in dividing the team into groups based on each individual member's interest and strengths. Each person was then assigned a specific role to play for the fabrication of ROVer or the management of our company. Checklists were also made and posted in the lab, consisting of things that needed to get done or that needed to be modified, ensuring that all team members were on track and completed the tasks at hand. This eliminated the possibility that another team member would begin a task that was already started or completed by someone else. We made sure to keep all written documents, including brainstorming, design proposals, and modifications in the team's Google Drive to allow the inclusion of all team members.

## 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 frame last year, we decided to build one much smaller, initially a circular design of 48cm in diameter. However, we quickly realized that when the tools, such as our clamp and valve spinner were mounted, 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 thoroughly each facet of the ROV design before making any final decisions. Fortunately, we could adjust the frame size to 47 cm in diameter and still can mount the newly improved clamp and the valve spinner to fit through the hole without difficulty.

### Interpersonal

One interpersonal lesson we have learned throughout this whole process is how difficult it is to keep track of things that are completed with a small team, because not every member was present daily for group discussions. From the very beginning it was clear that with a small team each person would need to fulfil a specific role and responsibility for the group. However, everyone worked at different rates, so it became difficult to keep track of what was completed to ensure optimal productivity. Due to this issue, it was decided that in the future we would make sure that incoming members agree to attend group discussions 90% of the time. Consistent attendance is crucial to produce a fully functional ROV that meets requirements, in addition to completing quality written documents, and marketing techniques required to ensure the success of the team.

# Future Improvements

Although this was a successful year, in the future our team would like to improve our time management. Every year we begin preparations in September and every year we work until the deadline making minor adjustments. If we start sooner and use our time effectively to complete minor adjustments earlier, we would have more time for practicing the maneuverability and control of our ROV. Adhering to a detailed timeline. This would help us to plan for short term goals and allow us to allocate extra time to needed tasks. As well, an increase in pool time practice, with props, would be preferable, as it would benefit our pilot.

# 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, fresh in our heads from last year's international competition in Houston, Texas, we split off into groups where we could accomplish the construction of each of our designated tools and components. Working in small teams and cohesively together, we built and modified all the necessary components of the ROV. Our team felt 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 not previously imagined. People can learn a lot in the classroom, but this competition allows for hands on experience in approaching a variety of real world problems, which allowed our team 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. Sean Purchase, who have guided us and helped us gain knowledge and expertise 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. We are also grateful for our sponsors listed below. Without these individuals, this ROV would not be where it is today.

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# Appendix

## Appendix A: Safety Checklist

**Safety procedures during construction include:**

- Safety is a priority in discussions, displays and actions.
- No loose clothing.
- Long hair tied up.
- Closed toe footwear.
- Safety glasses are worn at all times since multiple activities are occurring in the shop.
- Proper safety equipment is worn when dealing with tools in the shop.
- Appropriate behavior: no running or horsing around.
- Safe materials handling: long or heavy stock moved by 2+ people/trolleys.
- Instruction and apprenticing for all shop equipment usage (power tools, heating, etc).
- Hazardous or toxic chemicals are permanently removed from the lab.
- Using the right tool for the job.
- Insured all tools are in working condition.
- Insure the team is educated on all of the tools being used.
- Supervision while using dangerous tools.

**On Deck Safety Checklist:**

- Ensure all employees have PFDs
- Ensure tether is not in way of congested areas
- Ensure all connections are made and no exposed wires
- Ensure all employees are in proper position and know their job
- The tether is in a figure eight.
- Everyone handling the tether is wearing gloves, safety glasses, and close toed shoes.
- The tether is above the ROV, not below it.
- When the ROV is not in use, the tether and ROV are stored in one pelican case for safe transportation.
- The tether is connected to the MVC (Main Vehicle Cockpit).

# Appendix B: Company Breakdown

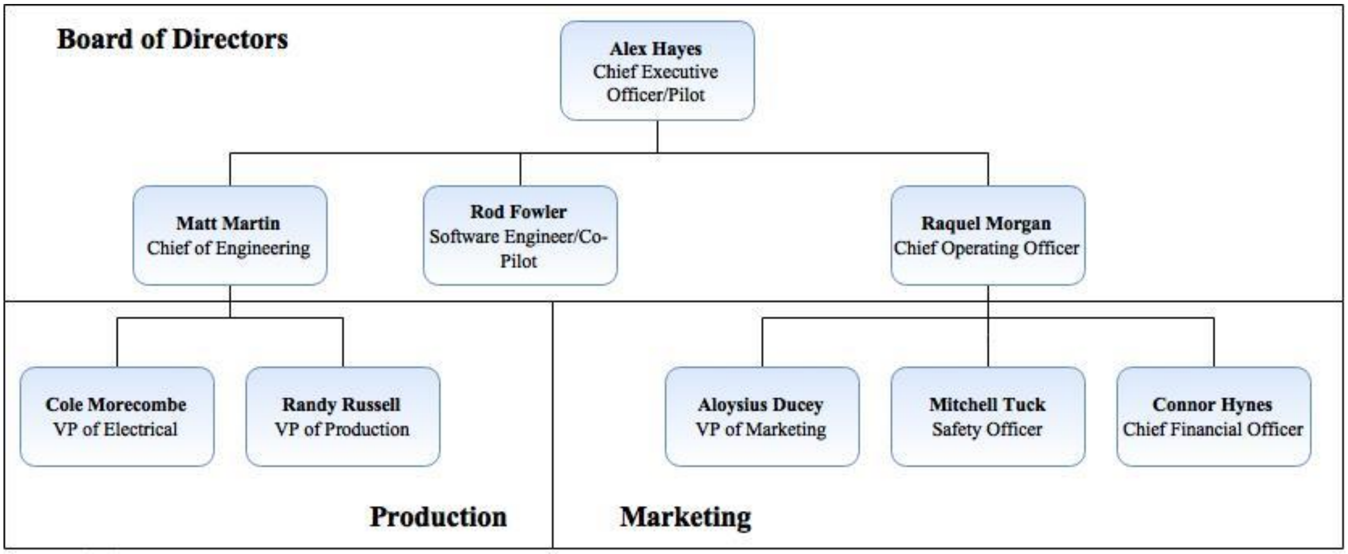


Figure 25: Organizational structure of Husky Explorer (Credit: Raquel Morgan)

# Appendix C: Husky Explorer Team

Figure 26: Left to right – Cole Morecombe, Randy Russell, Rod Fowler, Mitchell Tuck, Matt Martin, Aloysius Ducey, Raquel Morgan, Alex Hayes, and Connor Hynes. Missing from this photo is Mr. Paul King (Teacher Mentor) and Mr. Sean Purchase (Mentor).(Credit: Sean Purchase)

# Appendix D: System Integration Diagram

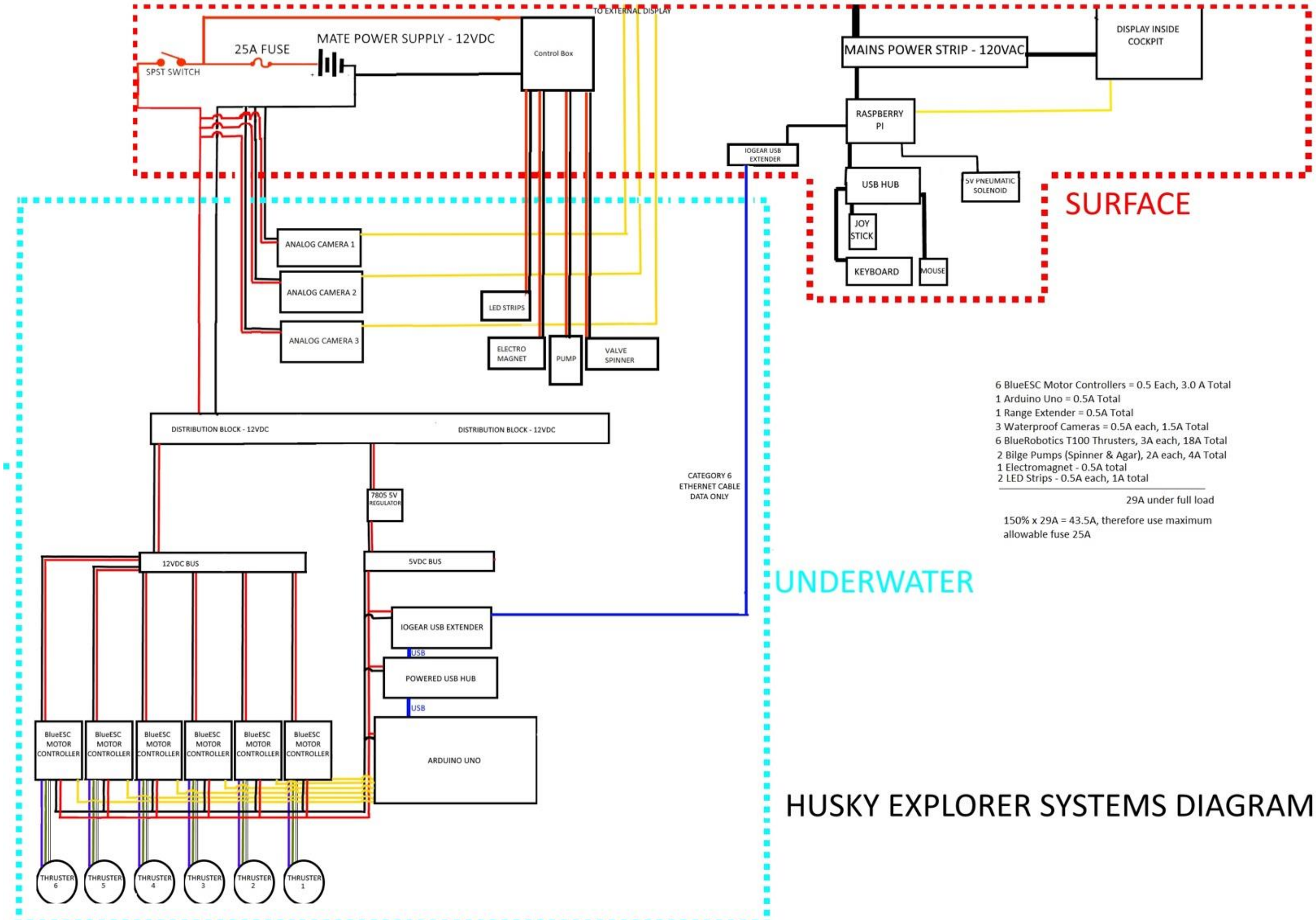


Figure 27: Systems Integration Diagram - This diagram shows all components of the vehicle's control and electronics system. Components are labeled as surface or as underwater. A fuse calculation is also shown. (Credit: Cole Morecombe)

# Appendix E: Project Costing (Canadian Dollars)

## ROV Budget

| Quantity | Product | Cost | Quantity | Product | Cost |
|---|---|---|---|---|---|
| 16 | 1/2 inch PVC, 90 Elbow | $19.01 | 1 | JB Marine Weld | $13.87 |
| 20 | 1 inch PVC ,90 Elbow | $47.91 | 2 | #TEE 1" Insert | $2.24 |
| 9 | 1/2 inch PVC SCH40, Tee | $13.41 | 1 | Cast Acrylic Tube | $72.25 |
| 20 | 1 inch PVC SCH40, Tee | $62.80 | 1 | #CLAMP/PVC | $6.31 |
| 4 | 1/2x10' PVC SCH40 Pipe | $63.26 | 1 | Dewalt Tough Chest | $182.85 |

| | | | | | |
|---|---|---|---|---|---|
| 4 | 1x10' PVC SCH40 Pipe | $117.01 | 1 | UPS Standard | $25.13 |
| 1 | Competition | $79.33 | 1 | Electrical Tape | $14.48 |
| 2 | ML-22F*1508 | $21.57 | 2 | Coloured PET 15 meter | $134.60 |
| 2 | ML-34F*1508 | $32.45 | 2 | Speed controller motor | $66.89 |
| 3 | car rear view camera | $68.97 | 1 | Electrical Tape | $14.48 |
| 1 | Pneumatics Quiz | $17.25 | 2 | T-100 Thrusters | $437.30 |
| | | | | **Total Purchased:** | **$1265.38** |

| Quantity | Product | Reused (CMV) | Quantity | Product | Reused (CMV) |
|---|---|---|---|---|---|
| 1 | End cap with 10 holes (4" series) | $32.10 | 1 | Raspberry pi 2 ultimate kit | $94.95 |
| 1 | Arduino Cana kit | $42.95 | 1 | USB 2.0 boostlinQ | $99.17 |
| 2 | Velcro wrap | $8.99 | 2 | O-Ring Flange - 4 in | $77.60 |
| 1 | Cable Penetrator | $10.70 | 1 | Cable Penetrator Bolt | $40.14 |
| 1 | Acrylic End Cap | $32.11 | 4 | T-100 Thrusters | $874.6 |
| 4 | Speed controller | $133.79 | 1 | Poster Banner | $130.00 |
| 1 | Acrylic | $200.00 | 2 | Used Pelican Cases | $500.00 |
| | | | | **Total donated: (CMV)** | **$2277.10** |

# Travel Budget

| Quantity | Product | Cost |
|---|---|---|
| 12 | Flights | $12,483.00 |
| 5 | Hotel Rooms | $9,597.00 |
| 1 | Ground Transportation | $2,500.00 |
| | **Total Purchased** | **$28,780.000** |
| Donation Type | Company | Amount |
| Grant | Government NL | $20,000.00 |
| Ticket Sales/Recycling | Husky Explorer | $6500 |
| Grant | Marine Institute | $800 |
| Money | Nutri-Lawn | $500 |
| | **Total Donated:** | **$27800.00** |

| | | |
|---|---|---|
| | **Subtotal Purchased (ROV)** | **-$1265.38** |
| | **Subtotal Purchased (Travel)** | **-$28,780.00** |
| | **Subtotal Donated (ROV)** | **$2277.10** |
| | **Subtotal Donated (Travel)** | **$27800.00** |
| | **Total:** | **$31.72** |

Figure 28: Budget (Credit: Connor Hynes)

# Appendix F: Schedule

Below is the schedule that was employed to keep our company on task. The schedule was divided into two sections: the date and task started or completed.

| Date | Task |
|---|---|
| 8/22/2016 | Started designing the frame. |
| 9/22/2016 | Got team assembled. |
| 10/13/2016 – 11/08/2016 | Began to design ROV frame. |
| 11/10/2016 – 11/29/2016 | Fabricating frame, mounting thrusters, and placing Main Control Pod on ROV frame. |
| 12/01/2016 | Whole team read through of mission tasks and assigning jobs. |
| 12/08/2016 – 12/15/2016 | Tether fabrication and attachment to ROV. |
| 01/05/2017 | Reassess progress with build of ROV. |
| 01/10/2017 – 01/17/2017 | Finishing touches on thrusters, tether, and Main Control Pod. Start of written part of Marketing Display. |
| 01/31/2017 – 02/09/2017 | Placement of cameras. |
| 02/14/2017 | Fluid Power Quiz completed. |
| 02/16/2017 – 03/30/2017 | Design of tools to complete mission tasks. Continue on written part and design of Marketing Display. |
| 04/04/2017 – 04/13/2017 | Mounting of tools, revision of Marketing Display, and writing parts for Product Presentation. |
| 04/18/2017 – 04/27/2017 | Practice of Product Presentation and practice of mission tasks with ROV. |
| 05/02/2017 | Finishing touches on all aspects of the competition |
| 05/05/2017 – 05/06/2017 | Regional Competition in Newfoundland and Labrador |
| 05/09/2017 | Start of Technical Report and Company Safety Review |
| 05/26/2017 | Submission of Technical Documentation including the Technical Report, the Company Safety Review, and the Spec Sheet |
| 05/29/2017 – 06/12/2017 | Practice with ROV doing mission tasks |

Figure 29: Schedule. (Credit: Aloysius Ducey)