Husky Explorer

2023 Mate ROV Competition: Technical Document

Mount Pearl Senior High School
Mount Pearl, NL, Canada

Employee	**Role/Responsibility**
Ben Riggs	Co-C.E.O. & Engineer
Dakota Squires	Co-C.E.O. & Mechanical Lead
Emily Smith	C.O.O & C.C.O
Kyla Chaytor	Presentation Coordinator & C.F.O
Jay Kendell	Marketing Lead
Shawn Pierce	Pilot & Engineer
Evan Whalen	Programmer Lead & Co-Pilot
Liam Edison	Lead Frame Technician
Michael Uhuangho	Tether Manager & Safety Officer
David Sodje	Tether Mechanic & Engineer
Maggie Hyslop	Teacher Mentor
Darryl Chafe	Teacher Mentor
Paul King	Teacher Mentor

FIgure 1: The 2023 Husky Explorer team
Back row - left to right: Kyla Chaytor, Emily Smith, Ben Riggs, Jay Kendell, Dakota Squires. Front row - left to right: David Sodje, Liam Edison, Shawn Pierce, Evan Whelan, Michael Uhuangho.

Abstract

Husky Explorer is a company consisting of ten students based in Mount Pearl, Newfoundland & Labrador (NL), Canada, which specializes in the design and construction of underwater Remotely Operated Vehicles (ROVs).

The Marine Advanced Technology Education (MATE) center is challenging the global community to come together to create a more sustainable future for Earth's oceans. The Husky Explorer team has produced the *Husky ROVER* (Remotely Operated Vehicle Eastern Region), which meets all requirements for proposal.

This ROV can effectively inspect vertical buoy ropes for damage via its three remotely controlled cameras, in addition to removing algal growths and installing monitoring equipment for endangered habitats using its pneumatic claw. It uses an onboard simulated UV light to irradiate areas of diseased coral tissue, and through the use of its variable buoyancy system, this ROV can quickly survey and monitor seagrass habitats. Finally, it can be equipped with measurement mission tools to assist in determining the dimensions of a coral head.

Husky Explorer is confident that this product will aid the global community to help deliver a more sustainable future. The *Husky ROVER* will combat climate change through the maintenance of marine renewable energies that can provide low carbon energy, ensuring the integrity and safety of reservoirs, as well as collecting coral eDNA samples to better the management and conservation of coral reefs.

Design Rationale

The *Husky ROVER* was designed with the global community's requirements in mind. All tools, sensors and actuators were tailored to an aquatic environment. Despite this, the ROV is extremely modular and can be customized for other uses in the future. The *Husky ROVER* is 34.0 cm tall, 52.5 cm wide and 59.0 cm long, and has a mass of 12.3 kg. The team decided to make the frame this size as it allows for many attachment points while minimizing drag. Additionally, the ROVER's horizontal thrusters were designed to fold inwards, and when folded it is 34.0 cm tall, 36.0 cm wide, and 44.0 cm long. This prevents the thrusters from being damaged during transportation.

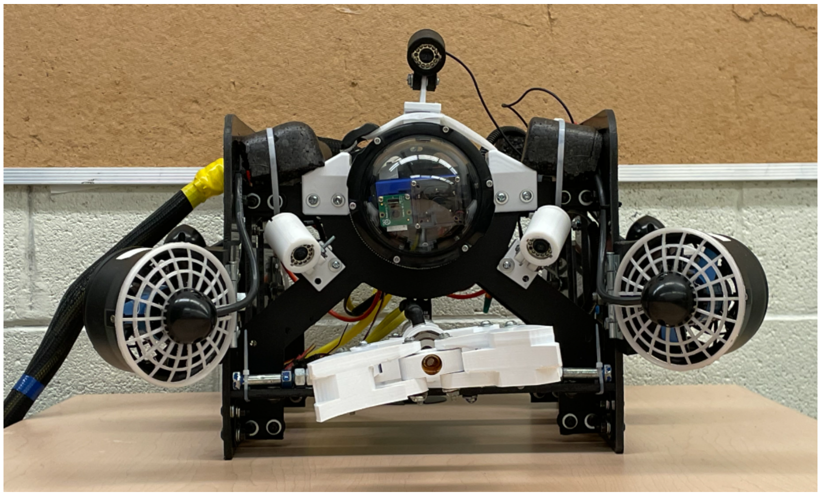

Figure 2: The 2023 Husky ROVER

Mechanical

Propulsion

The ROV is propelled by six Blue Robotics T100 thrusters. Four thrusters are used for horizontal movement and are vectored at 45° to allow for forward and backward movement, spinning and strafing, while the other two are used for vertical movement. This maneuverability is vital for completing tasks in a timely manner. For example: the ability to strafe is crucial for coral head imaging and moderating seagrass habitats.

Each thruster provides 9.4 N of thrusting force, leading to the following thrust calculations:

$$Vertical\ Thrust: 9.4\ N \bullet 2\ thrusters\ = 18.8\ N$$

$$Horizontal\ Thrust: 9.4\ N \bullet 4\ thrusters \bullet \sin 45°\ = 32.0\ N$$

Buoyancy

Without additional buoyancy, the *Husky ROVER* is slightly negatively buoyant. To counteract this downward force, pressure-resistant foam was cut and mounted to the frame to ensure the ROV was neutrally buoyant.

However, when the ROV carries a heavy object in its claw, it tilts forward considerably, limiting the pilot's ability to complete tasks. This is counteracted by a lift bag mounted on top of the ROV, towards the front. This bag also helps the ROV ascend faster, reducing the time spent returning objects to the surface. The bag is connected to the surface control box, and filled using an air compressor. This allows us to change the ROV's density, giving us variable buoyancy.

Frame

The ROV's frame is made of sheets of Ultra-High-Molecular-Weight Polyethylene (UHMWPE). These were milled using a Computer Numerical Control (CNC) router to give precise tolerances.

The frame is held together with a combination of metal and 3D-printed brackets that give it rigidity and durability. Despite this, it still has many surfaces for the mounting of tools, allowing for the use of custom tools onboard the ROV. We wanted to maintain the structural support for the electronics enclosure given by the middle support structure, but decided to leave an open top in this year's design for easier access to the electronics as this was a downfall of previous iterations.

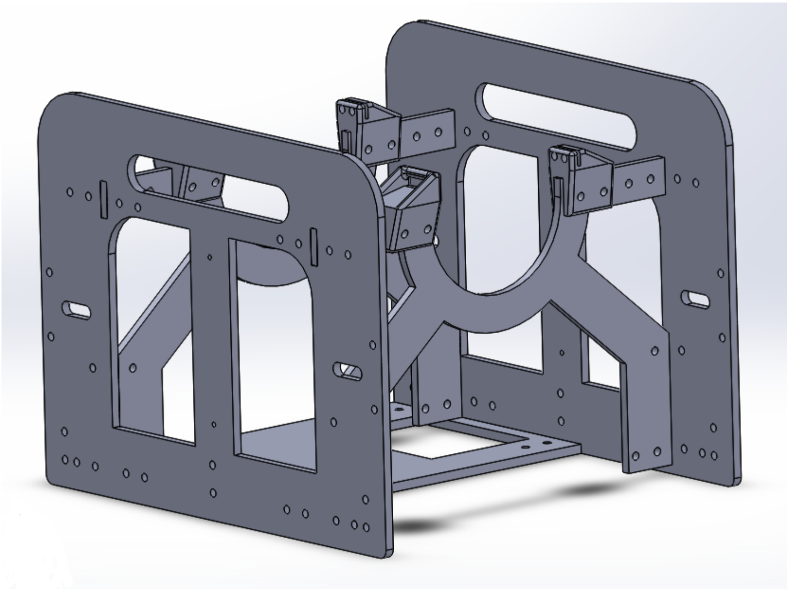

Figure 3: The Husky ROVER's frame, modeled in SolidWorks

The following table outlines the team's choice to use UHMWPE over other alternatives. While UHMWPE is typically weaker than other materials, it is relatively cheap, readily available, and lightweight.

	UHMWPE	**Acrylic**	**Polycarbonate**
Density (g/cm^3)	0.9	1.2	1.2
Yield Strength (MPa)	245	110	70
Tensile Strength (MPa)	43	71	70
Cost	Low	Moderate	Low

Figure 4: Chart detailing properties of frame materials that were considered

Pneumatics

The ROV uses a pneumatic system to power the on-board claw and for filling a lift bag. Air from an air compressor passes through a manual cutoff valve in the control box and a regulator set to 40 PSI. The air is transported to the ROV via ¼ in. pneumatic tubes housed in the tether. Two lines run to a double throw solenoid for opening and closing the claw, and a third line to a single throw solenoid for operation of the lift bag. A diagram of this system can be found in Appendix A.

Mission-Specific Tools

Several tools are used on-board the *Husky ROVER* and all are tailored to the given tasks:

Primary Manipulator

The ROV's primary manipulator is a pneumatic claw. It is computer controlled and is driven by a pneumatic solenoid valve at the surface. Pneumatic lines run the length of the tether and drive a dual action piston inside the claw, causing it to grip and release. The claw can also rotate up to 90° to grab objects at different angles thanks to a servo motor.

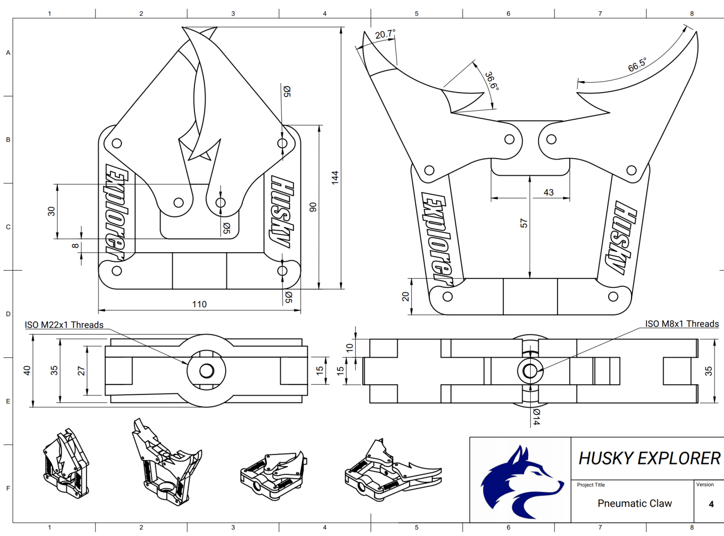

Figure 5: Mechanical drawing of the claw

The claw was first designed for the 2019 MATE contract. The design was prototyped using cardboard; then it was designed in Computer Aided Design (CAD) and animated to ensure that it could open and close with a full range of motion. When considering a claw for the 2023 contract, the team determined that the 2019 design met or exceeded all the necessary requirements, so it was reused. The claw was then 3D printed using Polylactic Acid (PLA) by members of the Husky Explorer team. The decision to use PLA over common alternatives is evident in the table below; while PLA, Acrylonitrile Butadiene Styrene (ABS) and Polyethylene Terephthalate Glycol (PETG) all possess relatively similar physical properties, PLA is lighter and far easier to print with.

	PLA	ABS	PETG
Density (g/cm^3)	1.3	1.4	1.4
Elastic Modulus (GPa)	3.5	2.6	3.5
Tensile Strength (MPa)	50	70	60
Ease of Printing	Simple	Difficult	Moderate

Figure 6: Chart detailing properties of 3D printing plastics that were considered

The claw is very strong as a result of its high-force pneumatic piston. This is a change inspired by the sub-par gripping forces from claws in previous years, which were based on smaller pistons. This year, the piston features a larger cross-sectional area, meaning that the resultant gripping force will be larger. At 40.0 PSI or 275.8 kPa, the piston's force can be calculated as follows:

$$F = plunger\ area \bullet air\ pressure$$

$$F = \pi \bullet (1.25\ cm)^2 \bullet 275.79\ kPa = 135.4\ N$$

Measurement Device

A modified meter stick attached to a Polyvinyl Chloride (PVC) mount allows accurate measurements of the wreck of the Endurance. The ruler is held against the coal head such that the deceased area can be read on the ROV's main camera.

FISH System

This year's *Husky ROVER* features the new FISH (Fish Introduction to Safe Habitat) System for transportation of Northern Redbelly Dace fry into their native habitat. It is a vented containment system which allows for efficient acclimation to the habitat while also remaining lightweight and drag resistant for easier transportation by the ROV.

Fluid Extractor

A fluid extractor, modified with a custom 3D printed nozzle for easier collection of water samples, operated by the *Husky ROVER*'s pneumatic claw and attached to the ROV by a chain to ensure no debris is left behind.

Electrical

An electrical SID can be found in Appendix B. The components of the *Husky ROVER* electrical system are outlined below.

Control Box

The ROV is controlled from the surface by a portable control box mounted to a trolley. The box contains a router, a 120 Volts Alternating Current (VAC) power bar, the majority of the pneumatics system (including master shutoff valve, regulator, distribution manifold, and pneumatic solenoids), a Raspberry Pi for controlling the pneumatics system, and the main camera multiplexer and monitor for piloting. It allows the entire ROV system to be moved anywhere with ease, and also provides a customizable area from which to control the ROV.

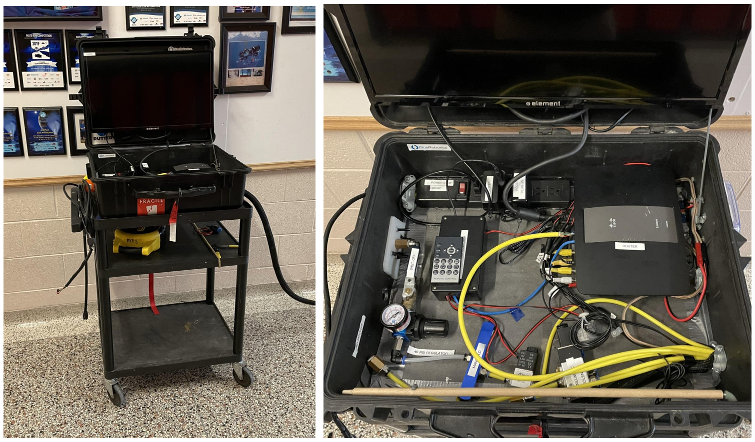

Figure 7: The portable control box

Tether

The ROV tether consists of one 12-gauge 12 Volts Direct Current (VDC) power cable, three analog video cables, a Cat 5e data cable, and all three pneumatic lines (see pneumatics section). Transportation is made effortless as the tether can be wrapped around the ROV and the cables are neatly bundled using black Flexo Polyethylene Terephthalate (PET) braided sleeves. This tether is lighter, less expensive and more flexible than commercial options. The tether can also be easily detached from the topside control box for ease of transportation.

Onboard Electronics Enclosure

The watertight electronics enclosure's contents are all secured to a removable tray to provide organization and modularity. This allows the ROV to be quickly configured to perform any tasks related to aquatic inspection and repairs.

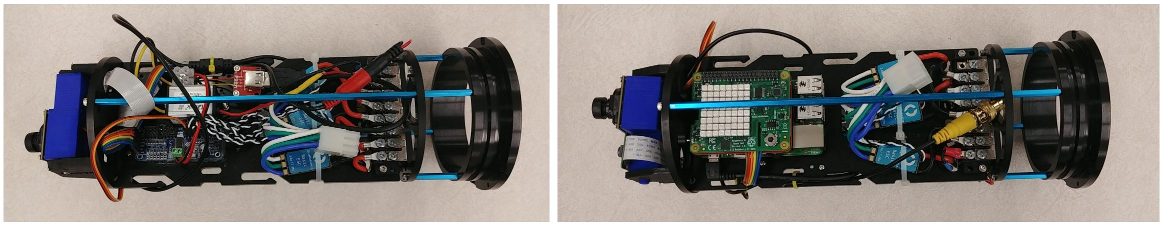

Figure 8: The electronics tray, housed inside the watertight electronics enclosure

Notable components in this enclosure are the onboard computer, 12VDC and 5VDC distribution blocks, a 12VDC to 5VDC step-down buck converter, 6 Electronic Speed Controllers (ESCs) for the thrusters, and the Pulse-Width Modulation (PWM) controller board for the ESCs.

Cameras

Three waterproof cameras are used onboard the *Husky ROVER*, each with its own unique role. Cameras are mounted as follows: One mounted above the can for a wide view of the surroundings, one just behind the claw for its manipulation, and one positioned underneath the ROV. Each camera is attached to custom mounts that allow them to be relocated with ease. This flexibility ensures the pilot has the best camera angles possible for any task.

Software

The *Husky ROVER* control system uses three distinct controllers: a computer onboard the ROV, a computer in the control box for operating pneumatics, and a laptop for the pilot.

In planning the software design, a large emphasis was placed on writing organized and readable code. The control software onboard the ROV and on the pneumatics computer is written in Python, while the pilot interface is written in HTML, CSS, and JavaScript. The pilot interface runs in a web browser and communicates with the ROV over websockets. This architecture allows the pilot interface to be easily modified to run anywhere (such as a laptop, tablet, or phone), as well as use different input methods such as a keyboard, touchscreen, or gamepad.

Software flowcharts can be found in Appendix C

Onboard Computer

The onboard computer is a Raspberry Pi 2 Model B. A Raspberry Pi was chosen due to its popularity, availability, high processing speeds and the ability to run Linux and therefore Python. This computer creates a web server on startup, to which all other controllers connect. Commands can then be sent to the onboard computer from the pilot where they will be executed.

Pneumatic Computer

The pneumatic computer is a Raspberry Pi located in the surface control box that runs a simplistic control scheme. It receives commands from the onboard computer to switch on and off the two pneumatic solenoids in the control box, allowing the pilot to control the pneumatic claw and lift bag electronically.

Non-ROV Device: Vertical Profiling Float

The *Husky ROVER* has the capability to deploy a vertical profiling float which is designed to complete multiple vertical profiles to monitor circulation, chemistry, biology, and overall ocean health. The float is constructed from a combination of 3 in. ABS piping and 3D printed parts. A waterproof electronics enclosure safely houses the Arduino Uno that controls the system, along with a relay board for controlling a solenoid, and the battery pack that powers it all.

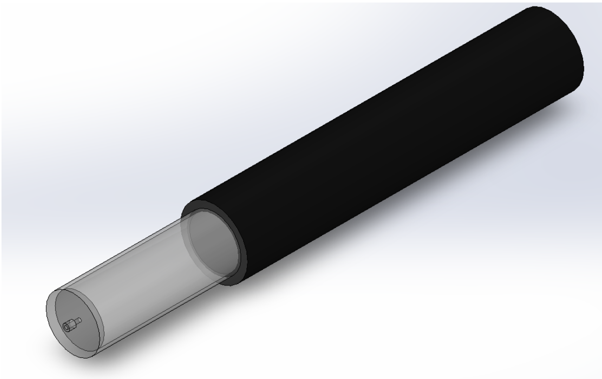

Figure 9: The Husky Explorer Vertical Profiling Float, modeled in SolidWorks

The float operates via the use of a buoyancy engine. The float is naturally negative, so it automatically sinks to the ocean floor. When it needs to resurface, air is released from a small air tank into a reservoir by a solenoid actuated by the Arduino Uno. This reduces the floats density, allowing it to rise to the water's surface. A small hole was made in the top of the reservoir to allow air to slowly escape, allowing the float to become negatively buoyant after it reaches the surface, allowing it to complete multiple profiles.

The vertical profiling float electrical SID can be found in Appendix D.

Build vs.Buy

Building custom parts offers many advantages, including cost-effectiveness and customizability. This year, many mission tools were designed and printed in house using Solidworks and a 3D printer. This can be seen with this year's primary manipulator - a custom-designed, 3D-printed pneumatic claw. This claw was relatively cheap to make, and was tailored to fit this year's mission tasks as it can easily grip ½ in. to 2 in. PVC pipe, as well as carabiners.

Along with the pneumatic manipulator, several other pieces of equipment on the ROV were made with this same 3D printing technology. This includes : Thruster shrouds to act as a safety procedure for the inner thruster blades, velcro mounts to secure the electronics enclosure, adjustable camera mounts for peripheral vision, and a syringe mount equipped to the claw in order to extract water samples which was a necessity for this year's contract.

Other components which were constructed included our ROV frame, which was made from sheets of Ultra High Molecular Weight Polyethylene (UHMWPE) and milled out using an in-house CNC router. This frame material was chosen due to its cost effectiveness, whilst also being lightweight.

With regards to buying, our team wanted to minimize the cost spent whilst not affecting the integrity and reliability of our company. In order to achieve this goal, our company only outsourced materials when they were necessary to meet the mission requirements for this year. With that being said, the only items required to be bought were velcro used for securing the electronics enclosure for ease of removal, and the parts needed to construct our team's vertical profiling float. Husky Explorer prides itself on minimizing the amount of waste we produce when outsourcing items, and aspires to be a resource efficient and sustainable company.

New vs. Re-Used

When determining which parts would be bought new and which parts would be reused from other years' designs, the team had to carefully consider both cost and ROV performance. The team opted to buy new in areas that were critical to this year's contract and overall ROV performance, while reusing what we could to reduce both costs and our impact on the environment.

In terms of equipment that was new this year, there was a primary focus around the components for the re-work of Husky Explorer's non-ROV device, the vertical profiling float. Due to the float's complete design overhaul, entirely new parts were required for the construction of this device. Things such as a FS90R Servo Motor to operate the syringe system, a DS3231 RTC Module to store time, and a 9V Battery Holding to secure the float's power supply, were specifically purchased to ensure our new vertical profiling float was able to effectively complete its role within the assigned mission task.

Six T-100 thrusters were reused from last year's design. These thrusters were high-performing and reliable previously, and have proven to keep these advantageous qualities when testing them with this year's ROV. In addition, we also re-used several materials this year which involve many of the electronics directly involved with the functionality of the ROV. For instance, we re-used a bulk of the onboard electronics and control box components, which includes the raspberry pi within the electronics enclosure, the video multiplexer and monitor, main computers, among other things. The decision for this reuse was made based on the fact these electronics were high-cost, and buying new offered no foreseeable advantages for the specific components in question.

Project Management and Teamwork

Scheduling and Planning

The Husky Explorer team prides itself on being extremely well organized. Each week, two mandatory meetings were scheduled for all team members which always began with attendance, a progress report, and discussion of the day's plan. These meetings gave all team members the chance to report on their department's progress on various tasks, and create action plans for the coming days. In this way, all team members could stay up-to-date on the happenings in other domains, and were always able to work on important tasks. Lead team members also met frequently to discuss high-level planning and discuss the allocation of tasks to other team members. Additionally, certain groups got together on other days for a physical space was necessary for construction and/or for better collaboration on marketing material.

While ambitious, the schedule helped deliver the team to a successful regional competition, with plenty of time to spare for testing and troubleshooting. It also simplified the organizational challenges that occurred while the team was simultaneously working on ROV manufacturing, Marketing Display creation, and Engineering Presentation preparation.

A graphical representation of this can be seen in Appendix E, the team's Gantt planning chart.

Organization

The team made use of several collaboration tools to simplify the project's workflow. The most influential of these was Google Drive, which allowed team members to collaborate in real time on any and all documents. This also allowed for live feedback from senior members, which helped guide junior members through difficult tasks. The team also used group chats and email to communicate with one another outside of working sessions.

Problem Solving

As problems arose during all phases of the project, they were dealt with using a logical, standard method with which all employees of Husky Explorer are familiar. The process is as follows:

1. Identify the issue and its underlying cause. Eliminate all other possible factors and distill the issue to its simplest form.
2. Evaluate possible fixes and implement the best, depending on cost, time and simplicity.
3. Monitor the solution and ensure that the issue has been resolved completely.

This method has proven to be very effective in treating design, manufacturing, testing and all other types of problems.

Safety

Safety Philosophy

At Husky Explorer, all employees are taught that safety is their highest priority. It is the philosophy of Husky Explorer and all of its members that safety comes before anything else. This means that the company is willing to spend more time, money and resources on the safest solution.

Every team member has been trained in the use of every tool in the workshop through quizzes administered by the team. Only an employee who has received a perfect score on a quiz can operate the corresponding tool. The motto "No Work, Unless It's Safe Work" is posted in all the workspaces and is drilled into every team member. In addition to this, firm In-Workshop and On-Deck safe operating procedures have been established, and can be found in Appendix F.

Safety Features

The ROV complies with every safety direction given by MATE, many of which are highlighted in the following table.

Feature	Description
Rounded edges	All sharp edges of the ROV are filed, removed or covered such that no harm can occur while the ROV is in use or being handled.
Strain relief on both ends of the tether	The tether is secured at the surface through a clamp on the side of the control box and on the ROV through rope that is attached to rotating tie-downs to ensure absolutely no strain on wires or connections on either side.
Shrouded thrusters	All thrusters on the ROV are shrouded to IP20 standards to prevent harm from rotating components.
Power supply fuse	There is a 25 A fuse placed less than 30 cm from the positive terminal of the power supply.
Caution labeling	All hazardous components of the ROV are labeled as such. These components include thrusters, rotating components, 12VDC and 120VAC power (separately) and pneumatic parts such as the claw.
Waterproofed electronics	All electrical components on the ROV are either housed in the watertight electronics enclosure or have been waterproofed using marine epoxy and silicone. There is no exposed wiring or other hazards in the electronics box on the surface.
Component ratings	No components are used outside their rated specifications. For example, all pneumatics are rated to above 100 PSI even though the system is regulated to 40 PSI.
Power cut off switches	A single pole single throw switch is located on the positive wire of the 12VDC supply, and the 120VAC power bar also has an easily accessible cutoff switch.
Electronics enclosure sensors	Temperature, pressure and humidity sensors are located inside the electronics enclosure and their data can be displayed on the surface. This allows the team to detect dangerous situations, such as a breach in the enclosure.

Figure 10: Chart of safety features on the Husky ROVER.

Accounting

Budget

At the beginning of the project, all team members met to discuss and formulate a tentative budget. Once finalized, all team members adhered to the budget during the ROV's build phase. To ensure reasonable spending, all purchases had to be cleared by the company's CFO or another senior member. In addition to this, all parts were sourced from multiple vendors before purchasing to ensure that all prices were fair. Travel estimates were based on flight data at the time as well as average accommodation pricing for eight students plus two mentors in Longmont, Colorado. A full budget along with travel estimates can be found in Appendix H.

Project Costing

A detailed breakdown of the ROV's cost can be found in Appendix H. The team adhered to the budget and no funds were wasted or misallocated.

Critical Analysis

Testing and Troubleshooting

It was critical to the ROV's safety and performance that adequate testing be performed before any full-scale run. These tests are described in the table below:

Test	Description
Waterproofing Test	All components of the ROV were tested to be waterproof over an extended period of time, both separately and together, at depths of water, from 1-5 meters.
Power-On and Power-Off Tests	This test ensures that all controllers boot upon power-up, that all sensors read nominal values, and that all components of the ROV are powered on. Upon power-off, all components should return to a safe state, and should be OK to power-on once again.
Off-Nominal Connection Test	This test involves irregular connections from the pilot's control system to the ROV, and tests worst-case scenarios such as a mid-run disconnection. This ensures that if the connection were to be lost, the ROV will remain in a safe state until it is able to re-connect.
Max Current Draw Test	This involves setting all thrusters to maximum sensitivity and powering all six simultaneously for an extended period of time, to create a large current draw. This test ensures that all electrical components can handle that amount of current, and that other components in the system continue to receive enough power.

Figure 11: Electronics System Tests

If any of these tests were to produce unfavorable results, then troubleshooting would occur to find the source of the issue. Team members follow the problem solving steps found in the *Problem Solving* section, under *Project Management*. This clearly defined protocol provided a standardized way for all team members to troubleshoot issues quickly and effectively.

Of course, troubleshooting can be avoided by preventing issues with careful planning. The team prototyped almost all systems for this year's ROV before they were implemented at full scale. This allowed employees to work through potential issues before they became too difficult to fix and made actual implementations of ideas far easier to create.

For example: all onboard circuits were first tested on a breadboard before being made more permanent inside the enclosure. Another example is a cardboard mockup of the frame that was created before the frame's material was milled. This allowed for the testing of mounting locations and camera angles without any risk.

Company Evaluation

The roles of the Husky Explorer team are as follows, Ben Riggs: Co-C.E.O. and Engineer, Dakota Squires: Co-C.E.O. and Mechanical Lead, Emily Smith: Chief Operating and Compliance Officer, Kayla Charter: Presentation Coordinator and Chief Financial Officer, Shawn Pierce: Pilot and Engineer, Evan Whelan: Lead Developer and Co-Pilot, Jay Kendell: Marketing Lead, Liam Edison: Lead Frame Technician, Michael Uhuangho: Tether Manager & Safety Officer, and David Sodje: Teather Mechanic & Engineer. This distinct leadership model allowed the team's more senior members to be able to provide direction and assistance to those that need it. As well, all team members held an equal say in company decisions, and were free to be autonomous in their work.

The team found that this not only cut down on unnecessary interpersonal conflict, but also allowed all team members to feel more dedicated and invested in the project, while still tailoring their commitment levels to their personal schedules. This method of interpersonal relations has been incredibly successful and will continue to be used in future years.

Challenges and Problem Solving

Technical

While testing the floatation of the ROV, we discovered it was slightly negatively buoyant with a forward tip due to the claw extruding outside the regular footprint. To fix this, we knew we had to add some pressure-resistant foam to counteract the weight, however, there was no good position of the frame to mount the foam. Instead of wasting the time and money on designing and cutting a new frame, we thought it would be best to simply use our excess material to create a strip on the top edge for the foam. This is the optimal position as it directly affects the claw's weight, balancing the ROV perfectly.

This is how the Husky Explorer team problem solves: They create a temporary solution, brainstorm more permanent-solutions, and work as a team to implement the final solution. It is this kind of problem solving, working together, that has made the 2023 Husky Explorer the most efficient problem solving team to date.

Interpersonal

The Husky Explorer's 2023 team has a total of ten members, only one of whom is returning. It was difficult at first for everyone to find a meaningful role that suited their skills and interests; however, with the guidance of teacher mentors and many discussions, all employees of the company were able to find roles that suited their interests. This afforded every member of the team the opportunity to learn about a domain in business or engineering that interested them, while still allowing the team to develop a high-performance ROV.

Skills Learned

Over the past three years, the 2022 Husky Explorer team built their ROV from the ground up without being able to participate in previous MATE contracts. Due to the COVID-19 restrictions, no new members were recruited, thus their skills were not passed down to the 2023 Husky Explorer team. In addition to lacking skills from previous members, the team's main software engineer is entirely self-taught, with no team member to rely on. Finally, every single team member has spent their valuable time learning the necessary skills to not only complete their designated tasks, but to excel at them.

Future Improvements

One flaw with this year's *Husky ROVER* is our decision to downsize our number of cameras. Upon testing we determined that, while it is not necessary for operation, having additional cameras is a nice luxury. In the next design, we would like to add an upward facing camera for ease of resurfacing, and potentially others as precautionary backup.

One improvement the team would consider in a future design is a module tether for easier transportation and operation during missions as only the required amount of tether would be used at that time. This could be accomplished by using waterproof block connectors every ten feet on the tether with individual connectors for each wire/tube inside.

Additionally, we would like to improve our ROV design to be more power efficient to be able to power more tools on board the ROV and to create a more reliable product. Furthermore, being more efficient with power usage would allow Husky Explore to be greener for the environment with reduced energy consumption.

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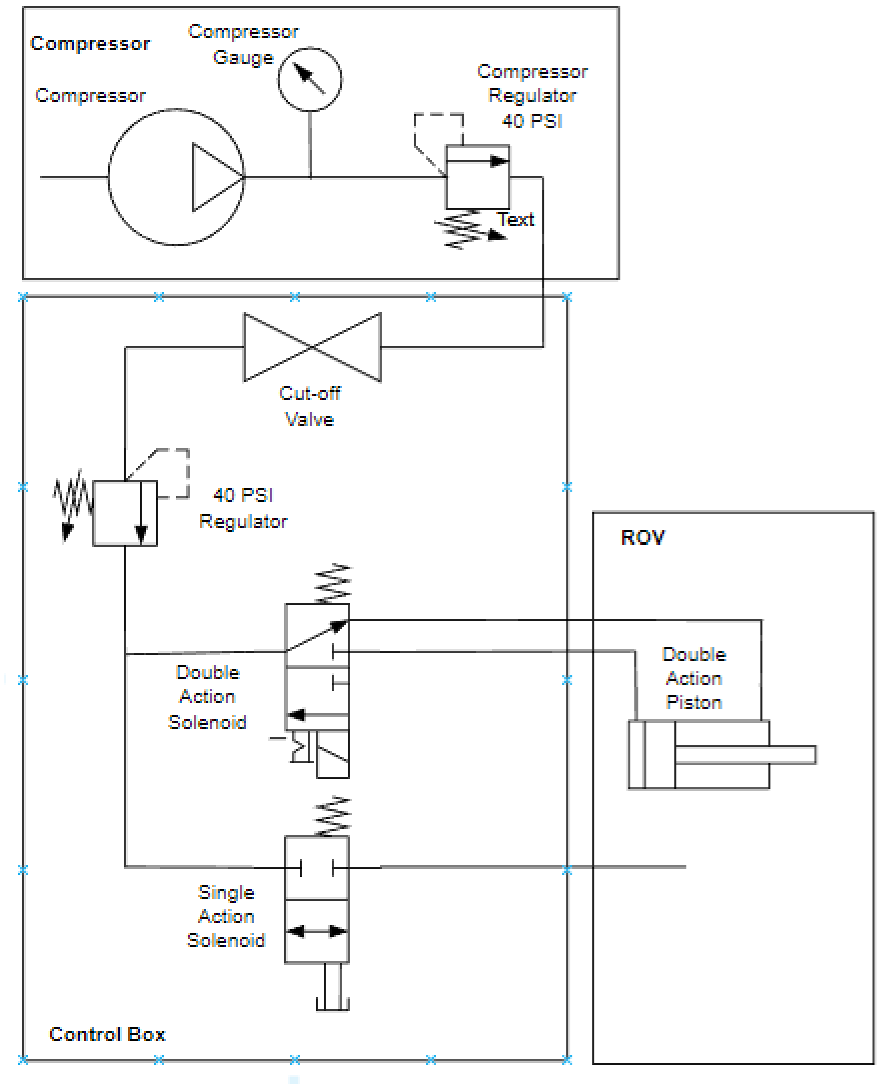
Without their continued support, we would not have been able to pursue our development in the field of underwater robotics. The company would also like to thank our teacher mentors - Ms. Maggie Hyslop, Mr. Darryl Chafe, and Mr. Paul King - for allowing us to use their workspace and guiding us along the way.

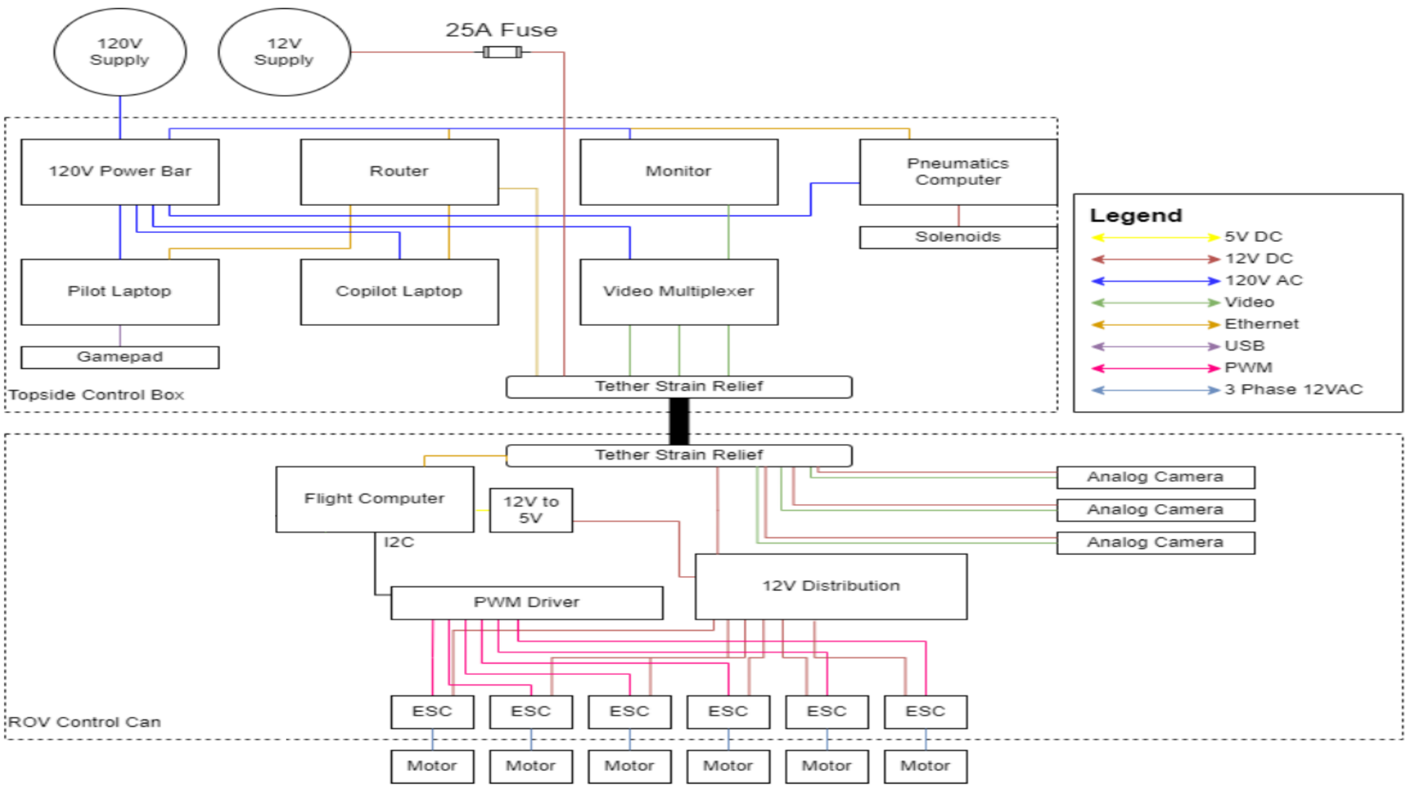
Finally, we are very grateful to the MATE organization for the annual ROV competition which has provided Husky Explorer with an incredibly valuable experience in science, technology, engineering, mathematics, and business sectors. For this opportunity, we are extremely grateful.

Appendices

Appendix A: Pneumatic SID

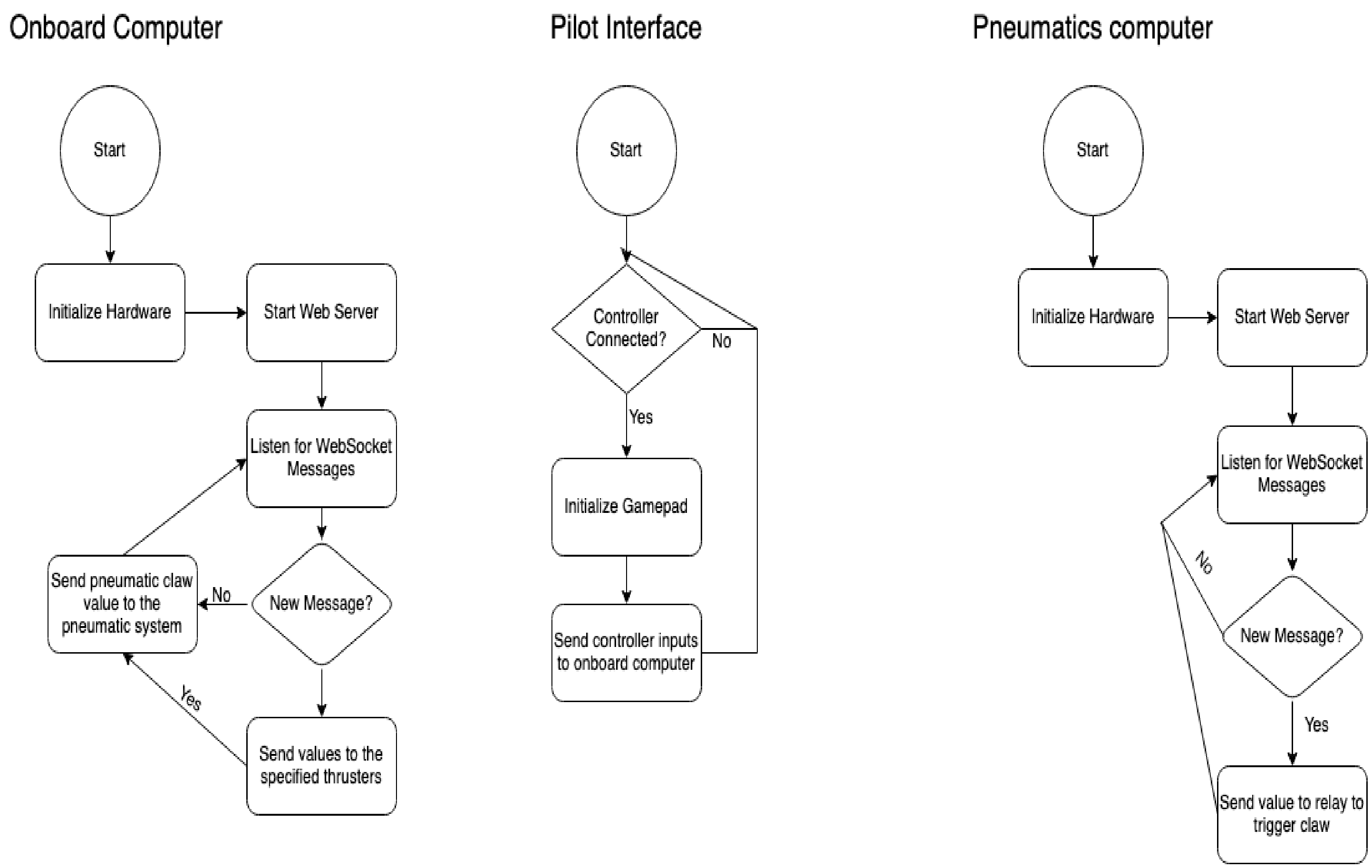


Appendix B: Main Electrical SID and Fuse Calculations

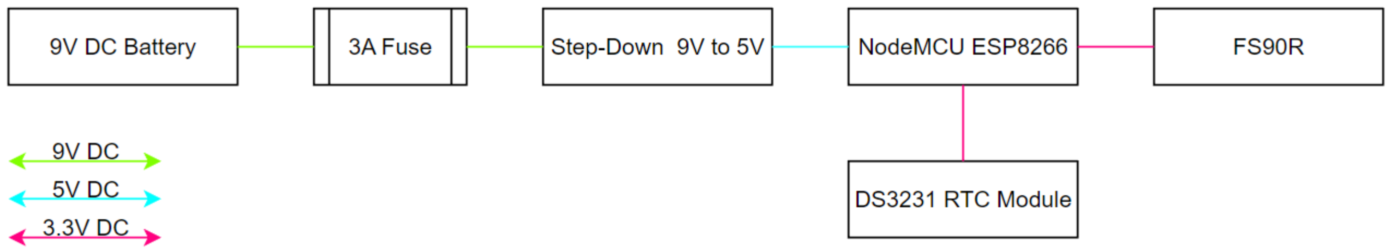


COMPONENTS	MAX DRAW	QUANTITY	TOTAL
Analog Camera	200mA	3	600mA
Servo	300mA	1	300mA
Raspberry Pi	700mA	1	700mA
Pi Sense HAT	400mA	1	400mA
ESC	100mA	6	600mA
T100 Thruster	3A	6	18A
5V Relay	60mA	2	120mA
		Total:	20.62A
		1.5 * Total:	30.93A

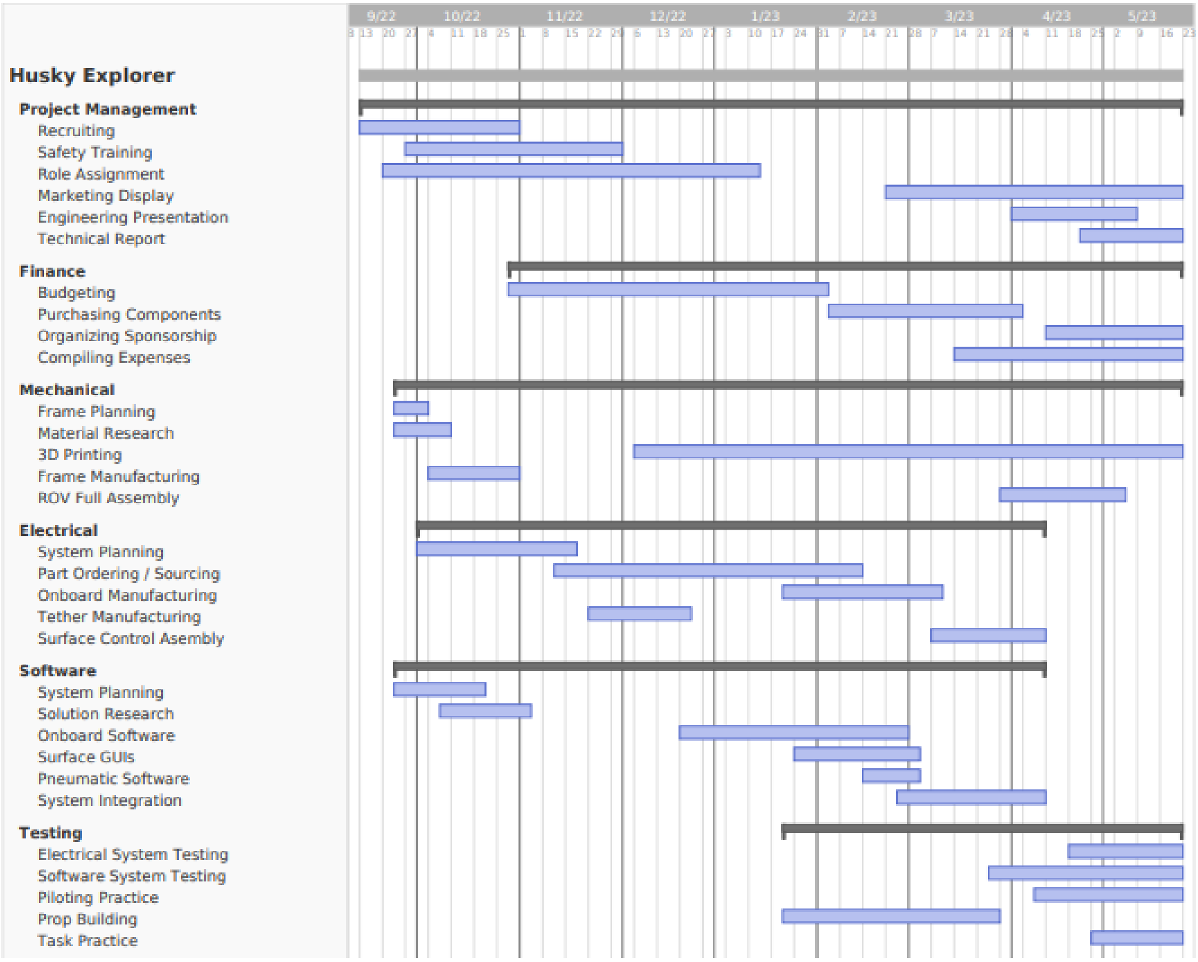
Appendix C: Software Flow Chart



Appendix D: Non-ROV Device Electrical SID



Appendix E: Gantt Chart



Appendix F: Safe Operating Procedures

In-Workshop

General Checklist
- Ensure workspace is clear, no tripping hazards
- PPE is worn when appropriate
- Check all equipment before use
- All employees in the workshop are safety trained

Soldering
- Wear safety glasses and a face mask
- Ensure no wires are live
- Ensure a clean workspace
- Inform others that you are soldering

Using Power Tools
- Wear safety glasses, gloves and masks when appropriate
- Ensure the workspace is clean
- Inform others that you are using those tools

On-Deck

Setup, Boot and Launch
- Ensure the area is clear and all team members are ready
- Attach the ROV's power supply, connect the compressor and control box to 120VAC power
- Connect the compressor to the pneumatic system
- Alert all team members and power on the ROV
- Connect to the ROV and ensure all sensor values are nominal
- Test thrusters, servos and pneumatics
- Place the ROV in the water and ensure all air is removed
- Deploy the ROV

ROV Retrieval
- Pilot alerts deck crew that the ROV is surfacing
- Deck crew informs pilot that the ROV has surfaced
- Pilot removes hands from controls
- Deck crew retrieves the ROV

ROV Maintenance
- Verify all electronics are in working order, all sensors are reading correctly
- Check for scratches, holes or other damage
- Check thruster guards, strain relief and other safety components
- Grease the O-Rings, clean the electronics enclosure and flush the pneumatic lines

Appendix G: Project Budget

Note: all values are in Canadian Dollars (CAD)

School: Mount Pearl Senoir High		**Orgianisation:** Husky Explorer		
Mentors: Mrs.Hyslop, Mr.Chafe & Mr.King		**Period:** Sep 12, 2022 to June 1, 2023		
Income				
Source				**Amount**
Marine Institute (contingnent upon advancing to the international compition)				$25,000.00
MATE				$750
MPSH				$2,000
Expenses				
Category	**Desciption**	**Type**	**Projected Cost**	**Bugeted Value**
Mechanical	Frame materials and hardware	Re-Used	$600.00	--
	Electronics enclosure and penetrators	Re-Used	$300.00	--
	PLA Filament	Purchased	$88.97	$88.97
	Pneumatics system	Re-Used	$200.00	--
Electronics	Trusters and ESCs	Re-Used	$1,350.00	--
	Control Laptop and Raspbarry Pis	Re-Used	$2,000.00	--
	Wire, solder, and other materials	Re-Used	$200.00	--
	Surface side control system	Re-Used	$700.00	--
	Tether cables and line	Re-Used	$300.00	--
	Non R.O.V. device pneumatics and electronics	Re-Used	$200.00	--
Travel	Airfare	Purchased	$18,470.00	$18,470.00
	Accomodations	Purchased	$6,000.00	$6,000.00
	Transportation	Purchased	$2,000.00	$2,000.00
	Food and Drink	Purchased	$2,500.00	$2,500.00
	Airline Fees for ROV and Tools	Purchased	$800.00	$800
General	Marketing Poster	Purchased	$55.00	$55.00
			Total Income	$27,750.00
			Total Expenses	$29,913.97
			Total Re-Used	$5,850.00
			Fundrasing Needed	$2,163.97

Appendix H: Project Costing

School: Mount Pearl Senoir High			**Orgianisation:** Husky Explorer		
Mentors: Mrs.Hyslop, Mr.Chafe & Mr.King			**Period:** Sep 12, 2022 to Jun 1, 2023		
	Item	**Units**	**Cost**	**Source**	**Total**
	Mechanical				
Enclosure	O-Ring Set.	2	$1.80	Re-Used	--
	O-Ring Set (4").	2	$3.55	Re-Used	--
	Cable Penetrator	14	$3.55	Re-Used	--
	Aluminum 14 Hole End Cap	1	$33.16	Re-Used	--
	O-Ring Flange (4").	2	$34.34	Re-Used	--
Frame	Dome End Cap (4").	1	$39.00	Re-Used	--
	UHMW Sheet 12 in. x 24 in.	3	$12.77	Re-Used	--
	Corner Brace (1-1/2")	12	$1.98	Purchased	$23.76
Pneumatics	Brass Coupling (1/8").	1	$1.79	Re-Used	--
	Brass Reducer (1/4" X 1/8")	2	$2.00	Re-Used	--
	Coupling (1/8").	1	$1.75	Re-Used	--
	Air Compressor	1	$169.29	Re-Used	--
	Pneumatics Kit	1	$150.00	Re-Used	--
Hardware	Pan Head.	1	$8.89	Re-Used	--
	Nut/Hex.	1	$5.61	Re-Used	--
	Washer/Flat.	1	$3.98	Re-Used	--
	250Pcs Standoff Spacer.	1	$17.69	Re-Used	--
	Control (Pelican) Box.	1	$49.99	Re-Used	--
	PLA Filiment	2	$25.99	Purchased	$51.98

	Electrical				
Onboard Electronics	15 Pin Ribbon Cable	1	$12.99	Re-Used	--
	Micro USB A to 90° USB B.	2	$5.99	Re-Used	--
	Blue Robotics T100 Thuster.	6	$230.00	Re-Used	--
	Blue Robotics Basic ESC.	6	$28.75	Re-Used	--
	Electronics Tray	1	$93.42	Re-Used	--
	HAT Shield For Raspberry Pi.	2	$14.99	Re-Used	--
	Water Proof Connectors	2	$15.19	Re-Used	--
	Raspberry Pi 3 B+ Kit.	1	$98.99	Re-Used	--
	Hook Up Wire Kit.	1	$25.88	Re-Used	--
	5V USB A Breakout Board.	6	$4.67	Re-Used	--
	1 Channel 5V Relay.	2	$8.99	Re-Used	--
	2.1 mm Board Camera.	1	$16.50	Re-Used	--
	12V to 5V Buck Volt Converte	3	$10.88	Re-Used	--
	Analog Waterproof Camera	4	$189.99	Re-Used	--
	Logitech C270	1	$32.99	Re-Used	--
Surface Electronics	DLink Router	1	$39.99	Re-Used	--
	Video Multiplexer	1	$249.98	Re-Used	--
	Cat 5e Cable	3	$7.99	Re-Used	--
	Monitor	1	$299.99	Re-Used	--
	4 Channel Relay Module	1	$10.19	Re-Used	--
	5 Port Power Bar	1	$14.99	Re-Used	--
	Apple Laptop	1	$1,850.00	Re-Used	--
	General				
General	Total Shipping Fees.	2	$10.54	Purchased	$21.08
	Team Registration.	1	$100.00	Purchased	$100.00
	Team Attire.	20	$20.00	Purchased	$400.00
	Team Business cards.	1	$10.00	Purchased	$10.00
	Team Marketing Poster.	1	$55.00	Purchased	$55.00
Travel	Airfare	1	$18,470.00	Purchased	$18,470.00
	Accomodations	1	$5,000.00	Purchased	$5,000.00
	Transportation	1	$2,000.00	Purchased	$2,000.00
	Food and Drink	1	$2,500.00	Purchased	$2,500.00
	Airline Fees for ROV	1	$800.00	Purchased	$800.00

Appendix H: Project Costing (Cont…)

Income					
Donations	Marine Institute	1	$25,000.00	Cash Donation	$25,000.00
	Belfor	1	$1,000.00	Cash Donation	$1,000.00
	DOF Subsea	1	$1,000.00	Cash Donation	$1,000.00
	JSM Electrical	1	$100.00	Cash Donation	$100.00
	KCA Deutag	1	$1,000.00	Cash Donation	$1,000.00
	Subsea7	1	$1,000.00	Cash Donation	$1,000.00
	Violet Ruelock	1	$100.00	Cash Donation	$100.00
				Total R.O.V. cost	$75.74
				Total Expenditure	$29,431.82
				Total amount fundraised (as of May 31th, 2023)	$29,200.00
				Total amount left to fundraise	$231.82

Note: all values are in Canadian Dollars

(CAD)