Mount Pearl Senior High

Husky Explorer

Technical Report

Evan Vokey	C.E.O / Pilot
Eric Goulding	Mechanical Lead/ Co-Pilot
Gavin Hull	Controls Lead/ Programmer
Logan Smith	Chief Financial Officer
Ben Riggs	Safety Officer / Engineer
Claire Murphy	Chief Communications Officer
Claire Dinn	Chief Operating Officer
Brooke LeDévéhat	Human Relations Manager/Engineer

Husky Explorer
Mount Pearl Senior High
Mount Pearl, NL, Canada

Mentors - Mr. Paul King and Mrs. Maggie Hyslop

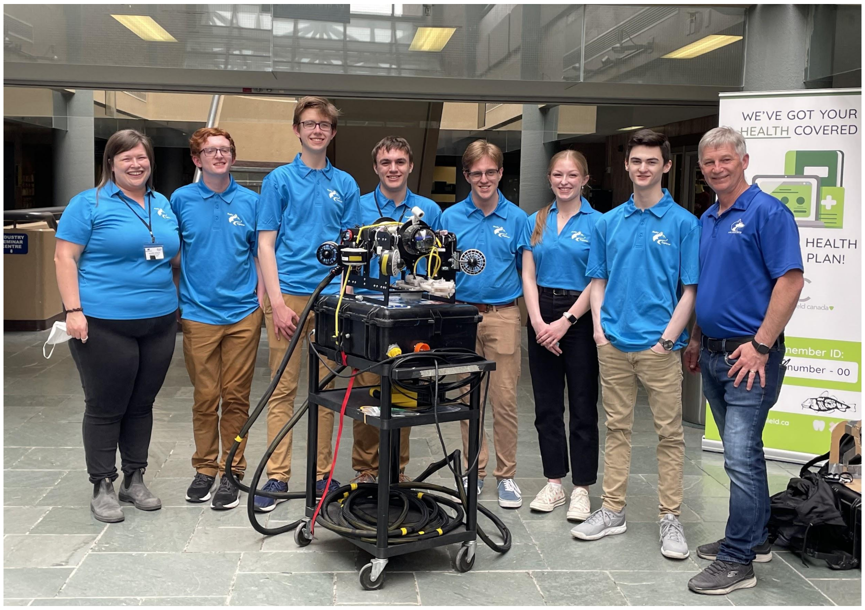


FIgure 1: The Husky Explorer team, regional competition, Marine Institute in St. John's, NL, Canada

Abstract

Husky Explorer is a company consisting of eight 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*, which meets all requirements for proposal.

This Remotely Operated Vehicle (ROV) can effectively inspect inter-array power cables via its six remotely controlled cameras, remove algal growths and collect fish mortalities using its pneumatic claw, as well as deploy both a hydrophone to identify the presence of marine mammals and a vertical profiling float to help monitor ocean health. It uses advanced image recognition software to monitor offshore wind farms and aquaculture reserves, and through the use of its variable buoyancy system, this ROV can quickly prune seagrass beds. Finally, it uses highly accurate measurement approximation software to estimate the size of fish to determine the health of fish cohorts.

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, help feed the growing global population by increasing efficiency and health of offshore aquaculture, successfully monitor and

tend to seabeds to improve ocean health, and preserve maritime history by mapping underwater archaeology.

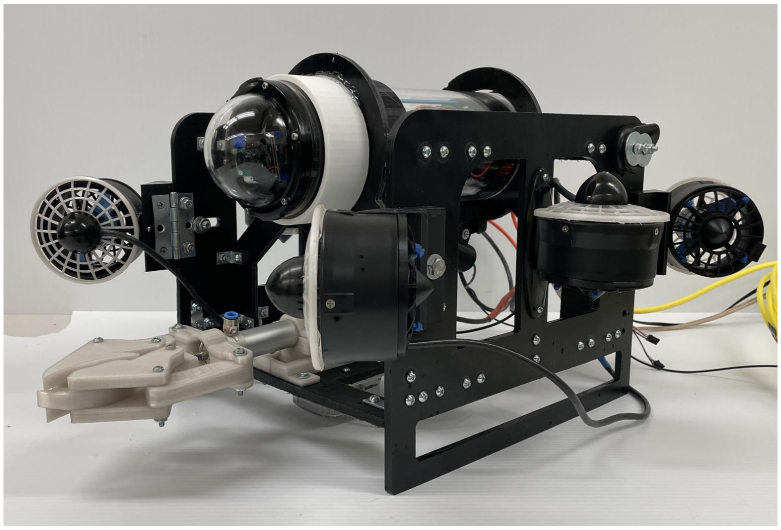


Figure 2: The 2022 Husky ROVER

Design Rationale

The Husky Remotely Operated Vehicle Eastern Region (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 this is done, it is 34.0 cm tall, 36.0 cm wide, and 44.0 cm long. This prevents the thrusters from being damaged during transportation.

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 following the fish pen's transect line.

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 lists 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.

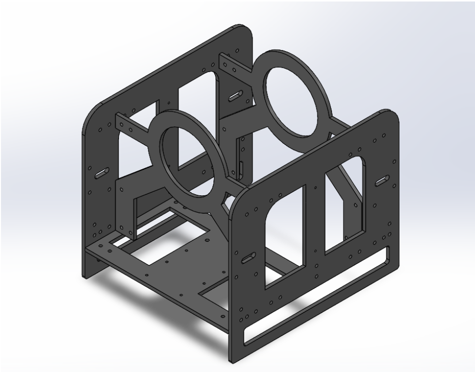


Figure 3: The Husky ROVER's frame, modeled in SolidWorks

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. The most significant improvement over previous frame designs is the middle support structure, which increases the frame's strength in every direction, preventing it from flexing or bowing under the weight of the electronics enclosure.

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 and a regulator set to 40 PSI before reaching the solenoids. The claw uses two double throw solenoids (one for opening and closing the claw, and the other for rotation) while the lift bag uses a single throw solenoid. This air then travels through the tether to the ROV through ¼ in. pneumatic tubes. 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:

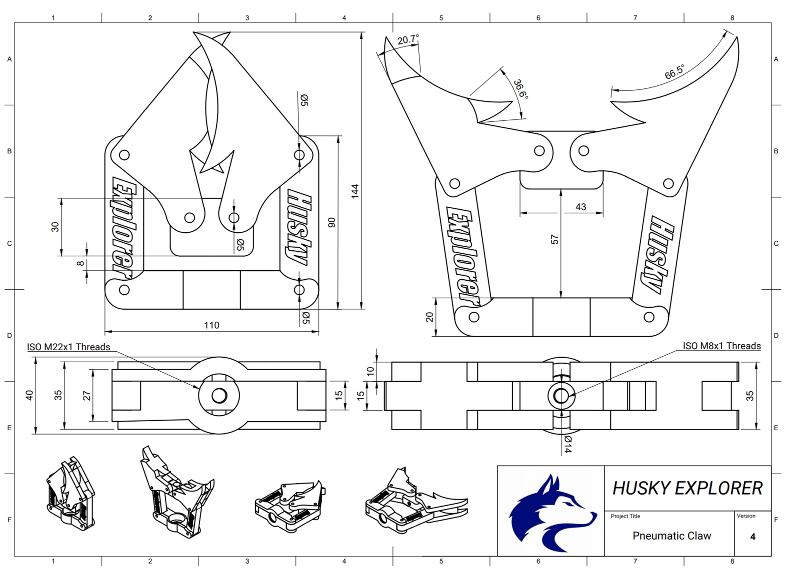


Figure 5: Mechanical drawing of the claw

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.

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 2022 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 wreck, and the measurement is read on the ROV's main camera.

Electrical

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

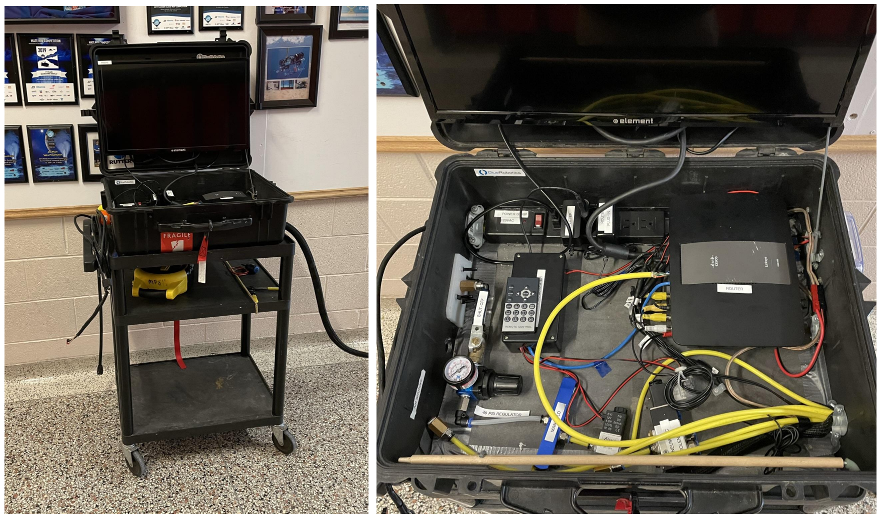


Figure 7: The portable control box

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. It allows the entire ROV system to be moved anywhere with ease, and also provides a customizable area from which to control the ROV.

Tether

The ROV tether consists of two 14-gauge 12 Volts Direct Current (VDC) power cables, four analog video cables, a Cat 5e data cable, and all 5 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.

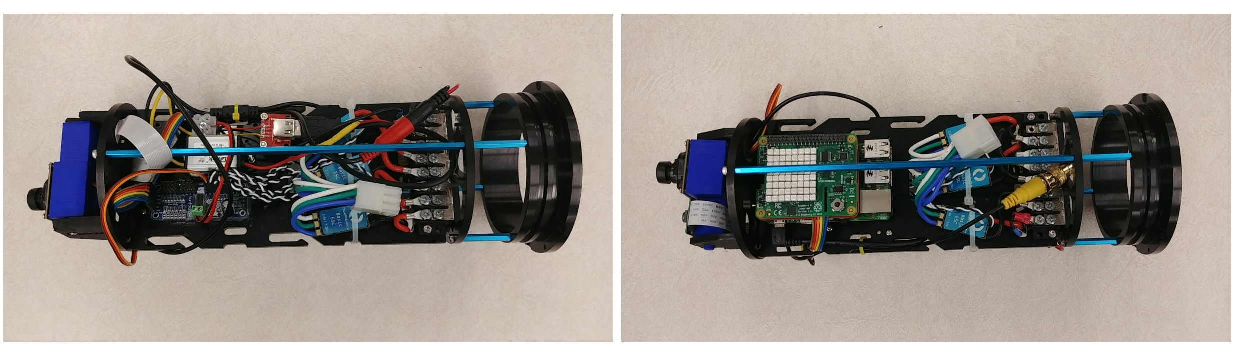


Figure 8: The electronics tray, housed inside the watertight electronics enclosure

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.

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

Cameras

Six cameras are used onboard the Husky ROVER, each with its own unique role. Two cameras, one analog and one digital, are located in a dome at the front of the vehicle and can tilt up and down using a servo to give the pilot a more complete field of view. Three other analog cameras are located on the ROV and are 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. A final digital camera is affixed to the underside of the ROV, allowing it to autonomously create photomosaics of the wreck site of the Endurance.

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 Model 2. 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 boot, 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.

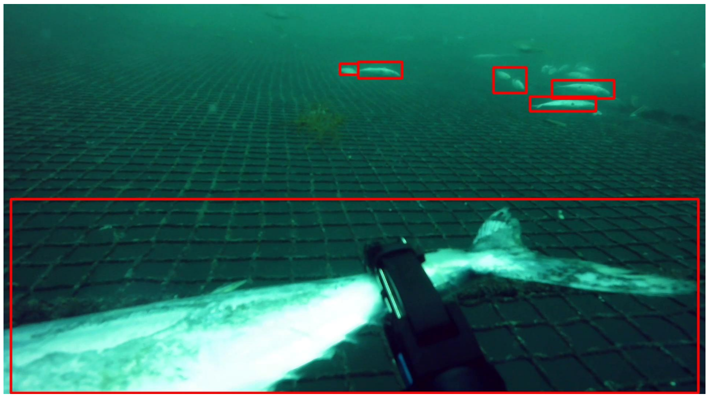


Figure 9: Object differentiation AI concept image

Computer Vision

The ROV has the ability to reconstruct wreck site images, through the use of its digital cameras, into photomosaics using complex homography and feature extraction algorithms. To accompany this, the ROV has also been equipped with multiple Artificial Intelligence programs, each created for a distinct purpose, including an object detection algorithm used to measure fish lengths and perform biomass calculations, and a state-of-the-art object differentiation algorithm to manage the mortality rates of local aquatic species, thereby aiding in the maintenance of a healthy environment.

As well as using complex methods to solve more complex problems, the ROV also uses simpler programs where feasible. For example, the ROV uses a combination of low level color segmentation and basic math to autonomously inspect offshore aquaculture fish pens.

Computer vision flow charts for the autonomous transect line following program can be found in Appendix D.

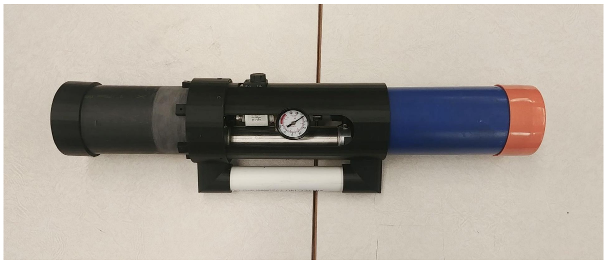


Figure 10: The Husky Explorer Vertical Profiling Float

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.

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 E, while the pneumatic SID can be found in Appendix F.

Build vs. Buy

Building custom parts offers many advantages, including cost-effectiveness and customizability. This can be seen in the design of 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 U-bolts.

Another custom-fabricated part of this ROV is the frame, which was milled out of sheets of Ultra High Molecular Weight Polyethylene (UHMWPE) using a CNC router. This process gave the team a great degree of freedom when designing buoyancy, tool and propulsion mounting.

Buying commercial components is also sometimes necessary, as it can offer a fast and often more reliable solution to any problem. For example: almost all electronics onboard are commercial products. This solution was chosen as it is far more time and cost effective when compared to custom Printed Circuit Board (PCB) design, and is more than enough to meet the needs of the Husky ROVER.

The lift bag was bought commercially, then modified for the 2022 MATE contract. This yields dual advantages: the bag has the reliability of a commercial component while still allowing for the flexibility of a custom-built part.

New vs. Re-Used

In 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.

Six T-100 thrusters were purchased from Blue Robotics. These are extremely popular, high-performing and reliable thrusters that the team felt were worth the relatively high cost. Also purchased new was the bulk of the onboard electronics, which was a necessity as this year's electronics system is massively redesigned to both complete mission tasks more effectively and improve the ROV's overall capabilities. For example: the inclusion of a pi cam and a webcam mounted on the ROV so that our machine learning programs were able to get the footage necessary to complete their tasks.

Re-used components of this year's ROV include the video multiplexer and monitor, pneumatic system and main computers, among other things. These were all high-cost items, where buying new offered no real performance advantages.

Project Management and Teamwork

Scheduling and Planning

The Husky Explorer team prides itself on being extremely well organized. Although the COVID-19 pandemic has made staying on schedule and adhering to plans challenging, we have successfully adapted and even continued to meet virtually for planning sessions during lockdowns. The team's design and manufacturing schedule was again modified and finalized in January 2022. A graphical representation of this can be seen in Appendix G, the team's Gantt planning chart.

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.

This schedule was followed closely, and progress was reported at twice-weekly team meetings. 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.

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.

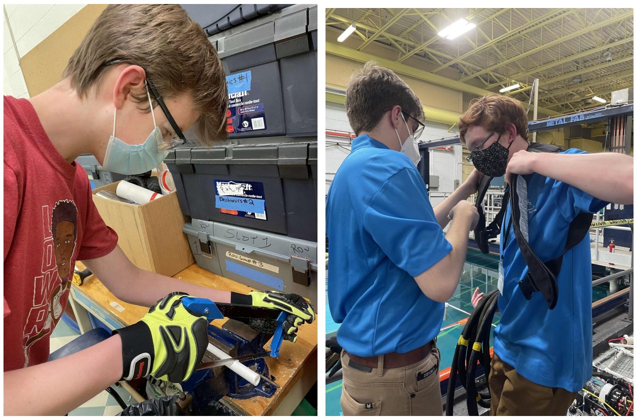


Figure 11: Eric working safely in the Husky Explorer workshop, and Ben assisting Logan with the proper placement and wear of a life vest.

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 H.

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 12: 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 Long Beach. A full budget along with travel estimates can be found in Appendix I.

Project Costing

A detailed breakdown of the ROV's cost can be found in Appendix J. 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 varying depths of water, from 1 to 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 13: 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, Evan Vokey: C.E.O. and Pilot, Eric Goulding: Mechanical Lead and Co-Pilot, Gavin Hull: Controls Lead and Programmer, Logan Smith: Chief Financial Officer, Ben Riggs: Safety Officer and Engineer, Claire Murphy: Chief communications Officer, Claire Dinn: Chief Operating Officer, and Brooke LeDévéhat: Human Relations Officer and 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 was also beneficial during COVID-19 lockdowns as it allowed team members to continue to accomplish their tasks when possible at home. 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 control code this year, a major leak was discovered in unused pneumatics lines which resulted in water pooling in the control box. This problem required our immediate attention, as any damage to the electronics in the box would have led to severe and possibly unrectifiable problems with the ROV. The team created a quick fix with duct tape until something more permanent (in this case, a screw that could close off the pneumatic line) could be prepared.

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 2022 Husky Explorer the most efficient problem solving team to date.

Interpersonal

The Husky Explorer's 2022 team has a total of eight members, five of which are returning. It was difficult at first to find meaningful roles for all members; however, with the guidance of senior members, 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 Husky Explorer team has built this ROV from the ground up. Due to COVID-19, none of the current members were able to participate in previous MATE contracts, and so, the team was forced to teach themselves the skills that would have otherwise been passed down from previous teams. Among other things, the team's main software engineers are entirely self-taught; the resident CAD expert was taught basics but refined their skills purely from self-experimentation, and 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 improvement the team would consider in a future design is to make the tether and thrusters easier to disconnect from the Blue Robotics Electronics Enclosure, which would significantly improve both transportation and troubleshooting. This could be accomplished by using waterproof quick connectors on the tether and attaching smaller connectors to the thruster cables inside the enclosure.

Another improvement that can be made is in team recruiting. This year's company was very heavily weighted towards engineers, so very few members specialized in accounting, marketing, and finance. This proved problematic as a large portion of the MATE contract involved accounting, sponsorship, budgeting, and other financial tasks. In the future, the Husky Explorer team will recruit more business-oriented students, who can also gain valuable experience through the MATE program.

References

Blue Robotics. (2022). T100 Thruster Technical Details. Blue Robotics. https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t100-thruster-core/

Curbell Plastics. (2022). Polycarbonate Properties. Curbell Plastics. https://www.curbellplastics.com/Research-Solutions/Plastic-Material-Properties/Polycarbonate

Dielectric Manufacturing. (2022). Acrylic Characteristics. Dielectric Manufacturing. https://dielectricmfg.com/knowledge-base/acrylic-thermoplastic/

Dielectric Manufacturing. (2021). UHMW Characteristics. Dielectric Manufacturing. https://dielectricmfg.com/knowledge-base/uhmw/

Hodanbosi, C. (1996). Buoyancy: Archimedes Principle. NASA. www.grc.nasa.gov/WWW/k-12/WindTunnel/Activities/buoy_Archimedes.html

SocketIO. (2022). SocketIO Documentation v4. SocketIO. https://socket.io/docs/v4/

Acknowledgements

The Husky Explorer team would like to give special thanks to our financial sponsors, especially the following:

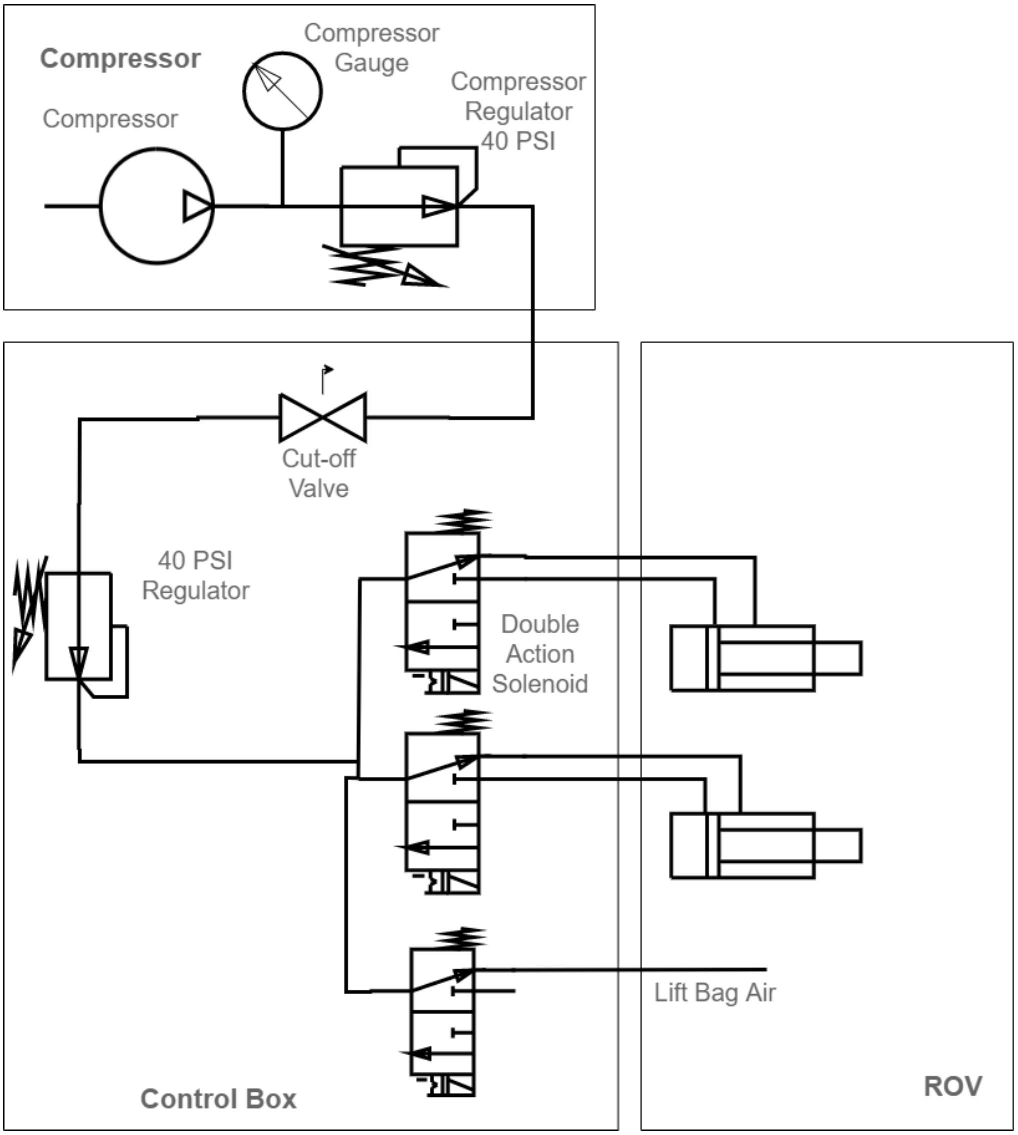
- Memorial University of Newfoundland
- Fisheries and Marine Institute of Memorial University of Newfoundland
- Mount Pearl Senior High

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 - Mr. Paul King and Mrs. Maggie Hyslop - for allowing us to use their workspace.

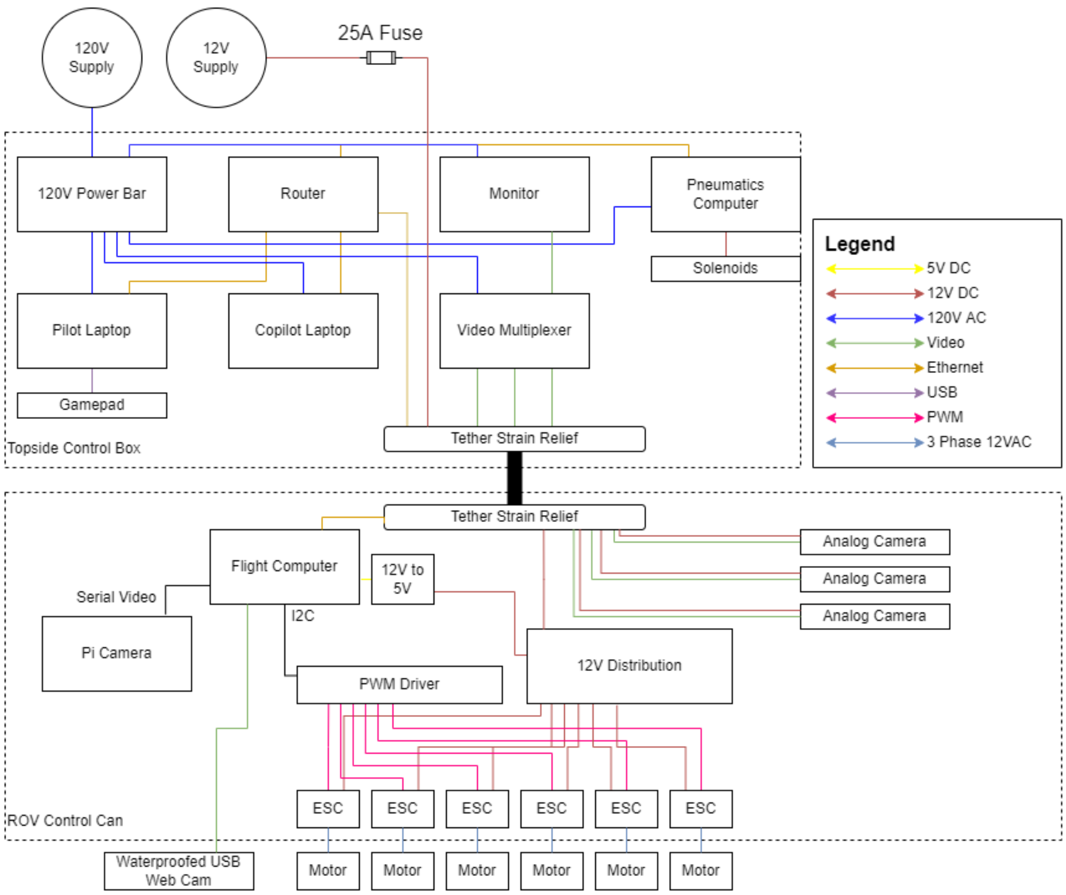
Finally, we are grateful to the MATE organization - the annual ROV competition has given Husky Explorer incredibly valuable experience in the fields of engineering, science, technology and business. For this opportunity, we are extremely grateful.

Appendices

Appendix A: Pneumatic SID

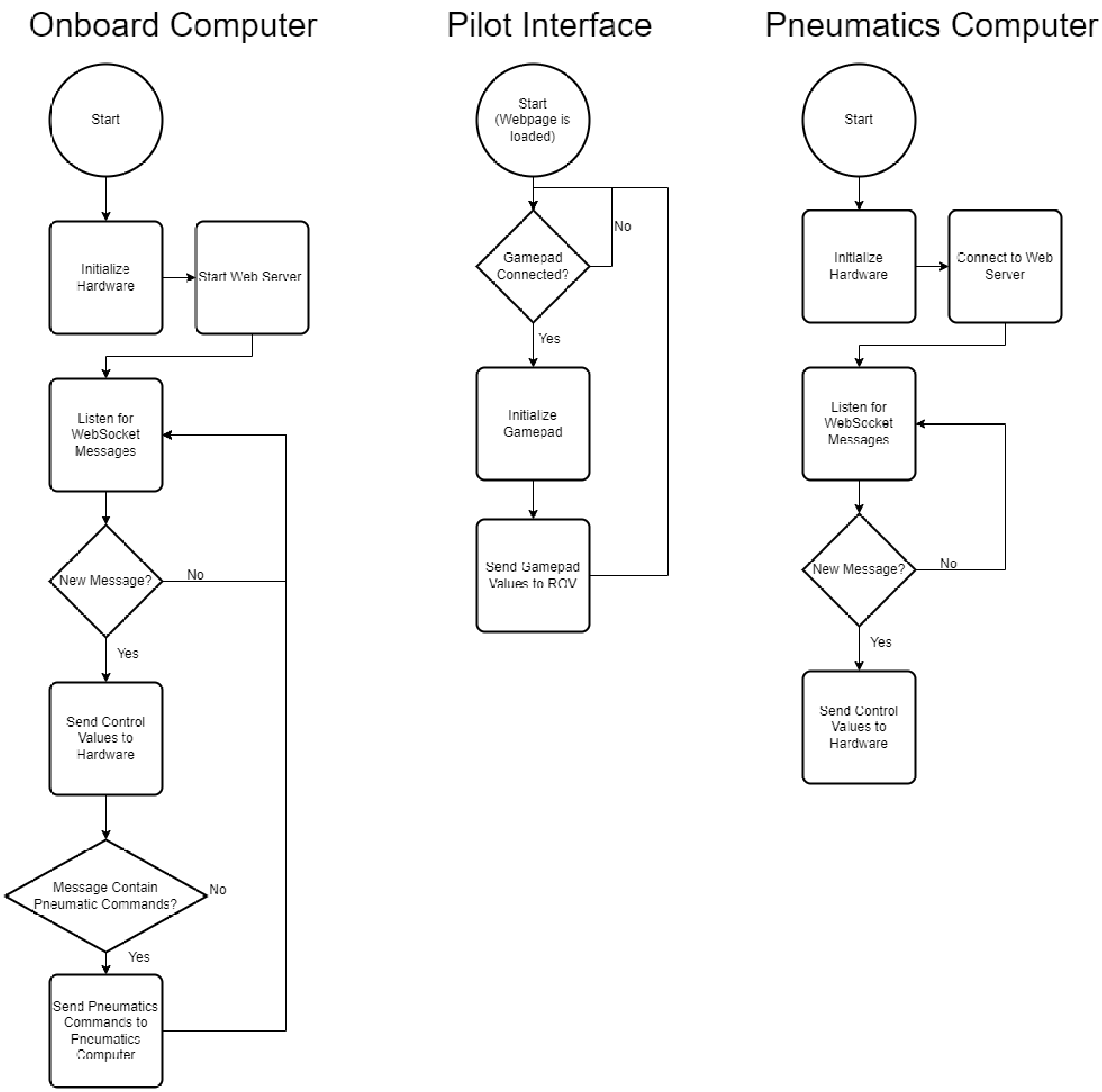


Appendix B: Main Electrical SID and Fuse Calculations

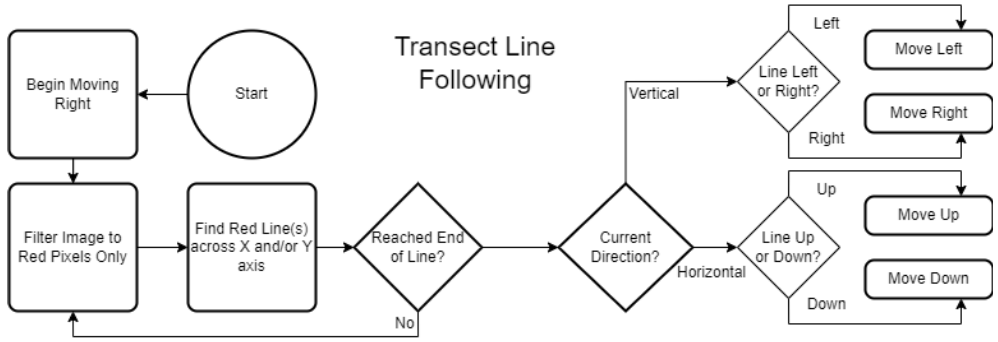


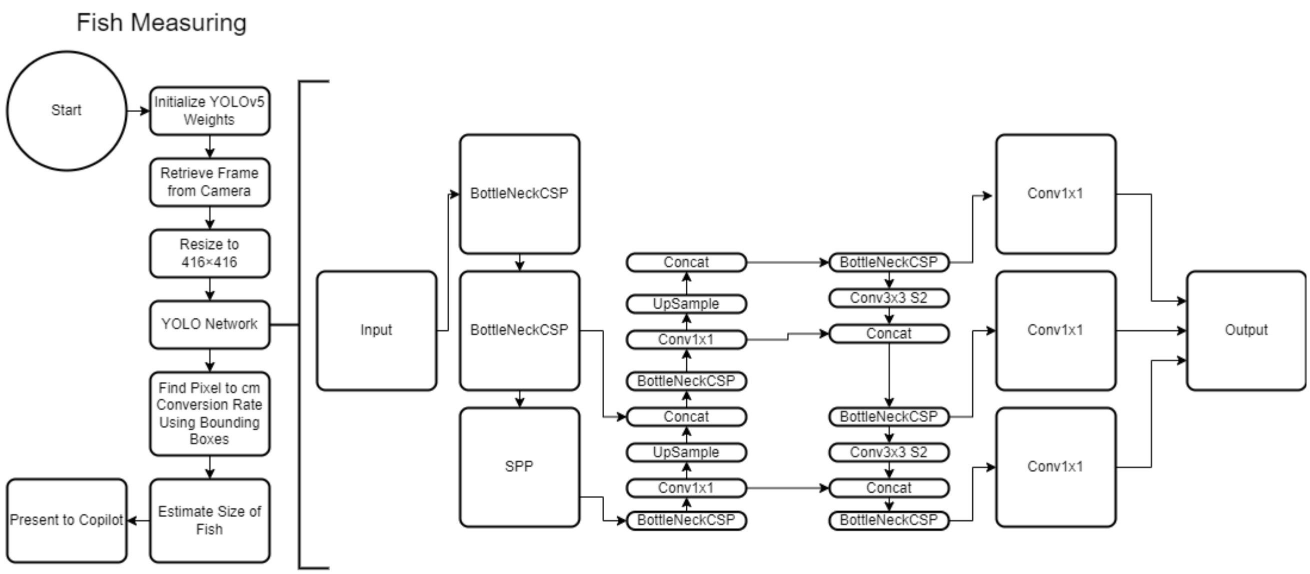
COMPONENTS	MAX DRAW	QUANTITY	TOTAL
Analog Camera	200mA	3	600mA
Servo	300mA	2	600mA
Raspberry Pi	700mA	1	700mA
Pi Sense HAT	400mA	1	400mA
ESC	100mA	6	600mA
T100 Thruster	3A	6	18A
5V Relay	60mA	2	180mA
Pi Camera	200mA	1	200mA
		Total	21.28A
		Total * 150%	31.92A

Appendix C: Software Flow Chart

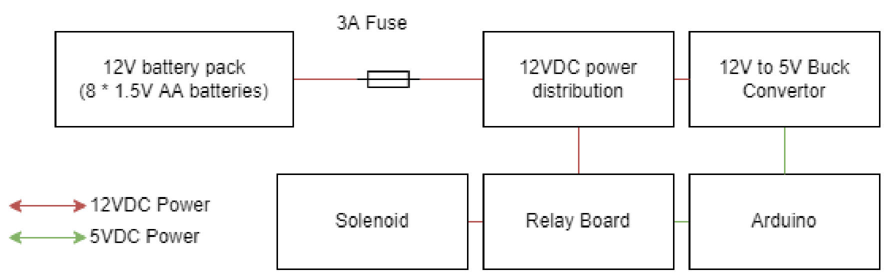


Appendix D: Computer Vision Program Flow Chart: Transect Line & Fish Measuring

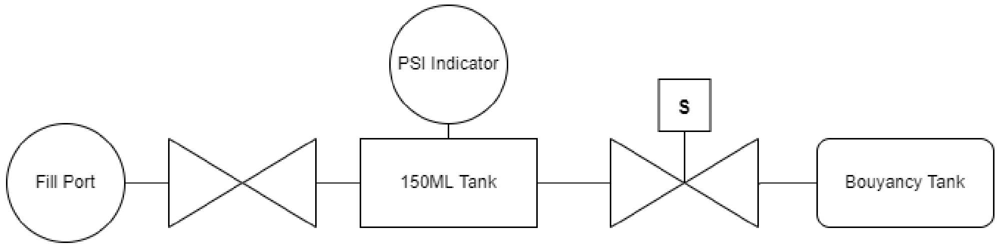




Appendix E: Non-ROV Device Electrical SID



Appendix F: Non-ROV Device Pneumatic SID



Appendix G: Gantt Chart

		Start	Finish
Project Management	Recruiting	9/16/2021	10/14/2021
	Safety Training	10/14/2021	11/11/2021
	Role Assignment	9/30/2021	10/21/2021
	Community Outreach	10/14/2021	5/19/2022
	Marketing Display	2/3/2022	5/12/2022
	Engineering Presentation	4/7/2022	5/12/2022
	Technical Report	4/21/2022	5/19/2022
Finance	Budgeting	9/23/2021	10/21/2021
	Purchasing Components	10/21/2021	3/10/2022
	Organizing Sponsorship	10/28/2021	5/19/2022
	Compiling Expenses	3/3/2022	May 19, 2022
Mechanical	Frame Planning	9/30/2021	10/28/2021
	Material Research	10/14/2021	10/21/2021
	3D printing	11/18/2021	3/31/2022
	Frame Manufacturing	11/4/2021	12/9/2021
	Claw Design	12/2/2021	1/13/2022
	ROV Full Assembly	3/31/2022	5/5/2022
	ROV piloting practice	5/5/2022	5/19/2022
Electrical	System Planning	9/23/2021	11/25/2021
	Part Sourcing / Ordering	11/18/2021	2/24/2022
	Onboard Manufacturing	1/6/2022	4/7/2022
	Tether Manufacturing	2/10/2022	2/24/2022
	Surface Control Assembly	3/17/2022	4/14/2022
	System Testing	4/14/2022	5/19/2022
Software	System Planning	9/16/2021	10/21/2021
	Solution Research	9/30/2021	11/18/2021
	Onboard Software	12/16/2021	2/24/2022
	Surface GUIs	1/20/2022	3/3/2022
	Pneumatic Software	2/10/2022	3/3/2022
	System Integration	2/17/2022	3/31/2022
	System Testing	3/31/2022	5/19/2022

Appendix H: Safe Operating Procedures

In-Workshop	On-Deck
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	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

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

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 I: Project Budget

School: Mount Pearl Senoir High			**Orgianisation:** Husky Explorer	
Mentors: Mr. Paul King & Mrs. Maggie Hyslop			**Period:** Sep 23, 2021 to Oct 21, 2021	
Income				
Source				**Amount**
Mount Pearl Senior High				$2,000.00
MATE				$750.00
Marine Institute (contingnent upon advancing to the international compition)				$20,000.00
Expenses				
Category	**Desciption**	**Type**	**Projected Cost**	**Bugeted Value**
Mechanical	Frame materials and hardware	Purchased	$600.00	$600.00
	Electronics enclosure and penetrators	Purchased	$300.00	$300.00
	PLA Filament	Purchased	$60.00	$60.00
	Pneumatics system	Purchased	$200.00	$200.00
Electronics	Trusters and ESCs	Purchased	$1,350.00	$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 from St. John's to Long Beach	Purchased	$15,000.00	$15,000.00
	Accomodations	Purchased	$5,000.00	$5,000.00
	Transportation	Purchased	$5,000.00	$5,000.00
	Food and Drink	Purchased	$2,000.00	$2,000.00
General	Marketing Poster	Purchased	$200.00	$200.00
			Total Income	$22,750.00
			Total Expenses	$29,710.00
			Total Re-Used	$3,750.00
			Fundrasing Needed	$6,960.00

Note: all values are in Canadian Dollars (CAD)

Appendix J: Project Costing

School: Mount Pearl Senoir High			**Orgianisation:** Husky Explorer		
Mentors: Mr. Paul King & Mrs. Maggie Hyslop			**Period:** Oct 21, 2021 to Jun 1, 2022		
	Item	**Units**	**Cost**	**Source**	**Total**
Mechanical					
Enclosure	O-Ring Set.	2	$1.80	Purchased	$3.60
	O-Ring Set (4").	2	$3.55	Purchased	$7.10
	Cable Penetrator	14	$3.55	Purchased	$49.70
	Aluminum 14 Hole End Cap	1	$33.16	Purchased	$33.16
	O-Ring Flange (4").	2	$34.34	Purchased	$68.68
Frame	Dome End Cap (4").	1	$39.00	Purchased	$39.00
	UHMW Sheet 12 in. x 24 in.	3	$12.77	Purchased	$38.31
	Corner Brace (1-1/2")	12	$1.98	Purchased	$23.76
Pneumatics	Brass Coupling (1/8").	1	$1.79	Purchased	$1.79
	Brass Reducer (1/4" X 1/8")	2	$2.00	Purchased	$4.00
	Coupling (1/8").	1	$1.75	Purchased	$1.75
	Air Compressor	1	$169.29	Re-Used	--
	Pneumatics Kit	1	$150.00	Purchased	$150.00
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	Purchased	$12.99
	Micro USB A to 90° USB B.	2	$5.99	Purchased	$11.98
	Blue Robotics T100 Thuster.	6	$230.00	Purchased	$1,380.00
	Blue Robotics Basic ESC.	6	$28.75	Purchased	$172.50
	Electronics Tray	1	$93.42	Purchased	$93.42
	HAT Shield For Raspberry Pi	2	$14.99	Purchased	$29.98
	Water Proof Connectors	2	$15.19	Purchased	$30.38
	Raspberry Pi 3 B+ Kit.	1	$98.99	Purchased	$98.99
	Hook Up Wire Kit.	1	$25.88	Purchased	$25.88
	5V USB A Breakout Board.	6	$4.67	Purchased	$28.02
	1 Channel 5V Relay.	2	$8.99	Purchased	$17.98
	2.1 mm Board Camera.	1	$16.50	Re-Used	--
	12V to 5V Buck Volt Converte	3	$10.88	Purchased	$32.64
	Analog Waterproof Camera	4	$189.99	Re-Used	--
	Logitech C270	1	$32.99	Purchased	$32.99

Surface Electronics	DLink Router	1	$39.99	Re-Used	--
	Video Multiplexer	1	$249.98	Re-Used	--
	Cat 5e Cable	3	$7.99	Purchased	$23.97
	Monitor	1	$299.99	Re-Used	--
	4 Channel Relay Module	1	$10.19	Purchased	$10.19
	5 Port Power Bar	1	$14.99	Purchased	$14.99
	HP Laptop	1	$850.00	Re-Used	--
General					
General	Total Shipping Fees.	115	$238.49	Purchased	$238.49
	Team Registration.	1	$155.00	Purchased	$155.00
	Team Attire.	20	$20.00	Purchased	$400.00
	Team Business cards.	1	$20.00	Purchased	$20.00
	Team Marketing Poster.	1	$182.85	Purchased	$182.85
Travel	Airfare	1	$18,000.00	Purchased	$18,000.00
	Accomodations	1	$5,000.00	Purchased	$5,000.00
	Transportation	1	$2,000.00	Purchased	$2,000.00
	Food and Drink	1	$4,000.00	Purchased	$4,000.00
Income					
Donations	Mount Pearl Senior High	1	$2,000.00	Cash Donation	$2,000.00
	MATE	1	$750.00	Cash Donation	$750.00
	Marine Institute	1	$20,000.00	Cash Donation	$20,000.00
	Brokerlink Insurance	1	$100.00	Cash Donation	$100.00
Totals					
				Total R.O.V. cost	$2,489.73
				Total Expenditure	$32,486.07
				Total amount fundraised (as of May 31th, 2022)	$22,850.00
				Total amount left to fundraise	$9,636.07

Note: all values are in Canadian Dollars (CAD)