2024 MATE ROV WORLD CHAMPIONSHIPS

HHM ROV

Holy Heart of Mary High School
St. John’s, Newfoundland and Labrador, Canada

Technical Documentation

COMPANY MEMBERS

Cole Murphy	Mentor
Allison Hutchings	Team Lead
Prajwala Chedella	Software Lead
Peyton Cashin	Software
Kenneth Le	Software
Frank Chen	Software
Benjamin Evans	Design and Fabrication Lead
Sophia Zhang	Design and Fabrication
Nikolas Brits	Design and Fabrication
Peter Trinh	Design and Fabrication
Lucas Lownds	Marketing Lead
Priya Purohit	Marketing
Evan Fang	Marketing
Natalie Mitchell	Graphic Design Lead
Daniel Cheng	Graphic Design
Waffa Zahralyn	Safety Lead

Figure 1: NEPTUNE in action. Credit: Carc Boli.

TABLE OF CONTENTS

ABSTRACT

The Holy Heart of Mary ROV Team (HHM ROV) is a company full of young and talented minds aiming to innovate and combat challenges in our ocean ecosystems. Our company consists of fifteen highly skilled engineers and talented technicians who have worked together to develop a remotely operated vehicle (ROV) to monitor and safeguard ocean resources.

This year, we created the Newfoundland Exploration and Probing Technology for Underwater Navigation and Evaluation (NEPTUNE). By combining our coding, CAD, and assembly skills with knowledge from previous contracts, our company designed our second-generation ROV to complete tasks efficiently and effectively. NEPTUNE featured a low-cost, small yet sturdy frame with custom 3D-printed parts and tools and advanced capabilities such as custom movement abilities, a multi-camera viewing system, and an accessible and adaptable control system. Together, these systems allowed NEPTUNE to complete tasks with precision and efficiency.

Based in St. John’s, Newfoundland & Labrador, Canada, HHM ROV understands the delicate balance required to maintain ocean health. With our island’s deeply rooted ocean history, we aim to preserve our marine ecosystem’s health for future generations. In the MATE ROV competition, our company has assisted in creating solutions to issues in the global marine environment. NEPTUNE has and will continue to address ocean health through ocean observation, coral preservation, promoting sturgeon populations, and deploying GO-BGC Floats.

Figure 2: HHM ROV Team Photo (Credit: Cole Murphy)
Back Row - Left to Right: Evan Fang, Lucas Lownds, Benjamin Evans, Frank Chen, Kenneth Le, Daniel Cheng, Peyton Cashin, Nikolas Brits, Peter Trinh
Front Row - Left to Right: Allison Hutchings, Priya Purohit, Waffa Zahralyn, Sophia Zhang, Natalie Mitchell, Prajwala Chedella

TEAMWORK

Company Profile

Founded two years ago, HHM ROV is competing in our first Mate ROV World Competition in June 2024. Established by our teacher mentor, Mr. Cole Murphy, our company has made it a top priority to introduce high school students to various engineering disciplines, develop student's skills, and promote marine and ocean health by designing and building an underwater ROV.

Our 15-member company consists of a CEO and five departments: software, design and fabrication, marketing, graphic design, and safety. Each department has an established lead who streamlines processes, sets goals, and effectively communicates between departments. Our team leads were chosen for their experience, skill, and ability to teach newer members the tools and trades of their department. Our CEO juggles multiple roles: communicating with company members, helping departments problem-solve, spearheading goals and objectives, and developing and managing company progress. Our company organization design creates more efficient and effective communication, allowing the company to complete tasks more quickly and easily. See Appendix C for a more detailed company overview.

This year, our company chose its members based on an interview system. Each potential member completed a thorough application process and was later interviewed for the role they applied for. Our CEO and teacher mentor then selected applicants who were the best fit for the company based on a set of criteria. This interview system ensured that selected members would show up regularly and passionately while also introducing the company to previously unaware members, which attracted new and exciting talent. Even rejected applicants gained valuable skills in interviewing and networking.

As a newer team, most members were new. As a result, teaching and training these members was prioritized throughout all stages of the design process. Experienced senior members collaborated with new members to cultivate their skills and foster problem-solving and critical-thinking capabilities. Through mentorship and collaboration, new members gained valuable insights and expertise, enabling them to contribute more effectively and further help the team.

Schedule and Planning

This year, HHM ROV employed a vigorous project management and timekeeping approach. Learning from our mistakes from last year, we decided to utilize our time thoroughly. We started by establishing clear and consistent means of communication between and within our departments. For example, the software department used Discord, while the entire company used Snapchat or WhatsApp to share ideas and concerns.

Weekly tasks were updated on a whiteboard in our company meeting room. After the team's inception, meetings every Monday and Thursday were established to work on the ROV for two hours. Those two hours were used to plan and execute ideas in an effective and timely manner. The CEO and the team leads meet every Wednesday to observe progress, develop ideas, and set plans for the following week's meetings. To use our time as effectively as possible, we developed a schedule (Appendix I) to manage our work. During Wednesday's meetings, the team leads set and enforce deadlines for items of completion.

They employ a variety of tools to meet their needs. One way they do that is by delegating tasks (Appendix H) to individual members of the team.

The team leads communicate with their department to inform them of their responsibilities. For example, the Design and Fabrication Department had two members working on the ROV and one member each on the claw and float. This allowed them to finish NEPTUNE and TRIDENT faster than the previous year.

To preserve efficiency, HHM ROV documents previous ideas, methods, and problems. Thorough documentation mitigates time loss as it prevents employees from redoing already completed tasks. In the Software Department, old working code is kept to fix issues in newer code. A document kept for research purposes indicates potential problems and their solutions. This allows the software department to manage their time more effectively. Any old code is downloaded and saved on Google Drive.

In the case of missed deadlines, the company utilizes several strategies to catch up. For example, the software department can take home components to work on. This allows them to use the time spent at company meetings to work efficiently and effectively at a rapid rate. When problems are encountered by team members, each team member collaborates with their fellow department members and department lead to solve this problem. If a very difficult problem is encountered that cannot be solved by one department alone, our team lead allocates additional departments to help solve the problem or complete the task.

DESIGN RATIONALE

NEPTUNE was designed carefully with marine navigation in mind. It is made from materials that were carefully chosen for their properties to make our ROV efficient and capable of succeeding in any task. With its compact design, it is lightweight and easy to maneuver.

The designs for our ROV began by being drawn out, then discussed, changed, and eventually designed in various CAD software. Using these designs, we used various technologies, such as our school's CNC router and many 3D printers, to cut out and print the parts to our ROV. The ROV has a length of 57.0 cm (the claw is 21.5 cm), a width of 42.5 cm, and a height of 28.5 cm, weighing 8.5 kg. Our electronics enclosure was attached to the ROV with 3D printed holders for easy access and our ROV was designed to be very compact allowing it to be very hydrodynamic.

NEPTUNE was designed to be modular, enabling easy maintenance, servicing, and repair.

Figure 3: TRIDENT, our Float
Credit: Daniel Cheng

Figure 4: NEPTUNE, our ROV
Credit: Nikolas Brits

Figure 5: NEPTUNE's side view
Credit: Nikolas Brits

Innovation

Using our newfound knowledge from the 2023 contract, our design team incorporated necessary modifications to improve our ROV's design. Last year, our electronics tube was attached using a mount that required unscrewing two screws to remove the tube to make repairs. This made the tube hard to access quickly during the request for proposal (RFP), due to the time it took to unscrew the mount, and the fact that it was mounted within the ROV's frame, making it difficult to access.

This year, to solve this problem, we opted to use Velcro straps to secure the tube into the mounts, as they were cheap, easy to remove, and reliable. Another improvement we made from last year's ROV was adding extra cameras, allowing us to view more of the ROV's surroundings which gives the pilot more maneuverability for the ROV.

These and many more examples showcase HHM ROV's desire to innovate technology and solutions.

Problem-Solving

Our company employs a vigorous problem-solving methodology. When we encounter a problem, we first diagnose the issue. By understanding the issue, we spend more time finding applicable solutions. Then, we figure out how to reproduce the issue reliably. For example, we discovered the ROV would unexpectedly stop functioning. The pilot repeated their movements and we discovered that moving the joystick too quickly caused the problem. After that, we researched the optimal way (requiring the least changes without sacrificing efficiency) to solve the problem. The software department read through their code and created potential solutions. After researching several solutions we discuss and share ideas to find an ideal solution. The software department noted the pros and cons of each solution and decided on the best one. Finally, we implement the optimal solution, testing to ensure it solves the problem without causing further problems. New code was created and rigorously tested to ensure the original problem was solved.

Figure 6: HHM ROV Problem Solving Methodology
Credit: Daniel Cheng

We encountered issues with accessing multiple cameras at once. We narrowed the issue down to being related to USB bus bandwidth limitations by using several computers and several cameras to ensure the issue wasn’t related to any other hardware. We researched different solutions, including: reducing the framerate of the cameras, showing two at a time, and more. During our discussion, we concluded that we always wanted to see through our main camera. We decided to purchase a USB to RJ45 extender for 2 of the 3 cameras. This solved the USB bus bandwidth limitations and isolated the primary camera from the external cameras. This provides a contingency in case our primary camera malfunctions, allowing us to continue piloting.

Systems Approach

Our main goal was to allow the system and components to work together in harmony. To streamline processes, we decided on a Graphical User Interface (GUI) to make it easy to control the ROV. We had a motor code from the previous year that we used and created a new custom movement script that uses voltage signals to power our thrusters. It was difficult for our pilot to navigate, so we increased the number of cameras and sensors. Doing this greatly improved the pilot’s ability to operate. By utilizing the socket library on Python, we can create two endpoints to stream data from our sensors reliably and quickly. By utilizing the socket library on Python, we can create two endpoints to stream data from our sensors reliably and quickly.

See Appendix D for the ROV SID.

Build vs. Buy, New vs. Re-Used

Components within our ROV were both built and bought to meet the mission requirements. Outsourced and bought materials were mainly the core components, and the self-built ones were made with either 3D-printed PLA material or a PVC derivative called Foamalux. Foamalux was used for the frame because of its low density of 0.55g/mL, helping the ROV remain neutrally buoyant. The material could provide great strength and be easily cut in our lab using a CNC router. The in-house components were altered from last year to fit the specific tasks. For example, the claw was redesigned, and tube holders with newly bought Velcro straps were added to enable easy access to the tube during the RFP.

For our float this year, we built a custom electronics board to control the float, used eight AA batteries as a power source, and bought basic components such as syringes, air tubes, and a stepper motor to build a custom buoyancy engine to control movement. We also reused a Blue Robotics pressure sensor to monitor pressure data. We custom-built all of the internal structures to hold the batteries and buoyancy engine. The internal structures were custom-designed and 3D printed to fit our exact dimensions and needs.

Deciding between new and reused/inherited components involves balancing cost, reliability, and compatibility with current requirements. Reused parts offer cost savings and proven reliability, aligning with this year's requirements while minimizing resource expenditure and maximizing sustainability. For example, the thrusters were reused because they work well, are reliable, and are very expensive to replace.

Vehicle Systems

Our ROV enables precise underwater navigation, manipulation of tools, and data collection using sensors in challenging aquatic environments.

Cameras are a vital component of our ROV’s system, allowing for crucial visual input for navigation and monitoring, and for use in various underwater applications including industrial inspections and scientific research. The controller utilized had a wide range of controls, including the ability to move along more than three axes by using numerous of buttons, triggers, and joysticks allowing for the desired movements to be achieved when piloted.

The control interface of an ROV serves as the nerve center for operators, facilitating precise maneuvering and navigation underwater. This interface allows operators to command the ROV's movements, manipulate its tools, and monitor its sensors for effective mission execution. The interface is displayed to the user, facilitating interaction with the system. The GUI features two pivotal subsections: The Information Sensor area, delivering live sensor data like depth, temperature, and power status for real-time assessment. Complementing this, the controller section provides an array of intuitive controls enabling precise operation of the ROV.

From directional navigation to camera adjustments, the GUI offers seamless management of essential functionalities, ensuring efficient and effective exploration and operation of the underwater vehicle.

Sensor devices within the ROV's systems collect data on vital parameters like depth, temperature, and pressure. This data is essential for assessing underwater conditions, guiding decision-making processes, and ensuring the safety and efficiency of operations in various marine environments.

Vehicle Structure

The main structure of our ROV is made from Foamalux, a PVC material, cut from sheets using our school's CNC router. We chose PVC as it is easy to work with, durable, lightweight, and inexpensive, as we had a significant amount left over from last year. The frame of the ROV was designed in MasterCam and was designed to be small and efficient, yet functional, so we can modify it to aid in completing the RFP tasks. The tube holder structure of the ROV was designed in SolidWorks, and 3D printed using PolyLite 2.85mm filament. We chose to 3D print this part of our ROV as it is hard and sturdy, and adds extra weight to help the ROV stay neutrally buoyant.

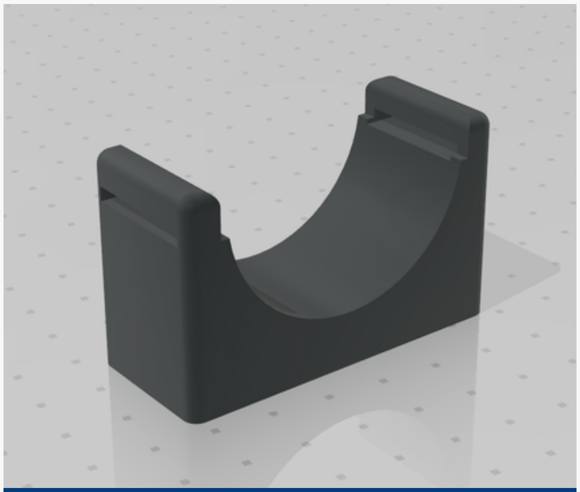


Figure 7: 3D Tube Holder Design
Diagram by: Sophia Zhang

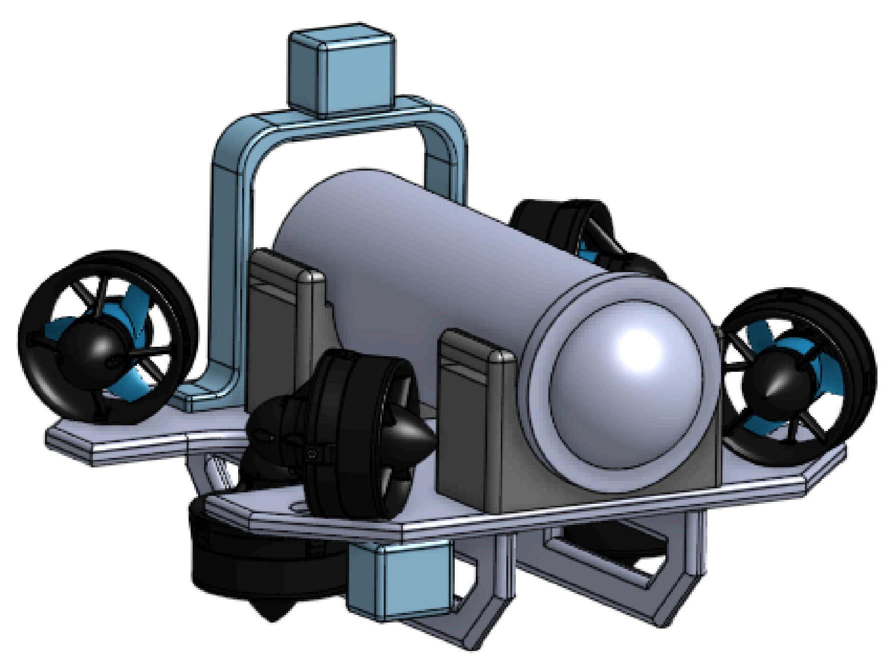


Figure 8: Assembly of NEPTUNE
Diagram by: Sophia Zhang

Tools and Payload

The ROV has various tools to assist it in the completion of ocean tasks. Tools include a temperature sensor to make measurements, a pneumatic claw that is used to manipulate various objects and complete tasks, custom-made camera enclosures, multiple cameras in various locations to provide a full field of view, and a vertical profiling float to make ocean climate readings at various depths.

Cameras

The ROV uses three USB cameras to transmit visual data, two of which were newly bought this year, while the remaining one was left over from last year. We initially had only one camera in our waterproof tube, capable of rotating vertically enabling us to view our claw. However, we decided to add two other cameras to provide more views and effectively maneuver our ROV.

Three cameras were chosen to maximize the pilot's field of view and mitigate latency. A Low-light USB camera from Blue Robotics is reused as our main camera due to its high quality and low latency. The two external USB cameras were chosen and bought for their low latency, performance, and low cost. Each of these cameras is mounted to provide the most important views necessary to help pilot our ROV.

Our main camera is mounted at the front of our electronics tube and will be the camera that oversees claw manipulation and the majority of tasks performed. This camera is connected to a servo, allowing us to tilt our camera and adjust our field of view for the pilot's ease of use. The servo is connected to the Raspberry Pi (see page 15 for more information about the Pi) and can be controlled using the D-Pad on our controller.

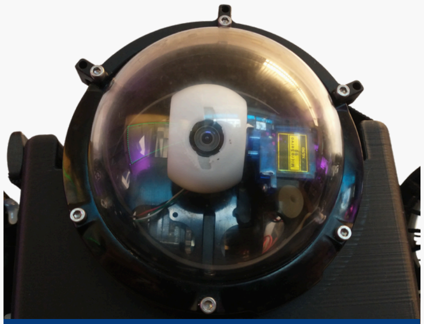


Figure 9: Main cam with servo
Credit: Nikolas Brits

The other cameras are placed outside of the ROV. These were waterproofed by potting the cameras in epoxy inside custom-made, 3D-printed enclosures, with a clear acrylic sheet at the front to maintain a clear view. One camera is placed to the back right of the claw. This allows us to see the surroundings of the claw, enabling smoother manipulations. We had inadvertently left no space to place our third camera so after some consideration, we 3D-printed a custom stand. The final camera is placed on this stand on the back of the ROV. This provides a bird's eye view of NEPTUNE making it easier for the pilot to view the ROV and its surroundings. These cameras were connected using the previously mentioned USB to RJ45 extender.

Figure 10: Camera Pictures with water proofing
Credit: Nikolas Brits

Claw

Our ROV's claw is composed of six 3D-printed PLA components and has six joints held together with M3 bolts. The components were designed and assembled in Tinkercad to ensure the functionality of the mechanism. The entire assemblage was then secured to the ROV frame with four bolts and a customized claw mount at the base of the pneumatic cylinder.

To perform various mission tasks, the claws were designed to interlace, allowing them to hold onto cylindrical objects of varying sizes as well as narrower objects such as ropes. Additionally, foam has been glued to the interior of the claws to increase friction and conform to non-cylindrical objects. For some tasks, rotation of the claw to a vertical position may be achieved via the rolling of the ROV using the two vertical thrusters. Lastly, the claw is highly customizable, allowing for the attachment of different claw heads for particular tasks if necessary.

The claw mount is composed of a cover, a compression flat, and a slope. The cover wraps around and behind the base of the pneumatic cylinder, preventing any unwanted rolling or sliding motion. The compression flat allows for the mount to securely grip onto the cylinder with a rubber band wrapping around the pneumatic cylinder's base. The rubber layer greatly increases the friction of the mount against the cylinder and reduces the strain on the components when forced. Due to the ROV's inability to pitch, the mount's slope angles it downward to allow it to reach the floor if needed.

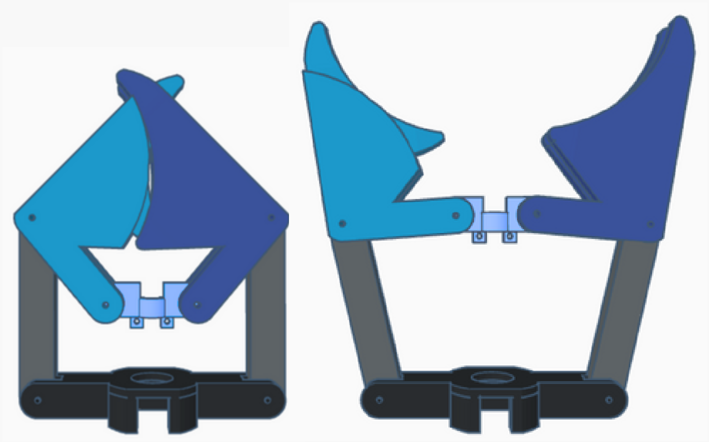


Figure 11: Claw in closed and open positions
Credit: Peter Trinh

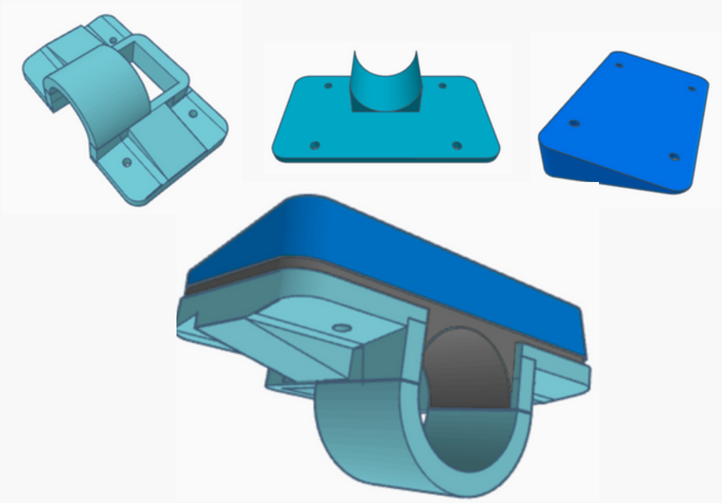


Figure 12: Components of claw mount
Credit: Peter Trinh

Pneumatics

The claw is controlled by two pneumatic lines that direct the inflow of compressed gas into either side of the pneumatic cylinder. The air from the compressor first passes through a manual regulator set to 40 PSI before being sent into a valve attached to the compressor. Whether the cylinder is in its extended or contracted position depends on which of the two pipes is pressurized, and this state is controlled by the three-state five-port lever-operated DCV (directional control valve). Its states include pressurizing either tube with the left and right states and restricting all airflow with the center state.

See Appendix E for the Pneumatic SID.

Float

Our custom vertical profiling float, TRIDENT, enables us to complete two vertical profiles. The float uses an ESP32-S3, which was chosen due to its low power consumption, built-in Wi-Fi, external antenna connector, and small size. The float captures pressure data as it moves vertically. Syringes with a ballast system adjust their mass for profiling while a motor-driven screw controls the syringe motion. Two motor control boards, managed by the ESP32-S3, handle motor control and networking. Data from the pressure sensor is broadcast via Wi-Fi to a control station. The electronics are housed in a waterproof 3-inch PVC pipe, sealed with an end cap, with tubing for water entry. We incorporated various 3D-printed components for the mechanisms, as we needed very specific dimensions to fit our components in such a small space.

The float is powered by 8 alkaline AA batteries wired in series to reach 12 volts. This is converted to 5 volts to power the control board and Blue Robotics Bar02.

Movement is achieved using a Nema 17 stepper motor connected to 2 Adafruit motor drivers.

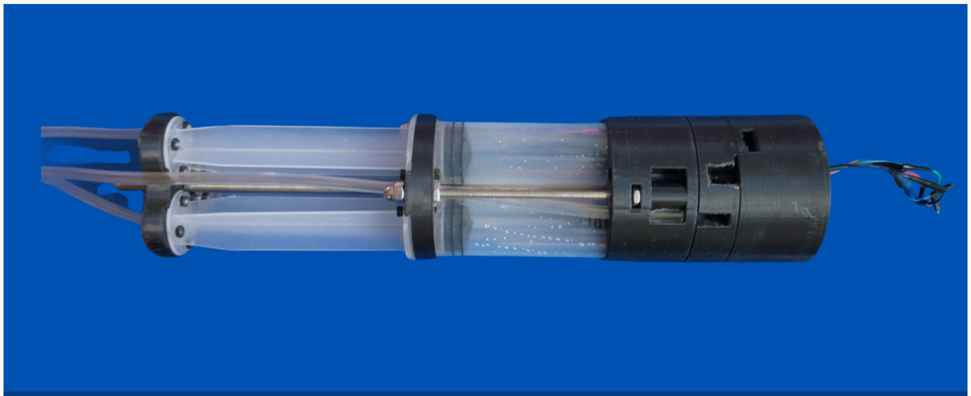


Figure 13: TRIDENT's buoyancy engine
Credit: Nikolas Brits

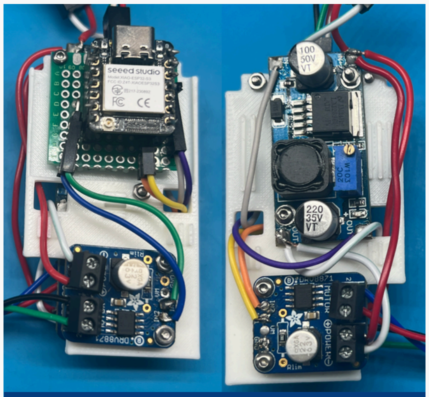


Figure 14: TRIDENT's electronic card
Credit: Peyton Cashin

Sensors

The ROV has a temperature sensor attached to the endcap of our Blue Robotics enclosure while the Float contains a pressure sensor. We had a dedicated temperature sensor and a pressure sensor that also measures temperature from last year. To choose and evaluate these sensors, we tested them against a calibrated thermometer. We found that the pressure sensor's temperature reading was consistently within two to three degrees, while the temperature sensor reading was within a degree of the measured temperature. We decided to reuse the temperature sensor for NEPTUNE (since it had the precision necessary to complete tasks such as Task 2.1 in the contract) and the pressure sensor for TRIDENT.

Propulsion

Our ROV uses six T200 thrusters from Blue Robotics to move. We decided to reuse them because of their high performance and versatility and to reduce costs. Each thruster provides nearly 3.7 kilograms of forward thrust and is connected to the Raspberry Pi via Electronic Speed Controllers (ESCs). We opted for a configuration that fulfilled our movement requirements without increasing the number of thrusters due to the power limitation imposed by the contract requirements. Two thrusters are placed vertically, enabling the ROV to move up and down. The other four are vectored and positioned on each corner of the ROV, which allows it to move forward and backward, left and right, and turn. The horizontal configuration allows for every thruster to be used when moving yielding faster and more efficient movement. They also direct any flow away from our electronics to protect them.

The thrusters are controlled through Pulse Width Modulation (PWM) frequencies sent by the Pi. This allows us to limit the power received by each thruster since last year as they would pull too much power and shut off our Pi. A PWM frequency of 1500 is neutral or stop. The thrusters draw more amperage and spin faster as the frequencies get further from this value. A value less than 1500 is counterclockwise rotation while a value greater than 1500 is clockwise. Limiting our frequencies between 1350 and 1650 prevents the Pi from powering off due to a power spike. We lose power and speed by reducing the PWM values but the thruster placement mitigates that loss by allowing the ROV to move precisely, saving time and energy. However, we realized that erratic movements on the controller would result in power spikes leading to a brief loss of power for the electronics inside the ROV, to mitigate this issue we developed code to ensure the maximum acceleration of the thrusters is reduced.

During our trials in our regional competition, we discovered we had trouble lifting heavier objects. To fix this issue, we created a custom command that diverts all thruster power to the vertical thrusters, allowing NEPTUNE to lift heavier objects. In this state, their PWM frequencies are between 1300 and 1700.

Figure 15: Blue Robotics T200 Thruster
Credit: Blue Robotics

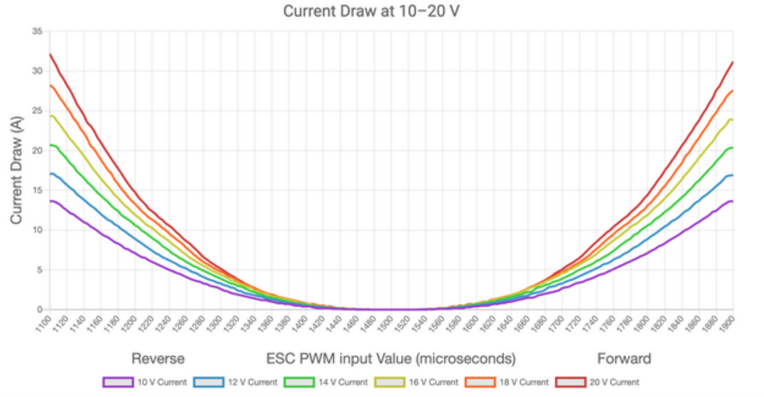


Figure 16: Thruster current draw
Credit: Blue Robotics

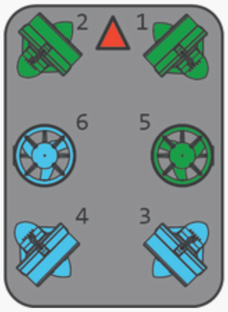


Figure 17: Thruster Configuration
Credit: Blue Robotics Community

Buoyancy & Ballast

The ROV will be kept at approximately neutral buoyancy, allowing it to remain relatively still at any depth. Drifting caused by a slightly non-neutral buoyancy can be easily mitigated by the thrusters. The components and materials that make up the ROV such as the acrylic tube and the PVC frame are positively buoyant, so the ROV had to be equipped with denser material to increase its average density to be closer to that of water. The ROV is kept at neutral buoyancy by two 200-gram weights at the front and one 100g weight in the center. The back of our ROV also has a small piece of foam attached, as the back of our ROV was heavier than the front, causing the back to dip.

ELECTRICAL

Tether

Our tether is the primary connection between the ROV and the topside computers. Running through the tether are two 12 gauge (AWG) power cables, two pneumatic tubes, and two waterproof CAT5e Ethernet cables. The tether allows us to connect to our Raspberry Pi 4B, operate the claw, capture video from our outer cameras, and power our onboard electronics.

Using the RPF requirements outlined in the MATE ROV competition manual, we concluded that we needed a tether that could go 13 meters horizontally and 5 meters vertically. Using the Pythagorean theorem, we calculated that our tether should be at least 13.9 meters long. The tether is approximately 15.25 meters long (to allow some tether to remain above the water) and covered in a black mesh that prevents our wires and cables from being twisted and tangled. To ensure the tether does not drag and harm its surroundings, foam pieces are adhered to the tether every 0.5 meters. This also prevents the tether's weight from interfering with the ROV's buoyancy. The top side end of our tether has Anderson Powerpole connectors to connect to the power box. The tether also has adequate strain relief on the top and ROV side to prevent damage to our electronics if pulled.

During operation, our dedicated tether managers will handle and maintain the tether, allowing the ROV and the company to complete tasks successfully.

Pre-Run Tether Protocol:

1. Unlatch the Velcro straps, uncoil the tether, and place it away to prevent tripping hazards
2. Check the ROV side strain relief
3. Pass the topside end for the pilots to connect to our laptops and air compressor
4. Attach topside carabiner for strain relief, ensuring there is enough slack

Post-Run Tether Protocol:

1. Remove the ROV from the water
2. Unlatch topside strain relief
3. Coil the tether and re-latch the Velcro straps

Figure 18: Our tether
Credit: Daniel Cheng

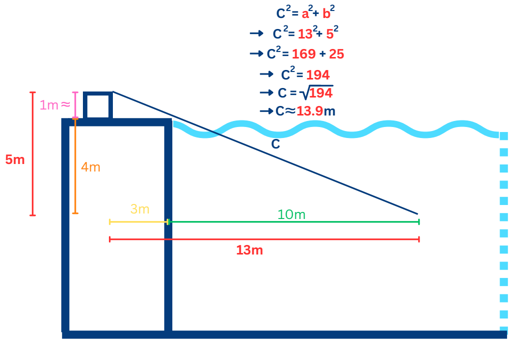
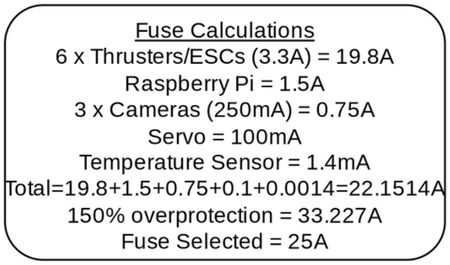


Figure 19: Tether Length Calculations
Credit: Prajwala Chedella



Fuse Calculations
6 x Thrusters/ESCs (3.3A) = 19.8A
Raspberry Pi = 1.5A
3 x Cameras (250mA) = 0.75A
Servo = 100mA
Temperature Sensor = 1.4mA
Total=19.8+1.5+0.75+0.1+0.0014=22.1514A
150% overprotection = 33.227A
Fuse Selected = 25A

Figure 20: Fuse calculations
Credit: Allison Hutchings

Raspberry Pi

Our ROV is controlled using a Raspberry Pi 4B connected to a topside computer through a waterproof CAT 5e Ethernet cable. We chose to use a Pi since we had previous experience with it. Its high performance, small size, and low power consumption allow us to have a power-efficient and compact ROV. It is easy to use, reliable, and has excellent support, making it an ideal choice for NEPTUNE. The Pi controls our motors, main camera, and data measurement tools. Our code is split between the Pi and the topside computer for efficiency and accessibility.

Electronics Enclosure

The enclosure onboard the ROV is where we keep our electronics. With the aid of leak sensors, the enclosure prevents its contents from getting damaged and wet. This allows us to reconfigure our electronics quickly and efficiently.

The acrylic tube contains our Raspberry Pi, USB to RJ45 Extender, temperature sensor, ESCs, and other wires and parts on a removable tray for accessibility. The endcap in the back allows for wires to be connected to both the inside and outside of the enclosure.

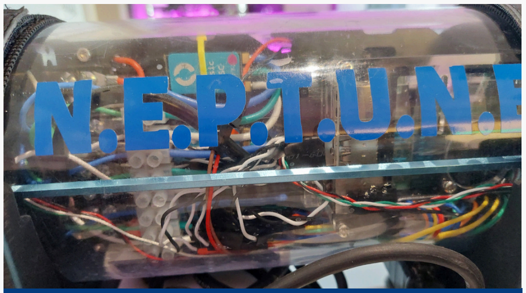


Figure 21: Closeup of Electronics Enclosure
Credit: Prajwala Chedella

Controller

To control the ROV, we use a Sony PlayStation 3 (PS3) controller. The PS3 controller's dual joysticks, analog triggers, array of digital buttons, low latency, and high levels of accuracy are vital for inputs controlling the thrusters and servos. Python libraries interpret the input from the PS3 controller for the thrusters and servos.

The controller and Ethernet adaptor are connected to the topside computer through the USB hub due to the topside computer's limited ports. HHM ROV does not use a remote piloting system (RPS) as the size of our control station did not warrant an RPS. Two computers are used for the ROV, one to view the external camera feeds and the other to view our main camera, configure the sensors, and send signals to the thrusters. The PS3 controller is used to control the motors and the pneumatic toggle controls the claw. A carabiner is attached to the table for topside strain relief.

SOFTWARE

Topside Software

This year, HHM ROV coded the functionalities of the ROV from scratch. We implemented an improved application in place of last years unreliable control software. The ROV is controlled through Python due to its ease of use and many libraries that speed up the troubleshooting and development process.

The software department built a GUI to streamline processes. Using a designer that came with the GUI library allowed quick prototypes and an overall better user experience. It is also heavily adaptable, fully cross-platform, easy to test, and not as limiting as other Python solutions. The GUI enables us to manually start the thrusters (via a button for safety) and collects and displays information from the Pi.

The thruster code converts controller inputs retrieved using the Python X-Input library into PWM signals. This library is used because it is simple, fast, and has better Windows support compared to other controller libraries. These PWM signals are sent using the PiGPIO Python library through an Ethernet cable inside our tether to our Raspberry Pi's GPIO pins which our thruster ESCs are connected to. By utilizing multiple libraries and custom code to gather inputs and generate outputs, our company has created a system capable of controlling our ROV. The GUI allows users to input data and displays output data, such as temperature sensor readings.

The topside computer also contains the sensor receiving code. The sensor's data is transmitted via UDP sockets by a companion script on the Pi. The code collects the data from the IP-based socket and displays it on the GUI, allowing for ease of use.

ROV Software

The Raspberry Pi inside the ROV also uses Python, containing the second half of the sensor script. Using a modified version of the tsys01 library, the Pi collects the data from the sensor. This is sent to the topside computer through UDP sockets from the socket library. UDP was chosen due to its versatility, reliability, and speed without requiring an external server. Sockets were also used to prevent lag on the Ethernet.

The Pi is also used to view the main camera feed. We use VNC to access the Pi and run the code to view our camera feed. We use the OpenCV and threading modules to view our camera feeds and a Tkinter GUI to select our camera. Furthermore, OpenCV enables image and video manipulations, allowing the possibility of measurement and other functions.

These multiple methods of communication allow the topside and ROV computer to work as efficiently and effectively as possible.

See Appendix B for the Software Flowchart for more information.

SAFETY

Safety Rationale

Safety is of the utmost importance to our company. At HHM ROV, we have gone to great lengths to ensure that our ROV meets all aspects of safety, preventing any avoidable accidents and guaranteeing the well-being of all our employees. Each of our employees is trained in safety procedures, as well as risk management protocols which are highlighted in our Job Safety Analysis (JSA). Each member has carefully analyzed all safety measures to follow on deck to ensure that no equipment or member is harmed. For example, it is necessary to wear closed-toe shoes and tie back long hair on deck. Additionally, we ensure to take extra precautions while using tools, including having a teacher supervising, safety goggles, and gloves, ensuring proper PPE is utilized.

We ensure to follow safety checklists for pre-run, construction, and on deck, which can be found in Appendix G.

Safety Features

Our ROV is equipped with many safety features and complies with safety guidelines provided by MATE. Our ROV frame was completely rounded with a hand router to ensure that there were no sharp edges. All other parts that could not be rounded with the router were sanded down with an electric sander. Our thrusters are shrouded to fit IP-20 standards with 3D-printed shrouds. The thrusters are also labeled as moving parts and potentially dangerous. These labels are also applied to our claw which can be classed as a potentially dangerous component. We have strain relief attached via two U-bolts on the back of our ROV, and topside via a carabiner that can attach to a surface on deck. A 25A fuse is placed within 30cm of our power supply -- connected via Anderson powerpole connectors -- to ensure no electronic damage due to power surges. Additionally, a 7.5A fuse is implemented on our float, Trident.


Figure 22: Anderson Powerpole connector
Credit: Waffa Zahralyn


Figure 23: Fuse ~10.5cm from power supply
Credit: Waffa Zahralyn


Figure 24: Strain Relief
Credit: Waffa Zahralyn


Figure 25: Shrouded thrusters
Credit: Waffa Zahralyn


Figure 26: Sanded down edges
Credit: Waffa Zahralyn

ACCOUNTING

Budget

At the beginning of the project, we set a tentative budget and discussed how we would attain it. This year our build budget was $3,000 USD, we obtained funding through a school recycling program and our sponsor, SubSea7, and funding from our MATE ROV regional competition. For travel, we received $14,680 USD from the MATE Regional, $2,000 USD from the Schmidt Ocean coalition, and $1,100 USD from Harvey's Home Heating. Once finalized, all operational groups adhered to the budget during the ROV's build phase and preparation. All purchases required approval from the supervisor and team leads. Furthermore, we investigated numerous vendors before purchasing all parts to guarantee fair prices for each product.

Project cost

A detailed breakdown of the ROV's cost to be built can be found in Appendix A. Our company adhered to the budget and no funds were wasted or misallocated to personal ventures. Alongside this, the expected travel cost is $ 21,972 USD for 11 of our team members to travel to Kingsport, Tennessee, USA which encompasses all hotel, food, and transportation costs.

CRITICAL ANALYSIS

Testing and Trouble Shooting

During our design process, our ROV underwent extensive testing, through multiple pool tests. One aspect of our ROV that we had to do a lot of testing on was the ROV's buoyancy. To achieve neutral buoyancy we did extensive testing of our ROV in water. During the inaugural test of our ROV, it floated, therefore we added some weight to the ROV. We then tested it in the water again and observed that it floated and additional weight was necessary. We repeated this process, adding weight when the ROV floated and buoyancy foam when it sank, to achieve neutral buoyancy. When we initially tested our ROV using props similar to those of the MATE competition we determined additional camera views were required for optimal operation. We then tested the cameras at several angles mounting them temporarily to the ROV using tape and determined the optimal camera angles to have the largest field of view. We then permanently mounted the cameras at these optimal angles using hot glue.

The 12V voltage limit and 25A current limit regulated by the MATE competition meant extensive coding and troubleshooting were required to prevent our T200 thrusters from overdrawing power. During our initial testing, we found that our electronics and Raspberry Pi would shut down. We troubleshot this problem by testing each electrical component separately to determine which was causing our electronics to shut down. We determined that if our thrusters were run for even a short amount of time our electrical systems would shut down due to the thrusters' overdrawing power. Our company built custom code that allows the user to limit voltage and amperage sent to each thruster by choosing a power value between 0-400. Testing was required to determine the optimal thruster value. We initially set the thruster power value to 100, we then increased the value by increments of 25 until the ROV shutdown due to thruster overdraw. We then decreased the value until the ROV stopped shutting down therefore determining the optimal power value.

During the design of the ROV's frame, the design and fabrication department created several wooden prototypes. These wooden prototypes were then compared and improved on to create the final design which was cut out of PVC derivative Foamalux.

While testing the lift capacity of our ROV we determined that our ROV tilted forward when lifting heavy objects. This meant we had to use our horizontal thrusters to lift heavy objects, as when the ROV is tilted forward the horizontal thrusters are positioned vertically. Pressing the backwards button when the ROV is in this orientation caused the ROV to move upwards and the forwards button caused the ROV to move forwards in the water.

ACKNOWLEDGMENTS

HHM ROV respectfully acknowledges the island of Newfoundland as the traditional unceded homeland of the Mi'kmaq and the Beothuk as well as the land in which the company is located. HHM ROV is appreciative of SubSea7 as our sponsor, providing us with resources, and for MATE II for hosting this year’s competition. Finally, we thank the Marine Institute for giving testing opportunities as well as Holy Heart for providing an environment for STEM learning. We’d also like to send our appreciation to Harvey’s Home Heating, MATE II, and the Schmidt Ocean Coalition for their generous stipends to aid our travel to the World Championships.

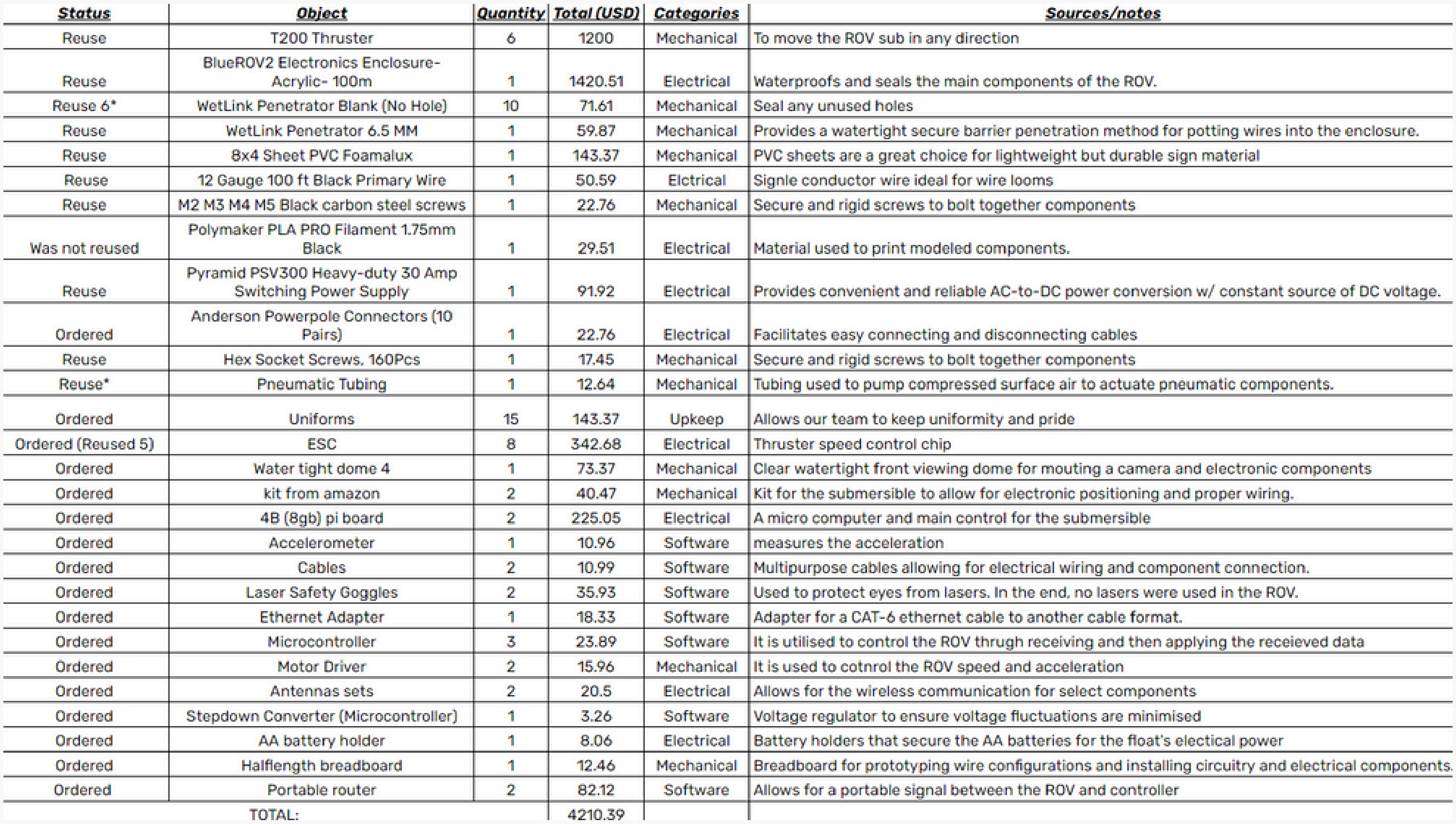
REFERENCES

- Mate ROV - https://materovcompetition.org/
- PiGPIO - https://abyz.me.uk/rpi/pigpio/
- OpenCV - https://opencv.org/
- PyQt5 - https://doc.qt.io/qtforpython-5/
- Qt Designer - https://doc.qt.io/qtforpython-5/
- tsys01-python - https://github.com/bluerobotics/tsys01-python
- ms5837-python - https://github.com/bluerobotics/ms5837-python
- X-Input - https://pypi.org/project/XInput-Python/
- gpiozero - https://gpiozero.readthedocs.io/
- FFmpeg - https://ffmpeg.org/documentation.html/
- smbus2 - https://smbus2.readthedocs.io/en/latest/index.html
- adafruit_mpu6050 - https://docs.circuitpython.org/projects/mpu6050/
- Adafruit_CircuitPython_Motor - https://docs.circuitpython.org/projects/motor/
- PySDL2 - https://pysdl2.readthedocs.io/
- Canva - https://www.canva.com/
- Blue Robotics - https://bluerobotics.com/
- Raspberry Pi - https://www.raspberrypi.com/
- Solidworks - https://www.solidworks.com/
- MasterCam - https://www.mastercam.com/
- TinkerCAD - https://www.tinkercad.com/

APPENDICES

Appendix A: Accounting

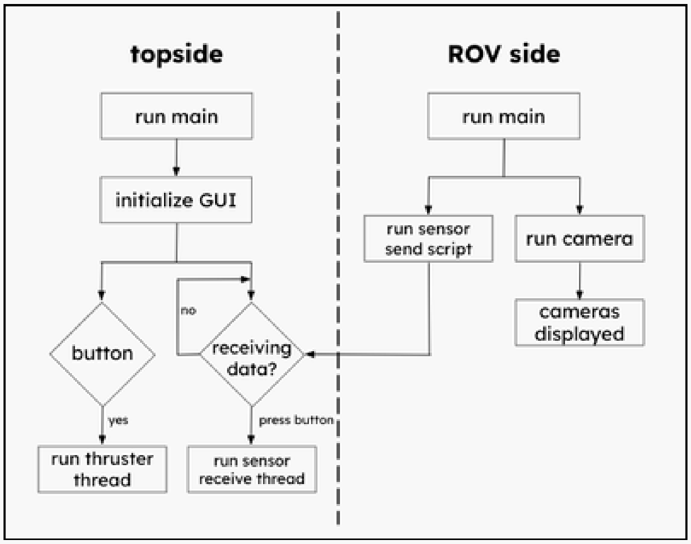
Table 1: Accounting Document | Credit: Lucas Lownds, Priya Purohit, Evan Fang, Frank Chen



Status	**Object**	**Quantity**	**Total (USD)**	**Categories**	**Sources/notes**
Reuse	T200 Thruster	6	1200	Mechanical	To move the ROV sub in any direction
Reuse	BlueROV2 Electronics Enclosure- Acrylic- 100m	1	1420.51	Electrical	Waterproofs and seals the main components of the ROV.
Reuse 6*	WetLink Penetrator Blank (No Hole)	10	71.61	Mechanical	Seal any unused holes
Reuse	WetLink Penetrator 6.5 MM	1	59.87	Mechanical	Provides a watertight secure barrier penetration method for potting wires into the enclosure.
Reuse	8x4 Sheet PVC Foamalux	1	143.37	Mechanical	PVC sheets are a great choice for lightweight but durable sign material
Reuse	12 Gauge 100 ft Black Primary Wire	1	50.59	Elctrical	Signle conductor wire ideal for wire looms
Reuse	M2 M3 M4 M5 Black carbon steel screws	1	22.76	Mechanical	Secure and rigid screws to bolt together components
Was not reused	Polymaker PLA PRO Filament 1.75mm Black	1	29.51	Electrical	Material used to print modeled components.
Reuse	Pyramid PSV300 Heavy-duty 30 Amp Switching Power Supply	1	91.92	Electrical	Provides convenient and reliable AC-to-DC power conversion w/ constant source of DC voltage.
Ordered	Anderson Powerpole Connectors (10 Pairs)	1	22.76	Electrical	Facilitates easy connecting and disconnecting cables
Reuse	Hex Socket Screws. 160Pcs	1	17.45	Mechanical	Secure and rigid screws to bolt together components
Reuse*	Pneumatic Tubing	1	12.64	Mechanical	Tubing used to pump compressed surface air to actuate pneumatic components.
Ordered	Uniforms	15	143.37	Upkeep	Allows our team to keep uniformity and pride
Ordered (Reused 5)	ESC	8	342.68	Electrical	Thruster speed control chip
Ordered	Water tight dome 4	1	73.37	Mechanical	Clear watertight front viewing dome for mouting a camera and electronic components
Ordered	kit from amazon	2	40.47	Mechanical	Kit for the submersible to allow for electronic positioning and proper wiring.
Ordered	4B (8gb) pi board	2	225.05	Electrical	A micro computer and main control for the submersible
Ordered	Accelerometer	1	10.96	Software	measures the acceleration
Ordered	Cables	2	10.99	Software	Multipurpose cables allowing for electrical wiring and component connection.
Ordered	Laser Safety Goggles	2	35.93	Software	Used to protect eyes from lasers. In the end, no lasers were used in the ROV.
Ordered	Ethernet Adapter	1	18.33	Software	Adapter for a CAT-6 ethernet cable to another cable format.
Ordered	Microcontroller	3	23.89	Software	It is utilised to control the ROV thrugh receiving and then applying the receieved data
Ordered	Motor Driver	2	15.96	Mechanical	It is used to cotnrol the ROV speed and acceleration
Ordered	Antennas sets	2	20.5	Electrical	Allows for the wireless communication for select components
Ordered	Stepdown Converter (Microcontroller)	1	3.26	Software	Voltage regulator to ensure voltage fluctuations are minimised
Ordered	AA battery holder	1	8.06	Electrical	Battery holders that secure the AA batteries for the float's electical power
Ordered	Halflength breadboard	1	12.46	Mechanical	Breadboard for prototyping wire configurations and installing circuitry and electrical components.
Ordered	Portable router	2	82.12	Software	Allows for a portable signal between the ROV and controller
	TOTAL:		4210.39		

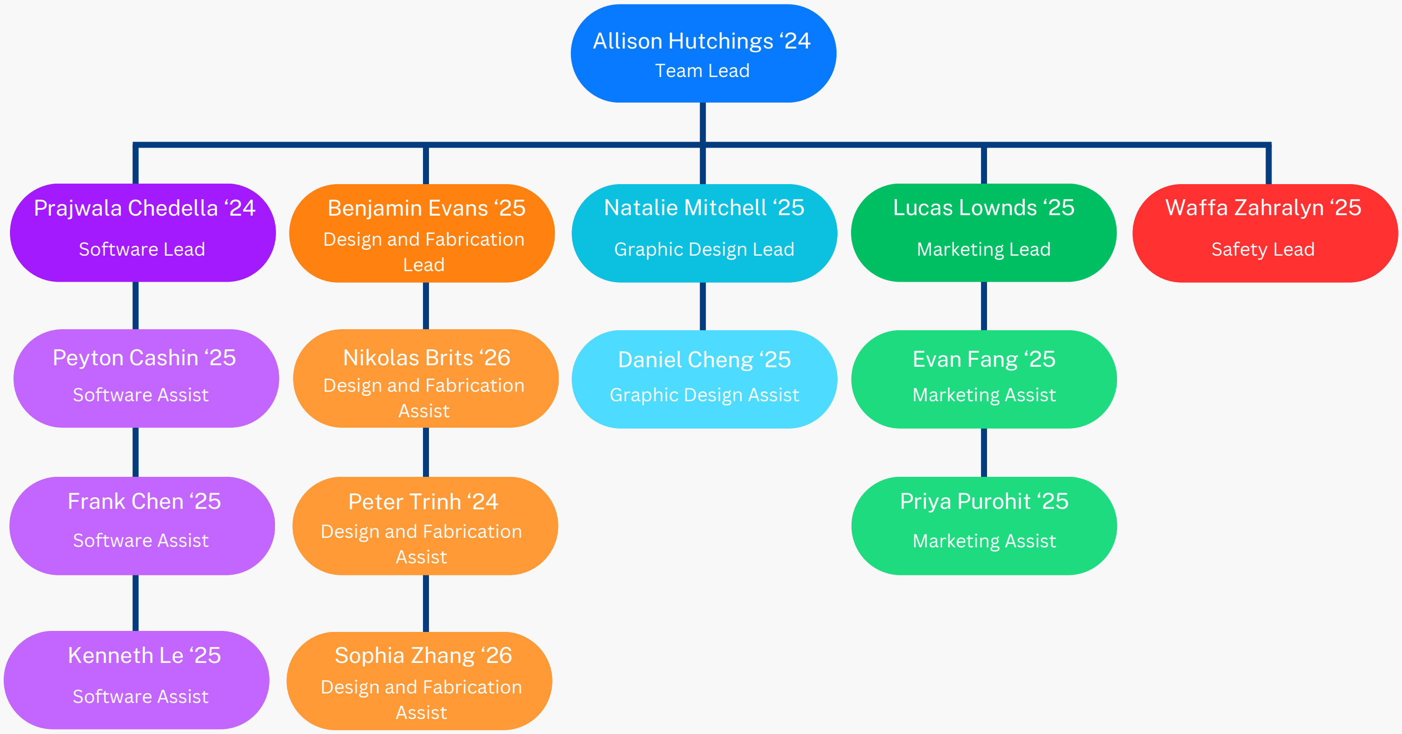
Appendix B: Software Flowchart

Figure 27: Software Flowchard | Credit: Prajwala Chedella, Daniel Cheng



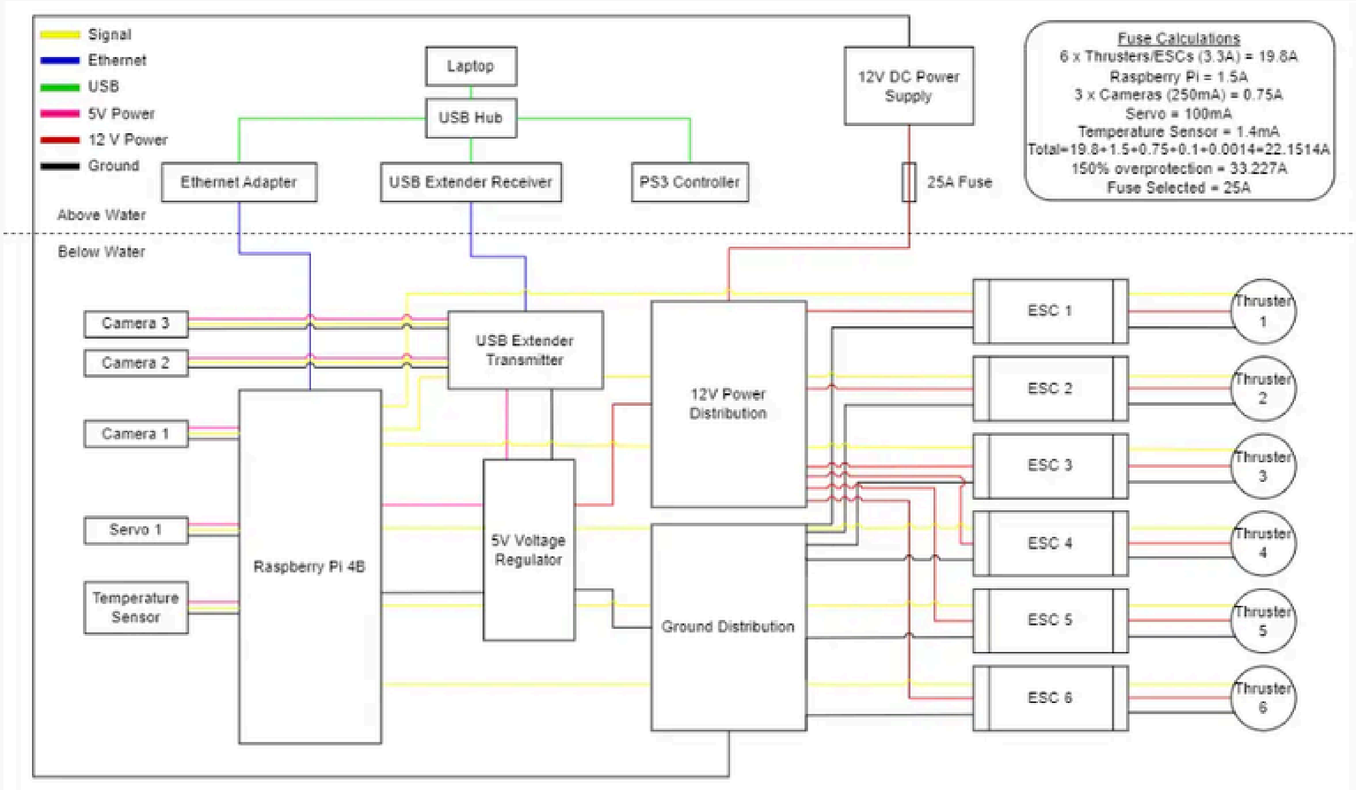
Appendix C: Company Organization

Figure 28: Company Organization Diagram | Credit: Prajwala Chedella, Daniel Cheng



Appendix D: ROV SID

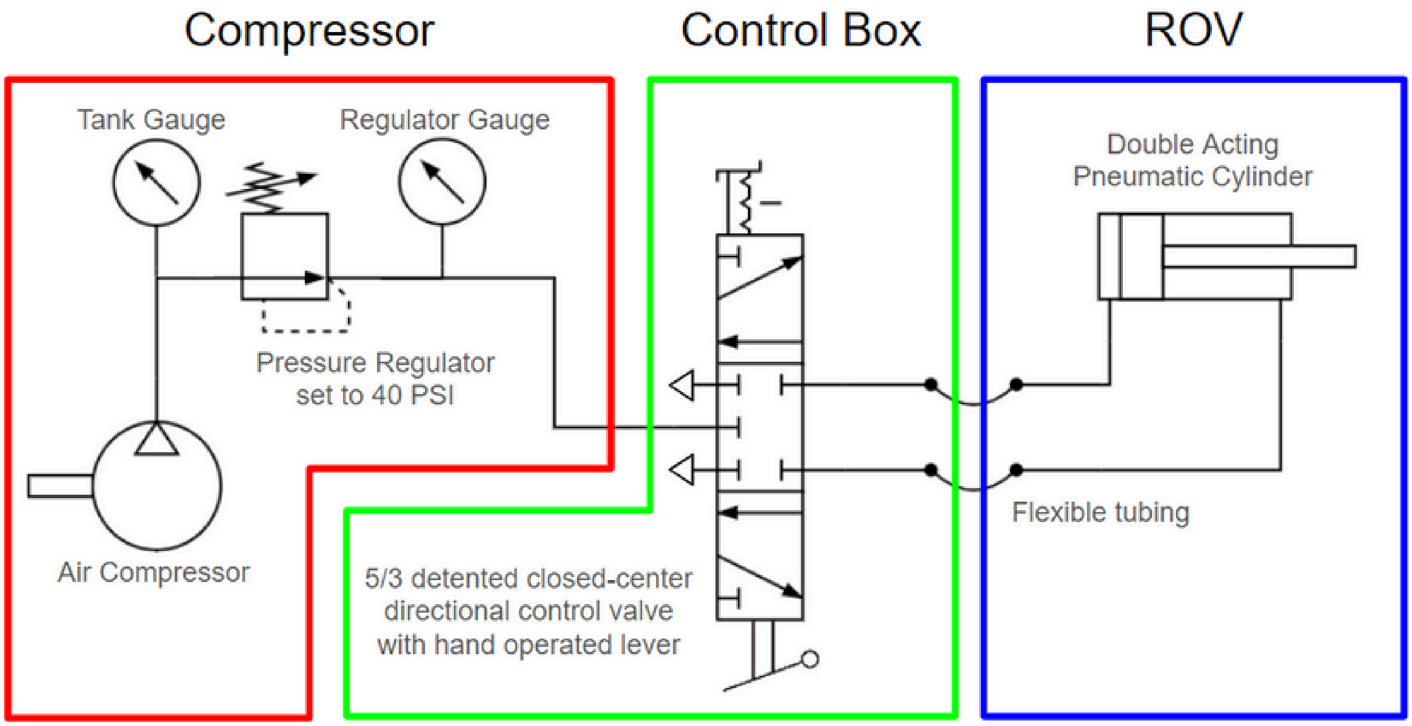
Figure 29: ROV (NEPTUNE) SID | Credit: Allison Hutchings



Fuse Calculations
6 x Thrusters/ESCs (3.3A) = 19.8A
Raspberry Pi = 1.5A
3 x Cameras (250mA) = 0.75A
Servo = 100mA
Temperature Sensor = 1.4mA
Total=19.8+1.5+0.75+0.1+0.0014=22.1514A
150% overprotection = 33.227A
Fuse Selected = 25A

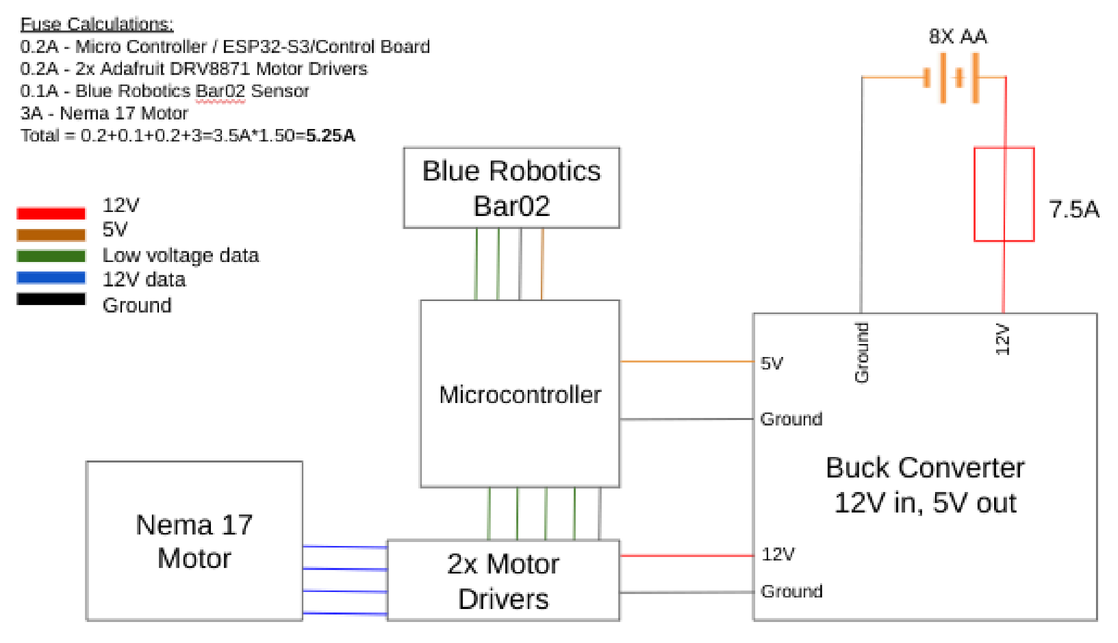
Appendix E: Pneumatics SID

Figure 30: Pneumatics SID | Credit: Peter Trinh



Appendix F: Float SID

Figure 31: Float (TRIDENT) SID | Credit: Peyton Cashin, Daniel Cheng, Allison Hutchings



Appendix G: Safety Checklists

Table 2: Safety Checklists | Credit: Waffa Zahralyn, Benjamin Evans

On Deck Checklist

- Ensure no tripping hazards
- Proper PPE is worn
- Wear closed-toed, non-slip shoes
- A Job Safety Analysis is carefully followed by all employees on deck
- Make sure the area is clean
- Ensure that long hair is tied back
- Make sure that the air compressor is set to a max of 40 PSI while on deck

Safety Procedure (construction)

- Have a teacher supervise at all times
- Wear proper PPE in the lab
- Safety goggles while working with tools/soldering
- Wear closed-toed shoes
- Tie back long hair
- Wear gloves when working with electrical components
- Unplug tools when not in use

ROV Maintenance

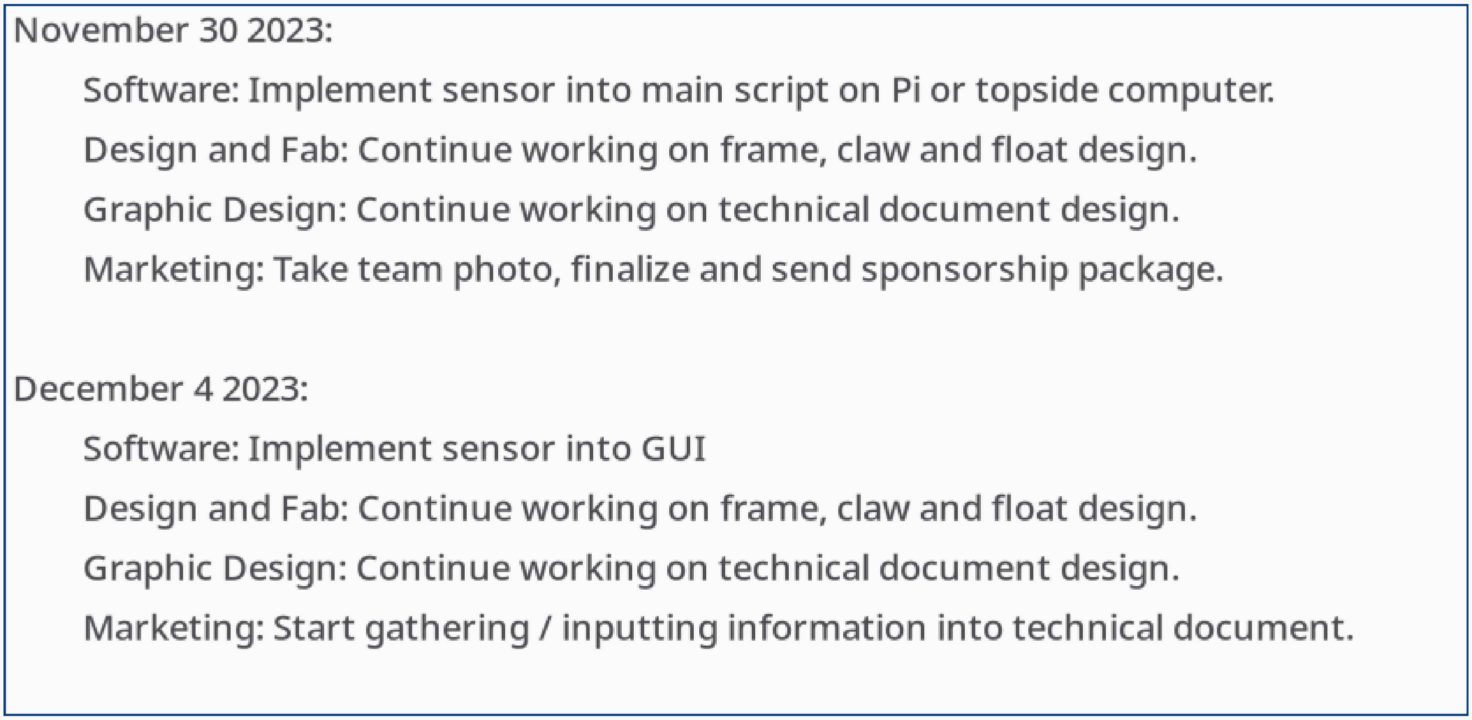
- Ensure all electronics are in proper working condition
- Check for any scratches, torn wires
- Make sure all edges remain unsharp
- Check for strain relief on the tether
- Ensure no splits in the tether
- Make sure no thruster guards are broken

Setup and Launch

- Keep the tether neatly coiled to make sure that it is not a tripping hazard.
- Attach topside strain relief to prevent wire pulling from ROV
- Communicate when ROV will be turned on and when thrusters will be tested
- Use proper lifting form when putting the ROV in the pool or taking it out

Appendix H: Team Task List

Figure 32: A sample of the team’s to-do list | Credit: Allison Hutchings, Peyton Cashin



November 30 2023:

Software: Implement sensor into main script on Pi or topside computer.

Design and Fab: Continue working on frame, claw and float design.

Graphic Design: Continue working on technical document design.

Marketing: Take team photo, finalize and send sponsorship package.

December 4 2023:

Software: Implement sensor into GUI

Design and Fab: Continue working on frame, claw and float design.

Graphic Design: Continue working on technical document design.

Marketing: Start gathering / inputting information into technical document.

Appendix I: HHM ROV Team Schedule

Figure 33: HHM ROV 2023-2024 Team Schedule | Credit: Daniel Cheng, Benjamin Evans