D-B EXCEL HIGH SCHOOL

# R-MATEYS *Kingsport, TN, US*

## 2024 MATE ROV Competition

*Ranger Class*

### Members

Kyle Gullion - VPF Specialist/VPF Operator
Elijah Hayes - CAD Engineer
Chase Howard - CFO/Co-Pilot
Micah Lawson - CEO
Riley Mars - Software Engineer/Poolside Tech
Alex Mccarthy - CAD Engineer
Connor McGlothlin - Pilot
Dawson Pendleton - Mechanical Engineer
Jack Reosti - Mechanical Engineer/Safety Specialist
Asy Smith - Lead Communication Specialist/Tether Manager
Devin Spears - Lead Documentation Specialist/VPF Operator
Chase Spears - Software Engineer
Zeva Zalewski - Communication Specialist

### Mentors

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Zackary Gardner - Eastman Chemical Company

# Table Of Contents



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# Abstract

The R-Mateys company, from D-B EXCEL High School located in Kingsport, Tennessee, comprises thirteen members ranging from 9th to 12th grade. When designing the mission tasks, the Marine Advanced Technology Education (MATE) center drew inspiration from the goals set forth by the United Nations Decade of Ocean Science for Sustainable Development to harness the energy of offshore wind and solar, ensure healthy ecosystems from mountains to sea, and deploy technologies to monitor ocean conditions. Determined to improve upon past experiences and inspired by Greek mythology's powerful immortal stingray, the R-Mateys created a remotely operated vehicle (ROV) named Trygon. Consisting of an extruded aluminum frame, two T200 Blue Robotics thrusters, four HAWK HOBBY thrusters, three analog cameras, and an electro-mechanical claw, Trygon was built efficiently and effectively to complete the mission tasks. This document describes the technical, digital, and company information that allowed the R-Mateys to fabricate Trygon, created to assist in the MATE Competition's objective, to expand the education of ocean ecosystems, climate, and wildlife.

# R-Mateys

### *Personnel*

*[Figure 1: Team Picture - Photo Credit: Daniel Day]*

Every R-Matey brings their expertise and interests to the team, contributing to the company's function and success. Within the team, members are divided into two distinct roles:  mentees and mentors. Based on a mentee's strengths and interests, they are paired with a more senior mentor. The senior members instruct and teach the younger engineers so that they can contribute this year and fulfill the mentor role themselves in the future. This strategic legacy planning process builds capacity in younger members and ensures that knowledge and experience are not lost as team members change.

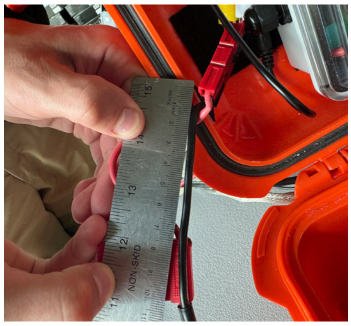
With this mentorship program in place, the company consists of three main departments: documentation, software, and building. Members of documentation are responsible for technical writing, marketing, and finances. The software team specializes in coding Trygon and its vertical profiling float (VPF). Fabrication of the ROV and VPF are handled by the build team. ***(View Appendix A: Company Structure)***

### *Project Management*

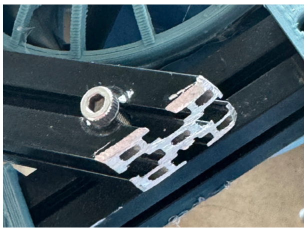
Construction of an ROV is not the only portion of managing a project of this scope. Early in the process, the company mapped out deadlines for the entire year, and consistently tracked progress against this schedule, making adjustments when necessary. The R-Mateys have also had consistent weekly practices on Thursday, Friday, and Saturday providing ample time for design, fabrication, and troubleshooting. During each practice, goals and objectives for the day were assigned to each team based on the project timeline. Debriefs of accomplished tasks were discussed with the entire company at the end of each practice to make plans for the next meeting. Outside of practice, the company used a combination of Google Drive and the BAND app for document storage and general communications. ***(View Appendix B: Team Schedule)***

### *Safety*

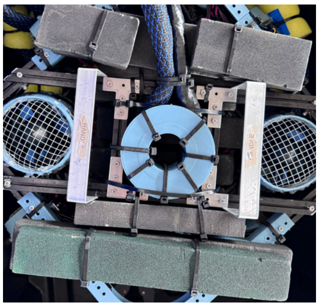
Safety is the number one concern of the R-Mateys. To ensure Trygon has achieved maximum safety and maximum efficiency, several intentional safety features have been included. For example, Trygon has motor shrouds, meticulously filed edges, and cut zip ties to prevent lacerations when handling the ROV. Taking this one step further, the R-Mateys decided to include two handles on the top of the ROV to ensure that all team members have a safe access point when manipulating Trygon. Both ends of Trygon's tether have proper strain relief to prevent pulling on the sensitive electronics within the ROV and control box. The control box contains a watt meter and a system kill switch protected by a 25 amp fuse. To ensure company personnel safety, the team members equipped themselves with safety glasses and gloves, and maintained a clean and organized workspace, with tools and equipment all reaching their appropriate locations. ***(View Appendix C: Safety Checklist)***



*[Figure 2: 25amp Fuse within 30cm - Photo Credit: Devin Spears]*



*[Figure 3: Filed Edges - Photo Credit: Devin Spears]*



*[Figure 4: ROV strain relief and safety handles - Photo Credit: Devin Spears]*

*[Figure 5: 3D printed Hawk Hobby motor shrouds - Photo Credit: Devin Spears]*

# Missions + UN Sustainability Goals

MATE is a company that strives to advance student learning and prioritizes real-world experiences. With this core belief, MATE decided to implement the United Nations Decade of Ocean Science for Sustainable Development and tackle the "10 Challenges for Collective Impact". This carefully curated list of ten challenges aims to enhance the condition of the ocean incrementally and serve as the source of inspiration for the tasks provided. The challenges are: (1) "Understand and beat marine pollution," which focuses on the research aspect, and understanding the amount of plastic and waste in the ocean; (2) "Protect and restore ecosystems and biodiversity," which prioritizes the understanding of the multiple issues and causes of pollution, and to, "protect, manage, and restore" ecosystems within the environment, with the heavy conditions affecting it; (3) "Sustainably feed the global population" which means to feed into the innovation and creativity of saving the ocean's health, which in turn is the primary food source for humanity, (4) "Develop a sustainable and equitable ocean economy" which supports and restores a healthy ocean economy and system, (5) "Unlock ocean-based solutions to climate change" which enhances the understanding of "Ocean Nexus", and to develop solutions to overall climate change and crisis in the ocean, (6) "Increase community resilience to ocean hazards" which creates and empowers warnings and hazard services, and encourages preparation for dangerous situations, (7) "Expand the global ocean observing system" encourages the creation of a system that will connect information and health-related data and transmit this information to all requested users, (8) "Create a digital representation of the ocean" asks teams to create a

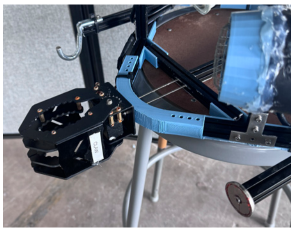

*[Figure 6: 10 Ocean Decade Challenges - Photo Credit: oceandecade.org]*

digital landscape with detail, including the past and present, along with the predictable future health of the ocean, (9) "Skills, knowledge, and technology for all" means to give the world equitable access to data and information about the ocean's health and safety, (10) "Change humanity's relationship with the ocean" charges the competitors to grow and expand the assistance and saving of the ocean's health (United Nations, 2023, pg. 15). These tasks allowed the R-Mateys to expand not only knowledge of the ocean's health, but also to save it. The MATE organization's challenges simulate real-world tasks that attempt to address current issues in the oceanic ecosystem, such as climate and pollution problems. The R-Mateys have designed Trygon, an ROV capable of completing the tasks asked of the competitors, while attempting to expand the community's and world's understanding of the current state of the ecosystems underwater, and the associated crisis.

## *Mission Task One: Coastal Pioneer Array*


*[Figure 7: Challenge 7 for Task 1 - Photo Credit: oceandecade.org]*

The Coastal Pioneer Array mission is oriented around the recovery of a float that begins at the bottom of the ocean. This float collects data on certain aspects of the water's health, allowing the R-Mateys to make observations and assist in improving the quality of the ocean based on the information given. This task is designed to test if the ROV can see and retrieve the malfunctioned recovery float.



*[Figure 8: Trygon's claw and auxiliary arms - Photo Credit: Devin Spears]*

*[Figure 9: Magnetic auxillary arm - Photo Credit: Devin Spears]*

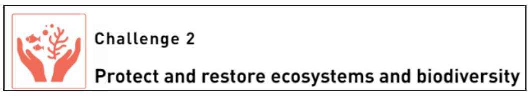
This task specifically is a claw-oriented mission, in which a two-prong claw was the best solution for the R-Mateys; the selected claw allows Trygon to have adequate strength and robustness for completing missions. Once the main release pin is pulled releasing the multifunction node's recovery float, Trygon will observe the recovery float finding that it incorrectly deployed and stayed tangled in the water with a front-mounted AV Camera. Upon failure, Trygon will use its auxiliary magnet arm to remove a newly revealed pin, detaching the recovery float from the node. Once properly deployed, recovery efforts will begin by attaching a recovery line to the multifunction node using the ROV's claw. Using Trygon's fourth positionable camera, the R-Mateys can easily locate the recovery float and allow Trygon to remove the float from the water.

## *Mission Task Two: SMART Cables for Ocean Observing*


*[Figure 10: Challenge 7 for Task 2 - Photo Credit: oceandecade.org]*

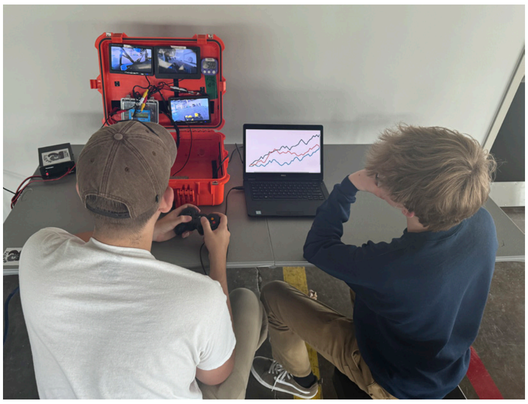
Science Monitoring and Reliable Telecommunications (SMART) Cables are an invention that has the potential to benefit the world in numerous ways. The SMART Cable is a design that connects the world for data communication and transmission, allowing data from undersea levels to be analyzed and used for the safety of the water, sea life, and the planet overall. This project is in development off the coast of Portugal and will reach from Libson to the Azores, to Madeira, and back to Lisbon. With this information, the company has designed an ROV that can deploy the SMART cable and included a SMART repeater, a tool used to measure water pressure and temperature. Task 2 simulates the deployment of the SMART Cable setup with SMART repeaters by connecting the cable through the required waypoints, returning the cable, and transferring data topside. The R-Mateys designed a custom detachable spool that is mounted on the back of the ROV using magnets. Once the SMART cable has been tied and wrapped around the spool, Trygon will drive the cable through the necessary waypoints and back to the surface. Trygon will then measure the temperature of the water, using a thermometer attached to the frame of the ROV, in the view of a live camera. After verifying the SMART repeater's temperature reading, the ROV will retrieve the power connector from the AUV docking station and connect it to the SMART cable repeater using its claw.

## *Mission Task Three: From the Red Sea to Tennessee: Understanding ecosystems and saving species*

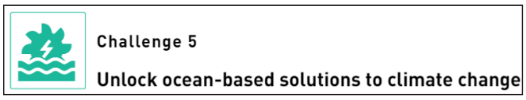


*[Figure 11: Challenge 2 for Task 3 - Photo Credit: oceandecade.org]*

Task 3 is focused on the repair of a coral reef and the gathering of data. Within Task 3.1, the first objective is to place a probiotic system near a coral head, and this will be accomplished by transporting it to the designated area using Trygon's claw and thrusters. After this, the ROV will place an irrigation line around the coral head and the irrigation system will be activated using the claw. Following the irrigation portion of the task, Trygon will then begin transplantation of the coral head in Task 3.2. The ROV will pick up a sample of coral using the claw and transport the coral head to the designated location.


*[Figure 12: Pilot and Co-Pilot graphing sturgeon thunder - Photo Credit: Devin Spears]*

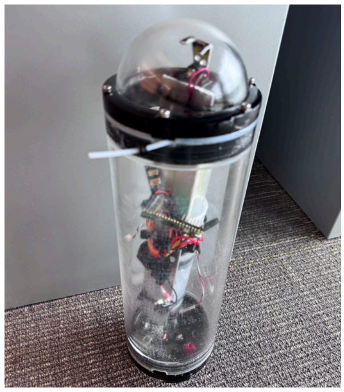
After performing Task 3.1 and 3.2, Trygon will 3D model the coral restoration area, and generate a scaled image of the coral to display on screen. As the 3D model is rendered, the ROV will locate the regions of sturgeon spawning grounds by retrieving the acoustic retriever with its claw. After retrieving the acoustic retriever, the company will create an accurate graph in Google Sheets of the sturgeon appearance rate over 15 days, which will be displayed on the screen.



*[Figure 13: Challenge 5 for Task 4 - Photo Credit: oceandecade.org]*

## *Mission Task Four: Mate Floats! 2024*

The MATE Competition set out a challenge: create a Vertical Profiling Float (VPF) that can gather data like water depth, pressure, and temperature, and send that information wirelessly to a computer above the surface. The GO-BGC Project by the National Science Foundation aims to help scientists worldwide access deep ocean data effortlessly. Over 4,000 floats are already in action, and the MATE competition wants a new one that can join this effort. To meet this challenge, the R-Mateys team devised a float capable of accomplishing this task.


*[Figure 14: VPF - Photo Credit: Devin Spears]*

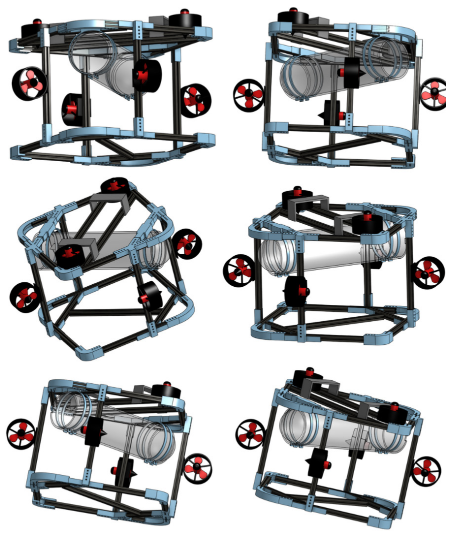
# Design Rationale - ROV

## *System Integration Designs (SIDs)* ***View Appendix D for Main ROV SID***

### *Initial Design*

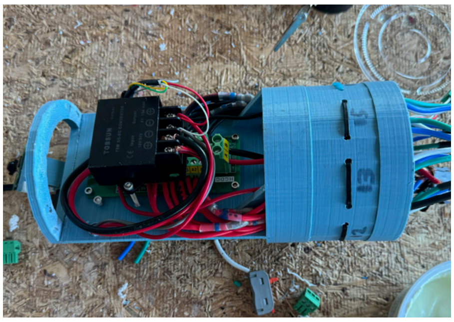
Trygon went through several design iterations before settling on its final shape. Initially, the team experimented with a hexagonal design for last year's competition. However, after weighing the advantages and disadvantages, such as buoyancy and overall balance, the company opted to revert to a cube-shaped ROV. This year's design deviates from the traditional cube by orienting the front at one of the corners. This adjustment allows for better accommodation of vectored motors and a smaller overall profile.

To determine the optimal size, the team considered various factors including height, camera positions, waterproof electronics enclosure size, and motor placement, while ensuring balanced weight distribution. After deliberation, the R-Mateys settled on dimensions of twelve inches in length and width and fourteen inches in height. This configuration allowed them to effectively accommodate all necessary components within Trygon, creating a versatile yet compact ROV.



[Figure 15: 3D model of Trygon - Photo Credit Alex McCarthy and Elijah Hayes]

The R-Mateys initially reused and incorporated a Blue Robotics 4-inch waterproof enclosure into this year's ROV design, aiming for fully onboard electronics integration. Power enters the enclosure and is distributed via a 12-terminal power distribution block. Within this enclosure, essential electronic components are housed, including six ESCs for the motors, along with two spares for rapid replacements, as well as the 12V to 5V power converter, a Raspberry Pi with a motor hat, and PiCamera (PiCam). This enclosure uses multiple O-rings and waterproofing grease to ensure that no water can enter the enclosure, while leaving the option to reopen the enclosure if necessary. To streamline maintenance and organization, a custom 3D printed tray was utilized, enhancing accessibility and orderliness for Trygon's upkeep.



[Figure 16: Trygon's onboard electronics in 3D printed tray - Photo Credit: Devin Spears]

Throughout the testing and troubleshooting phase, the R-Mateys discovered a serious waterproofing issue with the waterproof enclosure.  This problem persisted through many attempts to resolve this issue.  Four days prior to the Appalachian Highlands Regional Competition, the R-Mateys made a strategic decision to remove the waterproof enclosure and relocate all control electronics topside.  This resolved all of Trygon's operational issues. The size, shape, and orientation of the ROV, which was largely designed to accommodate the waterproof enclosure, was unaltered due to time constraints. However, the advantages of this design are still very prevalent, making Trygon very efficient in the pool.

## *Buy vs. Build*

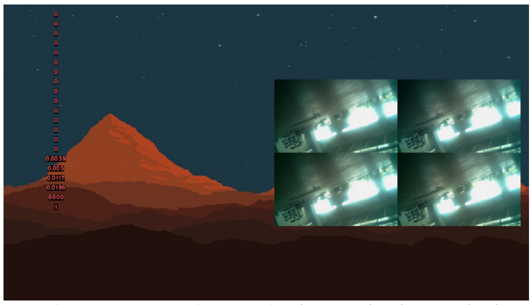
Trygon was the result of numerous hours of research and days of diligent work, all aimed at efficiently fulfilling the proposed tasks. Many components of Trygon were reused from previous years, aiding significantly in reducing this year's budget.  Materials like the extruded aluminum frame, all motors, buoyancy foam, the control box, and three monitors within the control box. Additionally, the R-Mateys utilized the Computer-Aided Design (CAD) skills of many company members to reduce overall spending. This allowed for the customization of specific items such as brackets for connecting the frame, motor shrouds, the ROV-side strain relief, and supplemental devices for completing specific tasks.

However, the team encountered a challenge due to the unavailability of all necessary materials at the outset. Consequently, the company meticulously assessed the essential components required for the ROV to function optimally and procured them based on a prepared list. This list consisted of servos, replacement cameras, a LewanSoul claw, backup motors, tether components, and filament for 3D printing.

[Figure 17: ROV and Control Box - Photo Credit: Devin Spears]

Regrettably, several purchased items turned out to be defective and did not perform as anticipated. These items were earmarked for either future use or donation. While the hydraulic claw utilized in the previous year was cost-effective, it did not possess the required strength or dependability. Thus, the decision to opt for a LewanSoul claw represented a clear and beneficial move forward.

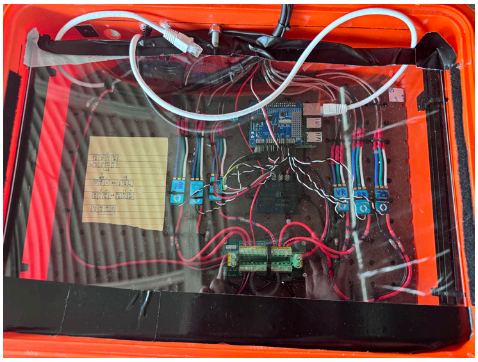
## System Operation



[Figure 18: Heads-Up Display on laptop - Photo Credit: Riley Mars]

Trygon is operated by two computers running Python programs. A laptop that functions as the host system and a Raspberry Pi 4B (RPi) that functions as a client system, both are connected via an ethernet cable. The devices share a Windows virtual drive, with Samba translating the RPi's Linux commands for the Windows host system. The shared drive is used by the Python program running on the host system to save the state of a connected gamepad's joysticks and buttons as a JavaScript Object Notation (JSON) file. The RPi will then load the JSON file and apply the saved values of the joysticks and buttons to its Pulse Width Modulation (PWM) motor HAT. The HAT will send PWM signals onto Blue Robotics Electronic Speed Controllers that will then control the thrusters of the ROV through the tether. The claw and PiCamera's servo, however, skip this final step because they are powered by a Servo and do not require an ESC to function, only the signal from the HAT. For example, if the left Joystick is pressed forward the host system will save this information and send it to the RPi, the RPi will then load this information and send it to the HAT which will pass the signal onto the designated ESCs and then activate the thrusters responsible for forward movement. This process is repeated for strafe, vertical, and backward movement except the designated ESCs and motors responsible for that movement will be activated.

## Control Box



[Figure 19: Control box electronics - Photo Credit: Devin Spears]

The R-Mateys' control box is housed within a waterproof hardshell case, serving as a central hub for the ROV's operations. Inside, essential components such as the power kill switch, watt meter, three AV monitors, RPi, ESCs, and tether connections are securely contained. Power is supplied via the standard Anderson Powerpole, then routed through the kill switch and watt meter before branching out to the AV monitors and power distribution block in the base of the container. From there, power is received by each ESC, camera power is sent down the tether through connectors in the back, and after going through a 12V to 5V power converter, the RPi and Motor HAT. Each ESC has three wires which go through independent tether connectors and to the ROV. The camera signal wires are connected to RCA jacks in the back of the box, providing video feed to the monitors in the lid of the control box. Two of these camera signals are connected to a RCA switch box, allowing the pilot to change the camera being displayed on one of the screens depending on the task being performed. Additionally, a hook on the back of the box, combined with a tether thimble provides strain relief for the cables and electronics inside. An ethernet cable extends from the RPi in the box to a laptop, completing Trygon's control system. Prior to the decision to move the electronics topside, the power distribution module, 12V to 5V power converter, ESCs, and RPi were housed inside the onboard waterproof enclosure.

## Cameras

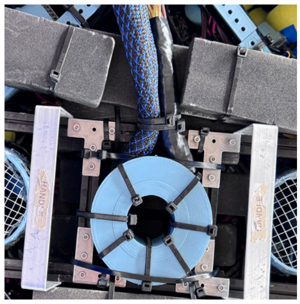
The ROV's design utilizes four analog cameras to provide the pilot with a clear field of view and sense of position in the pool. Analog cameras were chosen for their cost-effectiveness and interchangeability. The positioning of three of these cameras allows for a wide-angle view of the front while maintaining a sense of depth perception. The main camera is mounted on a bar just behind and above the claw mount, angled slightly downward for a centered view of the claw and

[Figure 20: Claw camera with back left and right below respectively - Photo Credit: Devin Spears]

forward direction. The other two cameras are mounted in peripheral positions on the back two vertical bars, angled partially outward from the front. These cameras expand the front-facing field of view by overlapping the edges of the peripheral cameras slightly with the respective edges of the main camera. This overlap helps to better the ROV's depth perception, as there can be multiple angles of one object. Additionally, the side cameras capture Trygon's two auxiliary bars, making the system more efficient.

Post-regional competition, the R-Mateys chose to add a fourth, moveable camera to allow Trygon to more efficiently complete the mission tasks. This fourth camera has an attached magnet that allows the team to change its position on the frame. For example, in Task 1 a surface-facing camera would be optimal for retrieving the recovery float. However, in Task 2, a rear-facing camera is ideal for the deployment of the SMART cable through the designated waypoints. This was a pivotal decision that allows Trygon to be more effective at completing tasks while minimizing product consumption, tether size, and overall complexity.

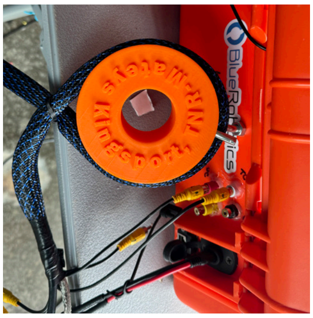
## Tether



[Figure 21: Strain relief on ROV - Photo Credit: Devin Spears]

The R-Mateys created an approximately 47-foot or 14.3-meter tether, consisting of five signal wires for cameras, two wires for camera power, and 21 wires for motor control, three on each motor that correspond with the motor control signals that come from each ESC. Additionally, Trygon features a 3D-printed strain relief mounted on top of its frame to ensure the safety of its components, as well as a detachable strain relief on the control box for the same purpose. To ensure tether management while poolside, the tether manager will visually determine the adequate tether length required for the ROV, however, the pilot may request for more or less tether from the tether manager, in which case the manager will respond accordingly.

In addition, the R-Mateys have created a spool system topside, ensuring the organization of the tether to prevent tangling when Trygon is not in use.



[Figure 22: Control Box Strain Relief - Photo Credit: Devin Spears]

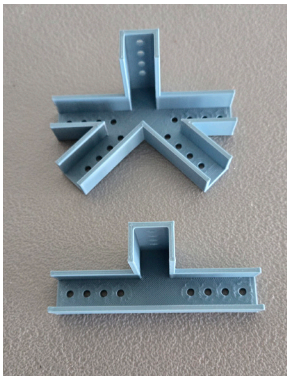
[Figure 23: Trygon tether - Photo Credit: Connor McGlothlin]

## Frame

Trygon's frame comprises 21 pieces of 15mm by 15mm T-slot anodized extruded aluminum. This material offers numerous advantages in construction, facilitating easy modifications and additions. The anodized coating provides resistance to rust and other forms of corrosion, crucial for operations in diverse environments. The T-slots present on all sides of the beam offer limitless possibilities for component placement and repositioning, including motors and custom 3D-printed brackets.

[Figure 24: MakerBeam extruded aluminum frame - Photo Credit: Riley Mars]

This year, the R-Mateys opted for a modified version of the traditional cube design for Trygon. The ROV's height slightly exceeds its width, enhancing stability in water by increasing the distance between the center of mass and the center of buoyancy. Moreover, the front-facing orientation of the ROV is situated at a corner of the cube, aligning each face along a diagonal.

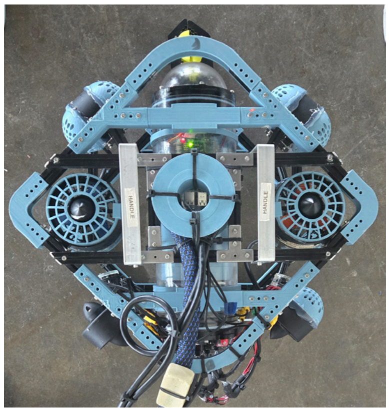


[Figure 25: Custom 3D printed brackets - Photo Credit: Riley Mars]

This arrangement facilitates the mounting of motors in a vector configuration without compromising stability or size. This aligns the motor along a diagonal axis from an overarching perspective, but keeps it parallel to a face of the ROV, allowing for ease of attachment and modification. With this frame configuration, the volume can be reduced by as much as 27% while still maintaining the same maneuverability in the pool.

### Motors

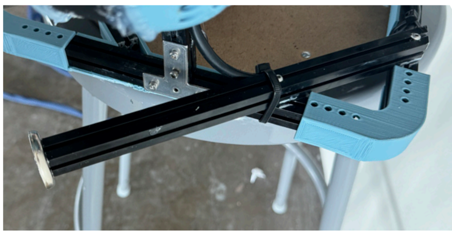
To provide propulsion to Trygon, the team has utilized two Blue-Robotics T200s as well as four HAWK HOBBY (HH) underwater thrusters. The T200s are mounted to the inner left and right corners at the top of the frame. These act as vertical motors allowing a quick descent and surface, even under load. The HH thrusters are mounted along the outside of each vertical support, in line with the center of mass. They are oriented in a vectored motor configuration. This allows each motor to act on two axes instead of a singular axis. Whichever axis the operator wants to move in, there is an opposing motor that will cancel out thrust in the unwanted axis. The motor and directional combinations are assigned in the code to inputs on the controller. This configuration allows for fewer motors to create more thrust on all axes (Moore et al., 2019, p 351-354).
When powered with a standard 12-volt power supply, each of the T200s pull 17 amps under load and the HH thrusters pull 15 amps according to each manufacturer's specifications. (Blue Robotics, 2024 & Amazon, 2024, pg. 15) To operate under the 25 amp constraint, the software team has added a governor to each motor, limiting the amperage pulled to 5 amps and 3.25 amps respectively as measured by the watt-meter during testing.



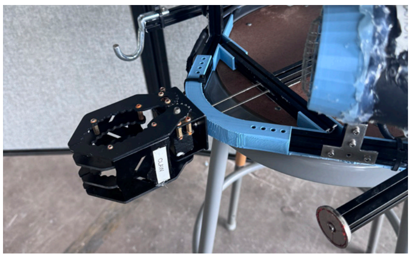
[Figure 26: Vectored motor configuration - Photo Credit: Riley Mars]

### Manipulators

The ROV features a LewanSoul mechanical robot claw, operated by a waterproofed servo motor directly connected to the motor hat of the RPi. This claw design offers substantial grip strength, capable of securely grasping a 4-inch diameter PVC pipe. Additionally, its four-fingered design provides a larger contact area for object manipulation. Trygon is also equipped with two backup manipulators in the form of a magnet and hook. These auxiliary bars, situated on the front left and right, enable Trygon to maintain operational effectiveness in the event of claw malfunction or failure.



[Figure 27: Right auxiliary arm with magnet - Photo Credit: Devin Spears]



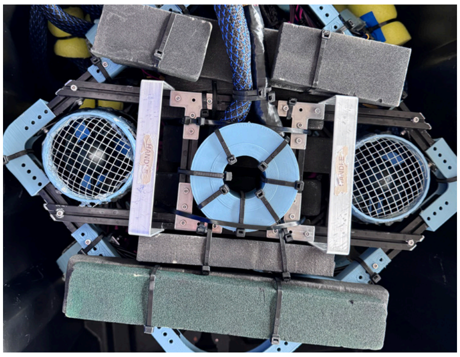
[Figure 28: Claw - Photo Credit: Devin Spears]

[Figure 29: Left auxiliary arm - Photo credit: Devins Spears]

### Buoyancy

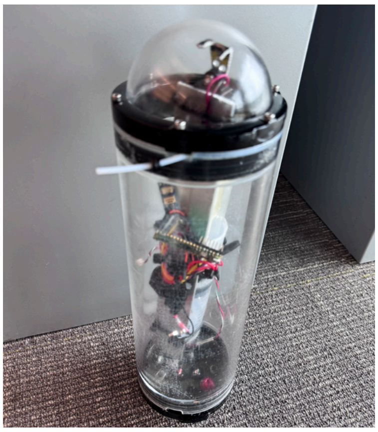
Trygon represents a significant improvement over last year's design in terms of weight management. With a total weight of 6.485 kg, the team faced no challenges in achieving buoyancy or ensuring agility in the water. The R-Mateys made use of a surplus of Subsea R3312 buoyancy foam, allowing Trygon to achieve neutral buoyancy. The design of Trygon resulted in a concentration of weight towards the rear of the ROV, primarily due to the majority of cable management funneling towards the back. To address this imbalance, a substantial portion of the buoyancy foam was affixed to the rear section. Fortunately, thanks to the symmetrical design of the frame, weight distribution remained even on both sides, maintaining equilibrium and stability for Trygon.

Originally, the waterproof enclosure was the major buoyant force for Trygon. The initial ROV needed 290 grams of buoyancy foam with the waterproof enclosure to achieve neutral buoyancy. However, after removing the waterproof enclosure, Trygon needed 587 grams of total buoyancy foam to return to neutrality. This was approximated via mathematical calculations and confirmed through testing the ROV in the water and weighing the actual amount of foam required.



*[Figure 30: All buoyancy foam - Photo Credit: Devin Spears]*

# Design Rationale - VPF



*[Figure 31: VPF - Photo Credit: Devin Spears]*

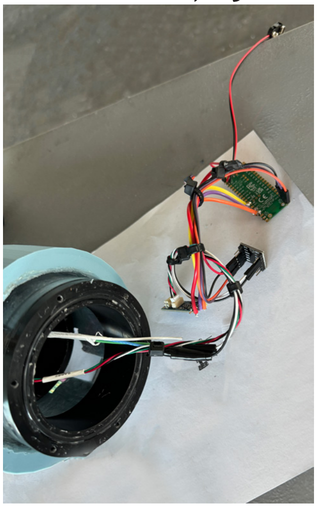
### *Initial Design*

The Vertical Profiling Float (VPF) the R-Mateys have meticulously designed consists of a waterproof enclosure, carefully designed to shield the electronic components from water, ensuring their dryness. The mechanism for water intake and expulsion is the syringe which is positioned downward and hooked to a tube protruding from the bottom of the waterproof enclosure to prevent it from leaving the water and possibly taking in air. Operated by a linear actuator controlled by a motor controller connected to the Pi, this setup allows the syringe to pump water in and out, thus altering the overall buoyancy.

The Pi, motor controller, and battery supply are stored next to the syringe. Mounted on the bottom of this enclosure is a water pressure sensor, which connects to an I2C converter, subsequently linked to the Raspberry Pi Pico W (RPi Pico). The RPi Pico communicates to the topside receiver via Local Area Network (LAN) using the Hypertext Transfer Protocol (HTTP). The RPi Pico hosts a HTTP page that is dynamically updated with pressure data. The receiver connects to the RPi Pico's LAN page via an internet browser.

### *VPF Electronics*

The VPF electronics are all controlled by an RPi Pico. The system is powered by a four AA battery pack wired in series to output 6v. The RPi Pico is connected to a motor controller that reverses the polarity supplied to the linear actuator driving the syringe. The RPi Pico is also connected to the water pressure sensor with its associated Blue Robotics I2C logic converter.



*[Figure 32: VPF Electronics - Photo Credit: Devin Spears and Kyle Gullion]*

### *Buy vs. Build - VPF*

After removing it from the main ROV, the team repurposed Trygon's waterproof enclosure for the VPF. Both the RPi Pico and the motor controller were also on hand from previous projects. The company decided to reuse the linear actuator from an earlier VPF model. The only new purchases were a water pressure sensor and an I2C converter, which enabled the RPi Pico to communicate with the pressure sensor.

***SIDs*** *View Appendix F for VPF SID*

# Accounting

A budget allows the R-Mateys to plan for future expenses, allocate resources effectively, and make informed decisions about purchasing and maintenance. By creating and following this budget, the company can avoid unexpected expenses and ensure that ROV operations are safe, efficient, and cost-effective.

## *Estimated Costs*

| Account Balance | | | Amount |
|---|---|---|---|
| R-Matey's Activities Account | | | $ 12,920.18 |
| | | | |
| Budgeted Expenses | | | |
| Category | | Description/Examples | Monetary Value |
| VPF | Purchased/New | VPF | $250.00 |
| Waterproof Enclosure | Purchased/New | Shorter Enclosure | $163.00 |
| ROV Components | Purchased/New | Frame material | $600.00 |
| ROV Components | Re-Used/Built | Frame Material, Motor, PLA Filament | $300.00 |
| Control Systems | Purchased/New | ESCs, Cameras, Motor Controllers, Raspberry Pi | $450.00 |
| Control Systems | Re-Used/Built | Motor Controller, Raspberry Pi | $100.00 |
| User Interface | Purchased/New | Monitors, Analouge Switch, Watt Meter | $250.00 |
| User Interface | Re-Used/Built | Monitors, Analouge Switch, Watt Meter | $125.00 |
| Electrical Systems | Purchased/New | Wires, Wire Connectors, Solder | $300.00 |
| Electrical Systems | Re-Used/Built | Wires, Solder, Heat Shrinks | $100.00 |
| Tools | Purchased/New | nuts/bolts | $100.00 |
| Tools | Re-Used/Built | Drills, Screwdrivers, Tape Measures | $850.00 |
| Team Expenses | Purchased/New | T-shirts, Polos, Registration, Travel | $400.00 |
| Team Expenses | Re-Used/Built | | $0.00 |
| Props | Purchased/New | PVC Pipes, PVC Connectors | $250.00 |
| Props | Re-Used/Built | PVC Pipes, PVC Connectors | $250.00 |
| Non-ROV Components | Purchased/New | RPi Pico, Plastic Tubing, Weights | $150.00 |
| Non-ROV Components | Re-Used/Built | Wiring, Linear Accuator, Accelerometer | $60.00 |
| **Total** | | | **$ 2,913.00** |
| Company Income | | | |
| Category | Type | Description | Total Amount |
| Fundraising Events | Team Led Events | Fundraisers | $ 200.00 |
| Donations | Individuals | Family and friends | $ 200.00 |
| Sponsors | Company & Corporate | Business | $ 1,500.00 |
| | | | |
| | | Total Expenses | $ 2,913.00 |
| | | Total Income | $ 1,900.00 |
| | | *2023 Closing Account Balanc* | $ 11,907.18 |

[Figure 33: Estimated Budget - Photo Credit: Chase Howard]

## *Travel Expenses*

| Travel Expenses | | | |
|---|---|---|---|
| Varible | Description | Value | Unit |
| X | Distance from DBE to DBHS Pool | 5.2 | Miles |
| Y | Distance from DBE to ETSU | 52 | Miles |
| $G | Gas price as of 4/30/2024 | $3.10 | Dollars |
| C | Gas milage for a 2021 chevy silverado | 18.5 | MPG |
| V | Gas milage for Kingsport City Schools van | 12 | MPG |
| P | Number of practices at DB's pool | 10 | Round-Trips |
| Z | Distance from DBE to KAC | 3.8 | Miles |
| $B | Gas price as of 5/19/2024 | $3.16 | Dollars |
| | | | |
| | Calculation | | |
| | (P(X/C+X/V)+(Y/C+Y/V))*$G+(Z/C+Z/V)*B | **$45.94** | |

[Figure 34: Travel Expenses - Photo Credit: Chase Howard]

## Actual Costs

| Account Balance | | | Amount |
|---|---|---|---|
| R-Matey's Activities Account | | | $ 12,920.18 |
| | | | |
| Budgeted Expenses | | | |
| Category | | Description/Examples | Monetary Value |
| VPF | Purchased/New | VPF | $391.28 |
| Work-space Organization | Purchased/New | Shelf, toolbox | $268.98 |
| ROV Components | Purchased/New | Frame Material,Nuts,Bolts,Motors | $748.32 |
| ROV Components | Re-Used/Built | Frame Material, Motor | $0.00 |
| Control Systems | Purchased/New | ESCs, Cameras, Motor Controllers, Raspberry Pi | $486.64 |
| Control Systems | Re-Used/Built | Motor Controller, Raspberry Pi | $0.00 |
| User Interface | Purchased/New | Monitors, Analouge Switch, Watt Meter | $73.80 |
| User Interface | Re-Used/Built | Monitors, Analouge Switch, Watt Meter | $0.00 |
| Electrical Systems | Purchased/New | Wires, Wire Connectors, Solder | $201.27 |
| Electrical Systems | Re-Used/Built | Wires, Solder, Heat Shrinks | $0.00 |
| Tools | Purchased/New | Soder,Flux,Soder Braid,Filamet | $95.23 |
| Tools | Re-Used/Built | Drills, Screwdrivers, Tape Measures | $0.00 |
| Team Expenses | Purchased/New | T-shirts, Polos, Registration, Travel | $742.40 |
| Team Expenses | Re-Used/Built | | $0.00 |
| Props | Purchased/New | PVC Pipes, PVC Connectors | $240.95 |
| Props | Re-Used/Built | PVC Pipes, PVC Connectors | $0.00 |
| Non-ROV Components | Purchased/New | RPi Pico, Plastic Tubing, Weights, Magnets | $9.99 |
| Non-ROV Components | Re-Used/Built | Wiring, Linear Accuator, Accelerometer | $0.00 |
| Total | | | $ 3,258.86 |
| Company Income | | | |
| Category | Type | Description | Total Amount |
| Fundraising Events | Team Led Events | Fundraisers | $ - |
| Donations | Individuals | Family and friends | $ - |
| Sponsors | Company & Corporate | Business | $ 1,200.00 |
| | | | |
| | | Total Expenses | $ 3,258.86 |
| | | Total Income | $ 1,200.00 |
| | | 2023 Closing Account Balanc | $ 10,861.32 |

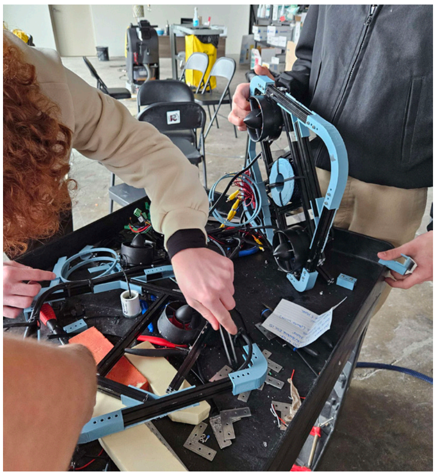
[Figure 35: Actual Cost - Photo Credit: Chase Howard]

# Critical Analysis

### Testing, Troubleshooting, and Challenges

Like any project, the R-Mateys encountered their fair share of challenges, and approached each problem accordingly,by convening, brainstorming, and implementing solutions found. The company encountered several major incidents with the ROV itself, including its collapse. However, the team members approached the situation with this process and tackled the incidents calmly and effectively.

The R-Mateys had several issues with the frame, particularly regarding the 3D-printed brackets. The frame, initially constructed with PLA brackets, turned out to be non-waterproof. Although the PLA brackets held up during initial water testing and throughout the first pool practice, Trygon collapsed upon unpacking, losing its original shape. In response, the team promptly replaced some of the PLA brackets with Makerbeam aluminum T-brackets.



[Figure 36: Half Robot - Photo Credit: Asy Smith]

The programming phase presented even greater hurdles. Motor programming, especially with reused T200 and HH motors from the previous year, proved difficult. Wiring errors occurred, and dysfunctional pins on the RPi's HAT, notably pin eight, were discovered. In addition, the programming team struggled with motor direction, which was inverted multiple times.

Additionally, integrating the PiCam into the code posed challenges due to limitations within the Windows operating system. To resolve this, a directory was mounted on the RPi, allowing files to be written directly to the topside laptop without issues. This solution facilitated seamless communication between the laptop and RPi.

The company encountered an even greater challenge, unforeseen by any of the members. The company had been struggling to ensure that the waterproof enclosure was completely waterproof. Each time Trygon was tested in deep water, about 10 ml of water was entering the enclosure. The R-Mateys tried several different approaches to properly waterproof the enclosure such as replacing o-rings, diligent greasing, replacing cable penetrators, using waterproof tape around the front, and dome of the enclosure. Eventually, the team decided to limit the number of potential leak points by setting the entire back plate and all penetrators in epoxy; this reduced the number of potential failure sites from 18 to 3. However, this did not resolve the issue. To maximize remaining pool time and ensure the reliability of Trygon, the team decided to completely remove the waterproof enclosure, and relocate all electronics topside. This presented an immense challenge due to time constraints, however, the company overcame the hardships and found an effective and immediate solution. The R-Mateys speculate that water was actually entering the system through solder joints between the motors and the waterproof enclosure, and traveling through the wires into the enclosure. This could potentially explain why individual motors would stop working initially followed by a total system failure when the water made contact with electronics.

*[Figure 37: R-Mateys Powwow - Photo Credit: Asy Smith]*

## *Lessons Learned & Future Improvements*

Upon deducing that the most likely reason for water leakage, the solder joints between motors and enclosure, the R-Mateys have improved the waterproofing process at these junctions.
Hot glue does not adhere to outer silicone insulation of the three wire motor cables. Moving forward this season, the R-Mateys are using multiple coats of liquid electrical tape to provide the necessary waterproofing. For future seasons, the R-Mateys is considering Blue Robotics's wetlink cable splice kit (Blue Robotics, 2024, pg. 15) as a potential alternative to waterproofing these joints.

*[Figure 38: CAD team working - Photo Credit: Asy Smith]*

Reflecting on lessons learned from last year's competition, the R-Mateys decided to steer clear of hexagonal frames. This frame configuration presented challenges in calculating the center of mass and configuring buoyancy foam. Additionally, the shortness of last year's frame design led to stability issues, resulting in capsizing due to reduced tipping tolerance. To address these shortcomings, the company opted for a cube frame for Trygon, significantly increasing the distance between the center of mass and buoyancy and thereby enhancing stability.

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# Conclusion

The R-Mateys have devoted endless hours to surmounting the hurdles of the MATE 2024 competition. Through unity and collaboration, they have forged Trygon, an ROV that embodies resilience and fortitude. The name Trygon symbolizes determination and strength, reflecting the ethos upon which the R-Mateys have built their company. Guided by the directives of the MATE competition challenges, Trygon's creation not only addresses the immediate competition goals but also contributes to the broader fight against climate change and the urgent global crisis of declining ocean health.

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# Acknowledgements


The R-Matey's would like to appreciate the MATE organization for allowing such an enjoyable and exciting competition and community as well as the following mentors for guidance and support through the 2023-2024 competition season.

- Erica Gardner, D-B EXCEL Teacher, and R-Mateys coach and sponsor.
- Zachary Gardner, Eastman Chemical Company-Chemical Engineer, and R-Mateys lead mentor
- Donald Mars, Software consultant, and mentor
- Lee Lawson, Software consultant and mentor
- Food City, Supermarket chain, and place to buy after-school snacks
- Barberitos, Mexican food, and best place for R-Mateys to get dinner

The Company also would like to acknowledge the support from the following supporters. The R-Mateys would not have been able to come this far without their support.

- Kingsport City Schools
- Braddock Holdings
- Streamworks

# Appendix

D-BEXCEL
Excellence in a Creative Environment for Learning

## Company Structure

| Department | | | | | |
|---|---|---|---|---|---|
| **Business** | | **Software** | | **Build** | |
| ***Mentors*** | | ***Mentors*** | | ***Mentors*** | |
| **Asy Smith**<br>Communications Specialist<br>*Third-year* | **Chase Howard**<br>Chief Financial Officer<br>*Second-year* | **Micah Lawson**<br>CEO & Motor Software<br>*Third-Year* | **Riley Mars**<br>Camera Software<br>*Second-year* | **Connor McGlothlin**<br>Pilot & Lead Mechanical/Electrical Engineer<br>*Fourth-year* | **Kyle Gullion**<br>VPF Specialist<br>*Second-year* |
| ***Mentees*** | | ***Mentees*** | | ***Mentees*** | |
| **Zeva Zalewski**<br>*First-year* | **Jack Reosti**<br>*First-year* | **Alex McCarthy**<br>*First-year* | **Chase Spears**<br>*First-year* | **Zeva Zalewski**<br>*First-year* | **Zeva Zalewski**<br>*First-yea* |
| **Jack Reosti**<br>*First-year* | | | | **Jack Reosti**<br>*First-year* | |
| ***Additional Members*** | | ***Additional Members*** | | ***Additional Members*** | |
| **Devin Spears**<br>Documentation Specialist<br>*Third-year* | | **Elijah Hayes**<br>CAD Engineer<br>*Second-year* | | **Dawson Pendleton**<br>Props Specialist<br>*Third-year* | |

*Appendix A - Company Structure*

# Trygon Project Timeline

## R-Mateys of D-B EXCEL

| Week | Task | Workable Dates | Completion Deadline |
|---|---|---|---|
| 37-38 | Applicant Interviews | 9/11 - 9/19 | 09/19/23 |
| 38-39 | New Member Onboarding | 9/18 - 9/25 | 09/25/23 |
| 39 | Clean & Organize Workspace | 9/25 - 10/1 | 10/01/23 |
| 39-41 | Mentor/Mentee Assignments | 9/25 - 10/12 | 10/12/23 |
| 39-41 | Project Brainstorming | 9/25 - 10/13 | 10/13/23 |
| 40-42 | Rubric Analysis | 10/2 - 10/19 | 10/19/23 |
| 42 | Schedule Confirmation | 10/16 -10/20 | 10/20/23 |
| 41-43 | Budget Development | 10/9 - 10/27 | 10/27/23 |
| 41-50 | Documentation Organization & Outlines | 10/9 - 12/4 | 12/04/23 |
| 42-5 | Prototyping and Fabrication | 10/16 - 1/29 | 2/1/24 |
| 3-6 | Props | 1/15 - 2/5 | 2/10/24 |
| 42-7 | VPF Prototyping and Fabrication | 10/16 - 2/12 | 2/15/24 |
| 40-9 | Fundraising | 10/2 - 2/26 | 3/1/24 |

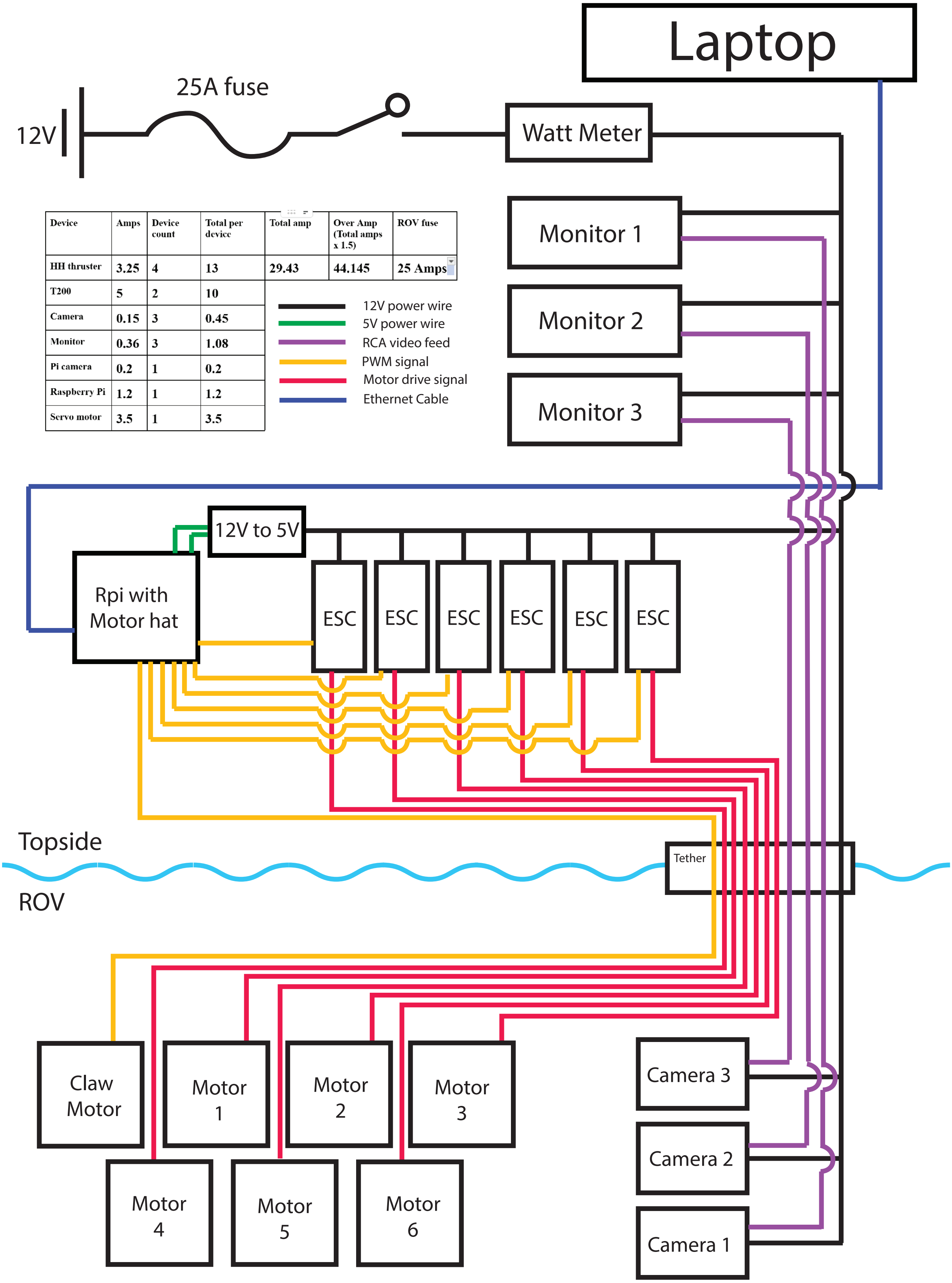
*Appendix B (1) - Team Schedule*

| Week | Task | Workable Dates | Completion Deadline |
|---|---|---|---|
| 2-9 | Final Purchase Orders Completed | 1/8 - 2/26 | 3/1/24 |
| 49-9 | Control Code | 12/4 - 2/26 | 3/1/24 |
| 49-11 | Camera Codes | 12/4 - 3/11 | 3/15/24 |
| 49-14 | Autonomous Code | 12/4 - 4/1 | 4/1/24 |
| 49-14 | Code Writing | 12/4 - 4/1 | 4/1/24 |
| 9-14 | Engineering Presentation | 2/26 - 4/1 | 4/1/24 |
| 2-16 | Testing and Troubleshooting | 1/8 - 4/15 | 4/15/24 |
| 49-16 | Documentation Writing | 12/4 - 4/15 | 4/15/24 |
| 10-19 | Pool Practices | 3/4 - 5/6 | 5/11/24 |
| 17-20 | Final Documentation Edits | 4/22 - 5/13 | Second Week of May |
| 20 | Compeititon | 5/11 | 5/11 |

*Appendix B (2) - Team Schedule*

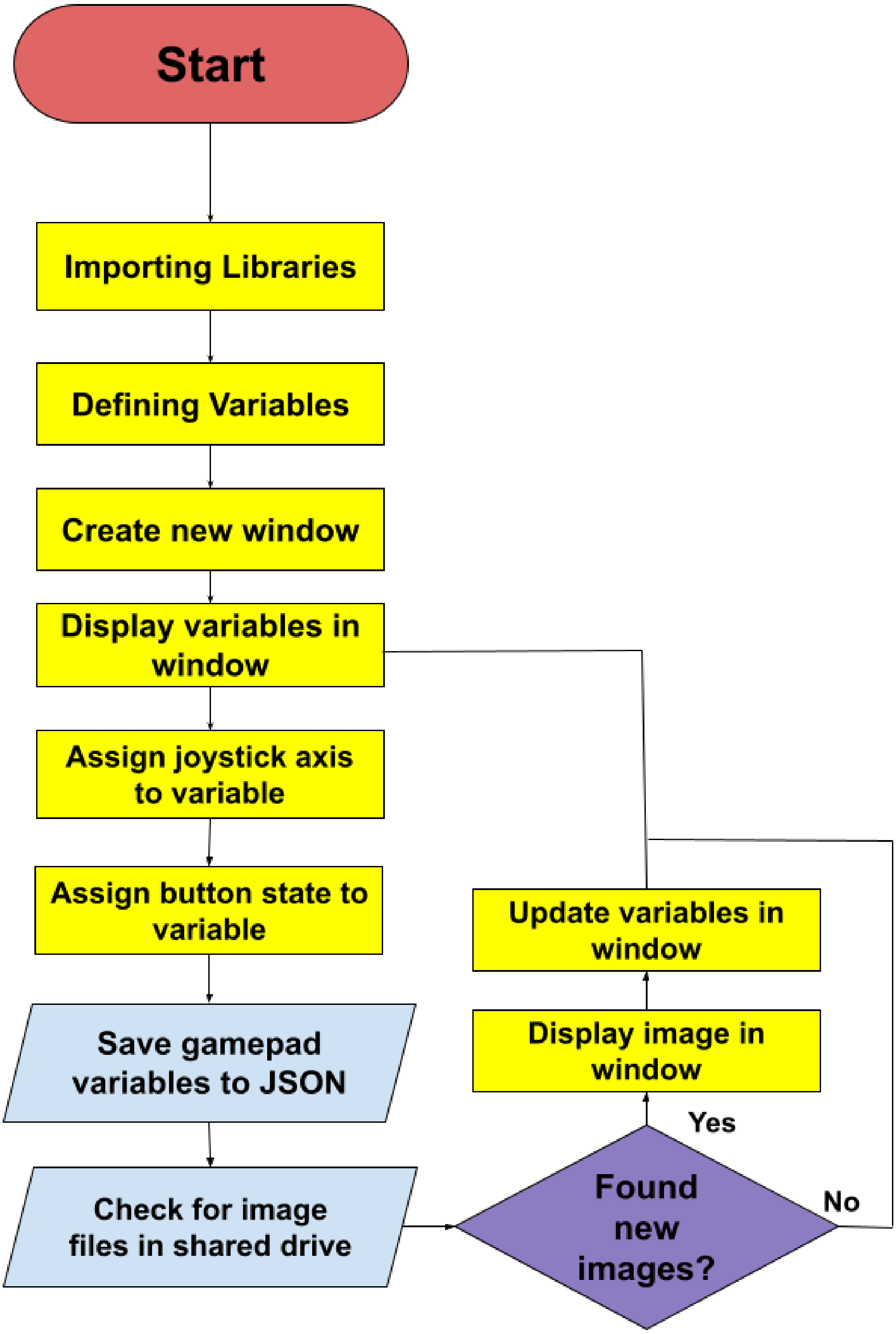
| Construction and handling safety checklist |
|---|
| ☐ Handles are properly secured and fastened<br>☐ All filed edges are smooth and easy<br>☐ All zip ties are appropriately cut<br>☐ All wires are contained and managed properly<br>☐ Motors are stable and fastened, with motor shrouds properly covering the entire motor |
| **Operation Safety Checklist** |
| ☐ Check strain relief stability on both sides, with all wires completely enclosed and connected<br>☐ Check motors and motor shrouds, both completely stable and safe<br>☐ All edges and zip ties are cut and filed<br>☐ Handle is tight and secure<br>☐ Power supply properly plugged into socket<br>☐ Laptop is fully charged, powered and connected topside<br>☐ Killswitch can be turned on<br>☐ Start program, test motors and all connections are properly accounted for |

*Appendix C - Safety Checklist*




| Device | Amps | Device count | Total per device | Total amp | Over Amp (Total amps x 1.5) | ROV fuse |
|---|---|---|---|---|---|---|
| HH thruster | 3.25 | 4 | 13 | 29.43 | 44.145 | 25 Amps |
| T200 | 5 | 2 | 10 | | | |
| Camera | 0.15 | 3 | 0.45 | | | |
| Monitor | 0.36 | 3 | 1.08 | | | |
| Pi camera | 0.2 | 1 | 0.2 | | | |
| Raspberry Pi | 1.2 | 1 | 1.2 | | | |
| Servo motor | 3.5 | 1 | 3.5 | | | |

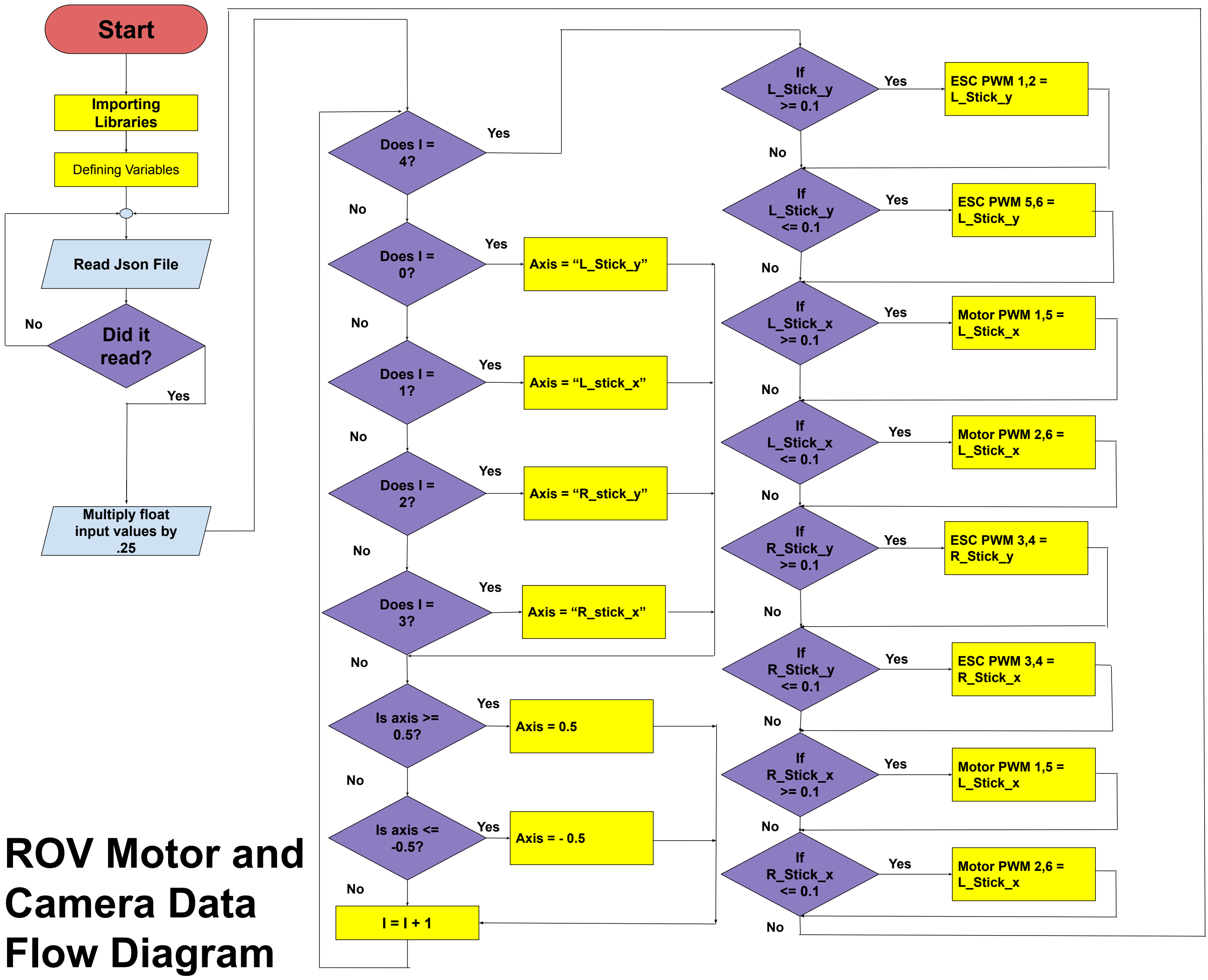
*Appendix D - Trygon SID*




# Topside Data Flow Diagram

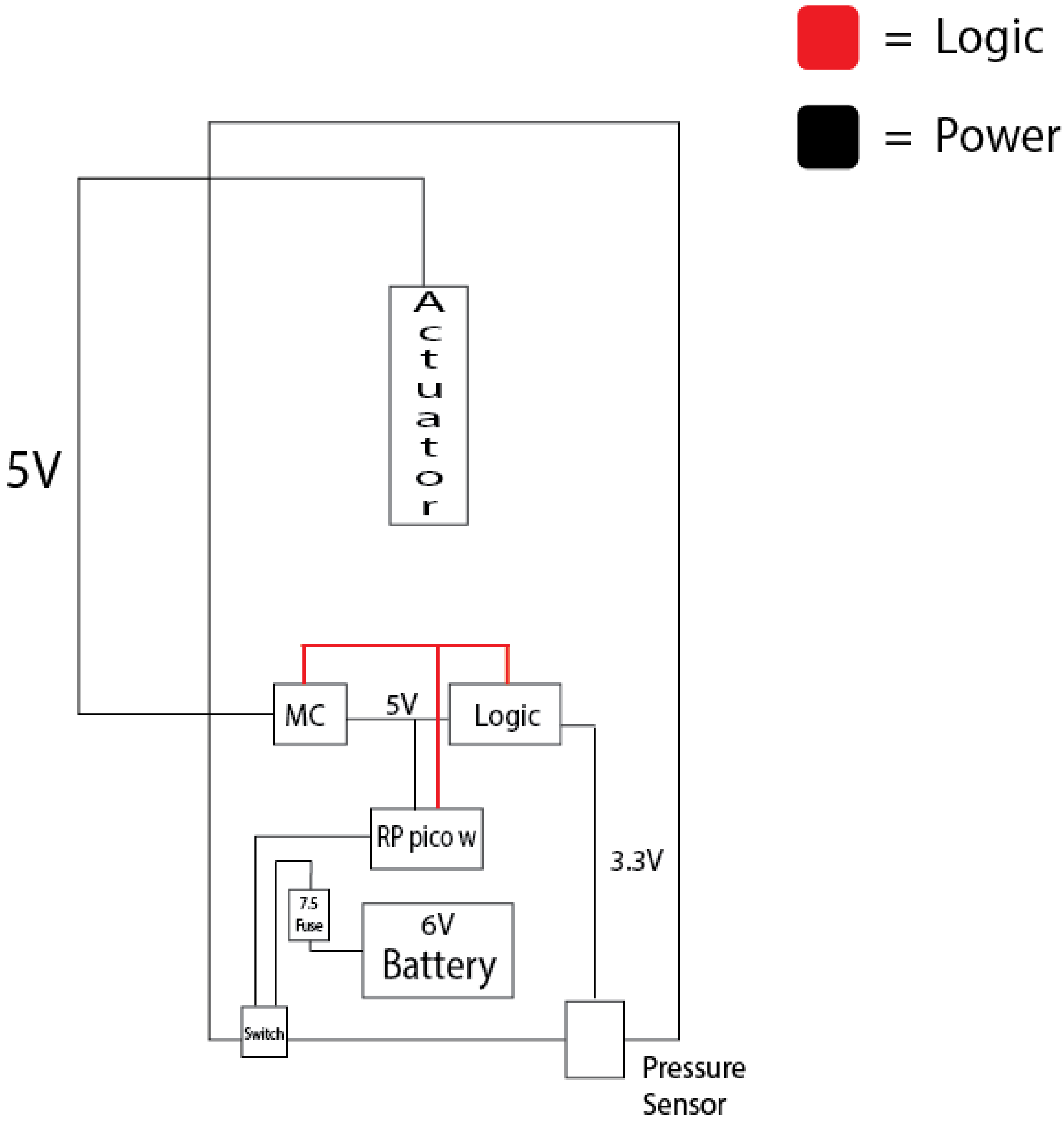
*Appendix E(1) - Topside Data Flow Diagram*

# ROV Motor and Camera Data Flow Diagram




*Appendix E(2) - ROV Motor and Camera Data Flow Diagram*

# Vertical Profiling Float SID




*Appendix F - VPF SID*