ROVOTICS TECHNICAL REPORT

2025

Mechanical: Ethan Bullard (CEO) '25, Mark Weeden '25, Caden Kroettinger (Lead) '26, Declan Cooley (Safety) '26
Luke Gatlin '27, Logan Larson '27, Rian Subakti '28, Oscara Pereira '28
Electrical: Charlie Kim '25, Koen Miyashiro '25, Harry O'Hagin (Lead) '26, Grant Munoz '27
Software: Jack Frings '26 (Lead), Ian Kim '27, Jonah Meyer '28, David Janssen '28
Coaches: Jay Isaacs, Cheryl Kiyama, Steve Kiyama, Michael Sharp

*All photos included in this report were taken by ROVOTICS.

Jesuit High School | Carmichael, CA, USA

Abstract

ROVOTICS is a long-standing, 17-member robotics team from Jesuit High School in Carmichael, California. The team is passionate about developing and deploying cutting-edge technology to help sustain aquatic environments. With nearly two decades of experience, ROVOTICS has improved skills in designing, manufacturing, and operating products. This year, the team is proud to introduce a new ROV, *Marlin*, the result of meticulous planning, diligent designing, iterative prototyping, and rigorous testing. Equipped with an adaptable frame, a high-performance electronics system, and versatile tools, *Marlin* is one of ROVOTICS' most efficient and user-friendly ROVs yet. In alignment with the United Nations Decade of Ocean Science goals, *Marlin's* capabilities include inspecting shipwrecks, servicing subsurface spotter buoys, monitoring lake conditions, collecting environmental DNA (eDNA), and more. In addition to *Marlin*, ROVOTICS has developed a GO-BGC-inspired float, GO-POD, which is designed to monitor ocean conditions while maintaining specific depths to optimize data collection. Together, *Marlin* and GO-POD represent the team's commitment to engaging in aquatic environmental conservation through robotics solutions and education. This technical report provides an overview of how ROVOTICS operates as a company, the team's processes for developing products, and strategies to tackle environmental challenges.

Table of Contents

TEAMWORK

COMPANY STRUCTURE

ROVOTICS's members contribute to product development based on their areas of interest. On a broad level, ROVOTICS operates through three main departments: Mechanical, Electrical, and Software, each led by a department lead responsible for managing assignments and priorities within their respective teams. The Chief Executive Officer (CEO) is responsible for organizing the activities of the team, assisting in interdisciplinary collaboration, managing the schedule, and enabling departments to complete their goals. The Safety Officer enforces protocols to ensure the safety of the team and the prevention of safety hazards during the operation of the ROV. For maintaining finances, the Chief Financial Officer (CFO) keeps track of the budget and spending. The inventory specialist helps keep track of tracking sheets for materials and quantities. Lastly, the writing lead helps members write about designs and rationales in a straightforward way, specifically in the technical report, the marketing display, and other documents.

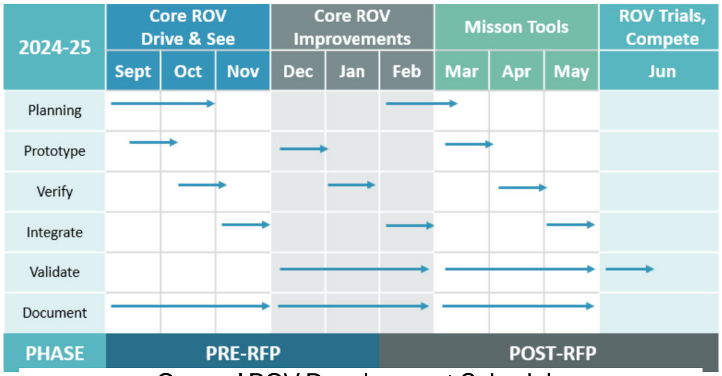
Since ROVOTICS is an ever-changing team with upperclassmen graduating and underclassmen joining each year, succession planning is crucial for ensuring that standard practices and policies remain on the team. ROVOTICS places a strong emphasis on continuous learning and cross-training among team members.

ROVOTICS Team Photo

Upperclassmen in each department take on the critical responsibility of mentoring and training underclassmen throughout the entire development process. This approach ensures that the team retains crucial skills and safe practices, even after members graduate.

PROJECT SCHEDULE

Over years of iterative development, ROVOTICS has established a proven schedule that serves as the foundation for product development. This schedule is divided into two primary phases: pre-RFP (Request for Proposal) and post-RFP. At the start of each season, the team conducts a comprehensive review of the existing ROV systems to identify components that require modification or improvement. This evaluation initiates the pre-RFP phase, during which ROVOTICS develops the Core-ROV—a standardized chassis equipped with full motion control and a dependable navigation and vision system. The design process begins by analyzing previous designs and considering modifications that would enhance ROV systems. The successful completion of the Core-ROV confirms the functionality of all essential subsystems while ensuring that mission-specific components can later be integrated onto a reliable foundation. The post-RFP phase of the season involves designing and testing new tools to complete tasks outlined in the RFP. At this stage in the development process, members perform market research about potential components and designs before creating innovative solutions to solve real-world challenges. These tools are prototyped and tested extensively before being integrated onto the ROV. After all the modifications have been integrated, ROVOTICS dedicates at least 40 hours to mission practice in the water so that the deck crew can gain experience and ensure everything on the ROV is reliable. This extensive in-water practice is crucial for ensuring products are reliable and safe. before they interact with aquatic wildlife.



General ROV Development Schedule

PROJECT MANAGEMENT

I. Bills of Materials (BOMs):

For respective subsystems, ROVOTICS manages Bills of Materials (BOMs) in spreadsheets to keep track of the number and types of parts needed. This year, BOMs were standardized to ensure clarity about where to order components and the number of parts needed, improving company organization and accelerating the production of the Core ROV. For further clarity, ROVOTICS' BOMs explain the functions and rationales for each component. Before ordering parts, section leaders and coaches review the BOMs to ensure only necessary and appropriate components are bought. By having a comprehensive list of materials and an easy way of ordering them, ROVOTICS is able to reduce manufacturing and lead times by several work days, in addition to ensuring clarity about the number and type of components needed for future products.

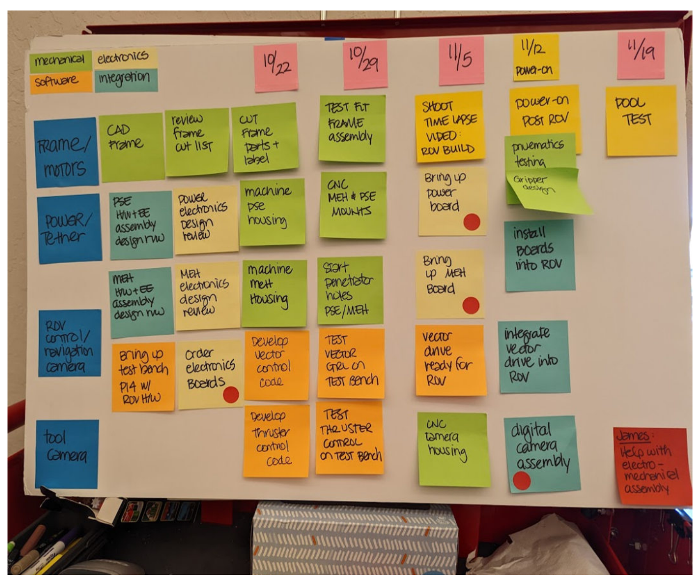
II. Managing Digital Designs and Software:

All departments have important ways of managing and organizing digital designs and software. The mechanical department uses Autodesk Fusion 360 for designing digital models. This platform allows members to collaborate while editing, reviewing, and revising designs. The electronics department uses Autodesk EagleCAD to design printed circuit boards while easily integrating with Fusion 360.

The software department uses GitHub for storing and sharing code. This web-based collaborative interface allows developers to manage projects, restore changes, and review one another's work.

III. Collaboration and Communication:

ROVOTICS splits the work week into two meetings. The weekly Wednesday virtual meeting serves as a platform for departments to share weekly achievements and goals. Additionally, the team can address resource and material requirements for maintaining project timelines and completing upcoming work. At the beginning and end of each seven-hour Saturday workday, the team holds standup meetings in which members review a project tracking (Kanban) board and adjust it if needed. Through this interactive scheduling system, the team consistently meets project deadlines and remains aligned with day-to-day objectives. ROVOTICS uses this system instead of Gantt charts because the Kanban board system is more flexible and adjustable. ROVOTICS stores valuable team information and files on Google Drive due to its large storage space and its accessible, cloud-based program that facilitates collaboration. ROVOTICS relies on Discord, a free messaging and collaboration app, for regular communication.



Team KanBan Board to organize future Pre RFP development of the ROV

Design Rationale

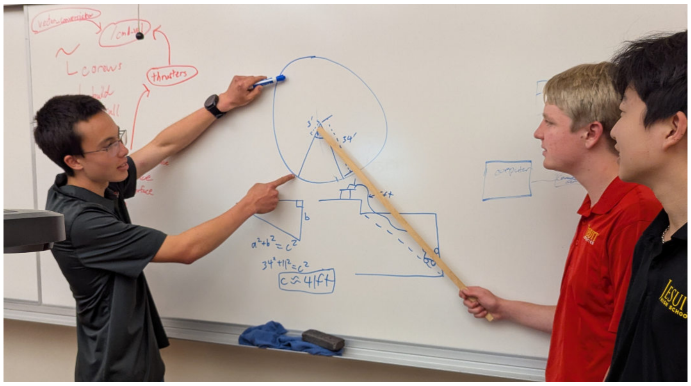
SYSTEMS APPROACH

With over two decades of experience, ROVOTICS has learned many lessons that have significantly influenced the way the team's products are designed and refined. Each year, ROVOTICS constructs a new ROV using new or repurposed parts, building on the successful designs of previous ROVs. The team's dedication to having a standard, holistic approach to the vehicle systems is capitalized in the development process. The design process begins with a pre-RFP planning phase in which an interdepartmental team of mechanical, electrical, and software leads discuss which previous technologies should be included in the new design, along with a proposed list of new improvements. Following an iterative design approach, ROVOTICS' systems have been continuously refined over the years to maximize their reliability, modularity, and serviceability. Since all systems depend on one another, the team's thoughtful approach to making simple and reliable designs is crucial for creating successful products.

The dependable, standard foundational design is called the Core ROV, and a new one is built every year due to the proven reliability of its designs—the frame, the sensors, the electronics system, the software system, and the buoyancy system. When the Core-ROV is completed, new sensors and tools that aren't part of the core systems are developed and then integrated. In this post-RFP phase, members design and manufacture necessary sensors (such as the external cameras and their housings), adhering to the engineering design process and testing extensively to ensure the reliability of crucial sensors. When the sensors are fully tested and integrated onto the ROV, the team begins developing tools and modifications needed for the ROV to combat marine conservation issues. At this time, members brainstorm and prototype until the designs are reliable and easy for the pilot to control. Once the tested tools are fully integrated onto the ROV, the team extensively practices piloting the ROV, ensuring that all environmental mission tasks can be successfully completed in the water. This point at the end of the season marks the overall success of ROVOTICS' designs as a result of methodical product development.

PROBLEM SOLVING

ROVOTICS is dedicated to making thought-through decisions that lead to reliable products and efficient operations. To achieve this, ROVOTICS follows a structured design change process. Whenever a new feature is proposed, a team member creates a document called a Change Request. These proposed changes often entail selecting which component or design would best allow the ROV to perform specific tasks in a cost-effective way. The Change Request document outlines the reasons for the proposed design update, what is required to implement the change, and the associated trade-offs. A crucial element of the Change Request is the design matrix, a table that evaluates and compares proposed designs based on market research and trade studies. Design matrices assist the team in making informed decisions by considering key factors such as ease of use, capabilities, costs, and manufacturability. Once the Change Request is prepared for review, all team leads assess it to understand the change's impact across all system areas—mechanical, electrical, and software. After many people review the changes, the proposal undergoes iteration to integrate feedback and update initial designs. The final change is only implemented after the department leads unanimously agree. This comprehensive approach ensures that significant decisions are made collaboratively, involving all departments that may be affected by the changes.



Charlie Kim, Declan Cooley, and Ian Kim
discussing design decisions

Systems & Structures

ROVOTICS designs each system to meet mission specifications while balancing weight, size, cost, performance, build time, and effort. Since most designs involve trade-offs, the team creates decision matrices to compare options and choose the best one. These decision matrices demonstrate how the team used data and trade studies to evaluate and select designs. When making decisions, all the leads review a design matrix and provide their input. To address comments and concerns, the design undergoes iterations and evolves to meet the needs of the mission specifications. This process helps ensure each part of the ROV is built efficiently and well-suited for underwater tasks.

As a result of the team's methodical decision-making process, ROVOTICS' products include this year's innovations and enhancements. The following list is an overview of ROVOTICS' innovations and enhancements from this year and how they result in higher functionality at reduced costs (money, time, or labor). Innovations featured will be explained in much more detail later on in their respective sections.

Innovations & Enhancements

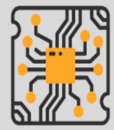
Autonomous Photosphere System
Quickly captures and stitches a 360° image of Marlin's current environment

Yaw Lock & Depth Hold
Autonomously stabilize Marlin's orientation and depth using PID controller software

GO-POD
Improved float design with simplified data transfers via ESP32 WiFi, faster maintenance, and enhanced sustainability with rechargeable batteries

Innovations & Enhancements

ROSbag Logging
Improved system level debugging capabilities by recording all values communicated between programs throughout mission runs.



SuperHat
Extends Raspberry Pi 4 functionality with streamlined integration for thrusters, sensors, and tools, plus onboard overvoltage protection.

Arducam Camera Sensor
Expanded pilot's view by 35%

I. Frame

Marlin's frame is an ideal foundation for the ROV's hardware. The modular frame is made out of aluminum extrusions with t-slots, which act as mounting rails that enable tools, cameras, and other components to be mounted anywhere along the frame for extensive flexibility. The aluminum segments are connected with brackets, screws, and sliding nuts, all of which create secure joints and allow easy adjustments. The team chose 15 mm x 15 mm aluminum extrusions because they provide ample strength without the cost, size, and subsequent drag that larger extrusions and polycarbonate sheet designs have in water. This year, ROVOTICS reused most of the material from a previous frame, saving money and minimizing waste. For safety, smooth end caps are placed on the ends of the extrusion, removing sharp edges.

II. Buoyancy and Ballast

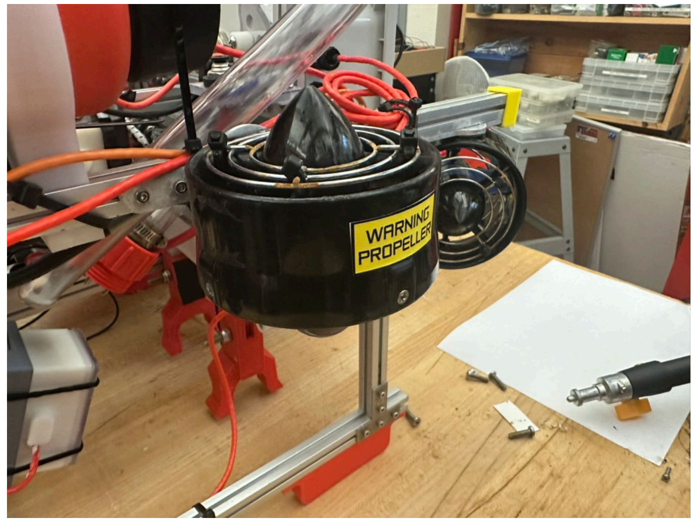
Marlin's buoyancy system is divided into static and dynamic subsystems. The static category is made of the electronics housings and two 1182 mL (40 oz) incompressible nacelles. These nacelles are positioned to allow for a stable ROV with easily serviceable electronics. The second subsystem is modular and consists of two adjustable stacks of hydrostatic foam squares. The ability to add or remove these squares using quick-release pins gives the deck crew the flexibility to rapidly change payloads while maintaining *Marlin's* neutral buoyancy, giving the pilot consistent control between payloads.


Jack Frings adjusting modular buoyancy

To calculate *Marlin's* buoyancy, the team measured the displacements and densities of *Marlin's* components by referencing the CAD model. Archimedes' principle was used to calculate how much the ROV weighs in water, and then the team calibrated the buoyancy by adjusting the amount of water within the nacelles. After this, performance tests were conducted with each unique payload, and ROVOTICS adjusted the modular subsystem to maintain neutral buoyancy throughout ROV operations. Additionally, *Marlin's* tools help stabilize the ROV by acting as ballast under the center of buoyancy.

III. Thrusters

For effective motion, six Blue Robotics T100 thrusters propel *Marlin* in all six degrees of freedom. Four of the thrusters are placed on the corners of the ROV frame at 45° angles for full lateral and rotational motion. The remaining two are mounted vertically on both sides of the ROV for ascent and descent. All thrusters are equipped with thruster guards, preventing people and wildlife from coming into contact with the propellers.



Thrusters secured with thruster guards and warning tape

Thruster: New vs. Used

Thruster Problem Statement:
Should ROVOTICS convert to Blue Robotics T200 thrusters or re-use discontinued T100 thrusters?

Thruster Decision:
Continue using refurbished T100 thrusters

Thruster Justification:
- ROVOTICS has a maintenance protocol for updating T100 cores to ensure reliability.
- The extra thrust of T200s isn't needed since most piloting is spent in fine motion.
- ROVOTICS has enough spare T100s for the next two years.

By conducting market research, ROVOTICS decided to continue using Blue Robotics T100s instead of transitioning to T200s despite the fact that the former model has been discontinued. This choice was made for three main reasons. First, the T100s, although less powerful than the T200s, provide plenty of thrust for the team's needs, as most mission tasks require fine motion rather than brute force. Second, ROVOTICS has been using T100s for several years, so the team was able to reuse the previous stock by simply replacing the thruster cores, improving reliability and reducing expenses. Finally, the T100s have a maximum power draw that remains within the power budget, preventing an ROV shutdown, while T200s, in contrast, could easily surpass this threshold.

ELECTRICAL

Marlin's electrical system consists of two subsystems: topside and bottomside electronics. These interface with each other via a tether for data transmission and power distribution. Topside consists of all the electronics above the surface and is responsible for powering and controlling the ROV through a simple pilot interface. Bottomside includes all submerged electronics, including the ROV's control electronics, the power system, and sensors.

I. Topside

The Topside Control Unit (TCU) consists of the hardware that controls and powers the ROV. All the components easily fit within a Pelican Case, which was chosen due to its durability and portable design. The monitor is set into the lid, while the TCU's organized bottom compartment contains hardware that can be easily accessed by lifting the hinged control panel. An Ethernet connection reliably transmits data to the bottomside electronics, and there are solenoids and bulkhead connectors for pneumatics. To maintain reliable power, ROVOTICS designates two distinct formats of high-current Anderson Powerpole connectors, one for the 48V MATE-supplied power and another for the 48V tether power.

In previous years, the TCU included a mini-PC to run software. However, this took several minutes to load, delaying mission operations. This year, ROVOTICS upgraded to a laptop that the co-pilot uses to launch and control *Marlin's* software. This approach allows any laptop to control unique software setups, improving adaptability. Also, the new laptop has significantly better performance, with a dedicated graphics card, reducing camera latency. Unlike the old mini-PC, the laptop doesn't need to be plugged in, which means software setup can occur immediately during the setup period of the mission run, increasing precious time in the water.

Charlie Kim and Jack Frings piloting and copiloting via the TCU

Criteria	MINISFORM NPB6 Mini-PC	Lenovo Legion Laptop Inside TCU	Lenovo Legion Laptop Outside TCU
Price	$400	$1,100	$1,100
Processor	13th Generation i7	14th Generation i9	14th Generation i9
Known Reliability	Several Years of Use	Years of Use for Software Testing	Years of Use for Software Testing
Replaceability	Costs money and time to replace	A substitute laptop would have to fit in the TCU	Any laptop can be substituted
Setup Time	Often slow to boot	Can boot before a mission run	Can boot before a mission run
Debugging	Difficult to interchange with other devices	Slightly difficult to interchange with other devices	Quick to interchange with other devices

TCU Laptop vs. Mini-PC Design Matrix

This laptop then integrates with several devices to provide an efficient and quality piloting experience. The laptop first connects to a joystick and monitor to enable pilot control over the thrusters and grippers. To adjust ROV settings and run mission-critical programs, the laptop itself also displays a Graphical User Interface (GUI). Altogether, these devices allow the pilot and copilot to run missions quickly.

Topside Control Unit: New vs. Used

TCU Problem Statement:
Should ROVOTICS design and build a new Topside Control Unit (TCU) or continue using the previous revision?

TCU Decision:
Continue using last year's TCU

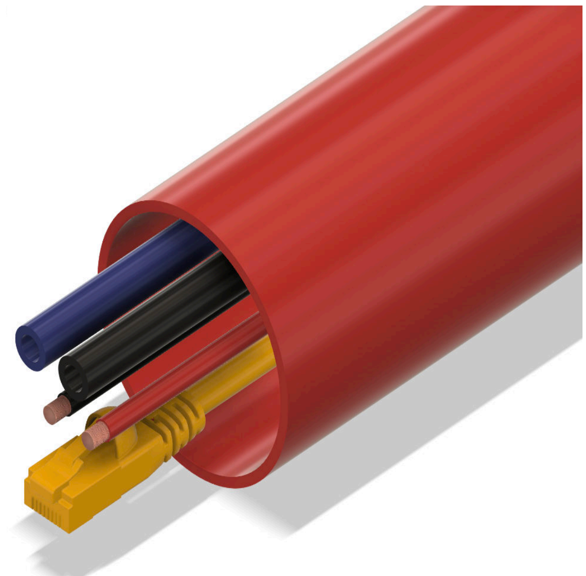
TCU Justification:

- Previous TCU meets all MATE safety rules and works reliably, so redesigning it wasn't needed
- Modular design and serviceability allows ROVOTICS to make changes like switching from a mini-PC to a laptop.

II. Tether

To connect the ROV to surface controls, the tether reliably delivers power, data, and compressed air while maintaining the ROV's full maneuverability. Connecting the TCU and ROV, a pull grip acts as strain relief to evenly distribute tension across the tether's durable polyester sheathing, protecting vital cabling from sudden movements. Additionally, this strain relief allows the ROV to be safely lifted by the tether without damaging connections. Incompressible buoyancy nacelles can be configured along the tether to create custom curve profiles, preventing the tether from disturbing the environment or obstructing operation. To fine-tune buoyancy, the deck crew can easily alter the amount of water in these nacelles. For an optimal design, ROVOTICS determined the tether length by analyzing the aquatic operating environment.

Power is transmitted to the ROV through a pair of 12 AWG wires, which were selected due to their optimal balance between flexibility, weight, and low-resistance electrical properties. A Cat6A Ethernet cable is used to transmit data due to its high transmission speed. Pneumatic lines were chosen to maximize airflow and flexibility. They are able to handle 2.5 times the maximum pressure of 40 PSI, which means they adhere to MATE safety specifications. One pneumatic line operates the horizontal gripper, and the other controls the vertical gripper.



CAD of the Tether

III. Tether Management Protocol

ROVOTICS adheres to the following Tether Management Protocol to ensure reliable and safe operations for protecting personnel and wildlife.

- Inspect for damage, and uncoil the tether.
- Attach strain relief, and then connect the tether's power, pneumatics, and signal lines.
- Continuously monitor and adjust the slack of the tether to accommodate changes in *Marlin's* position.

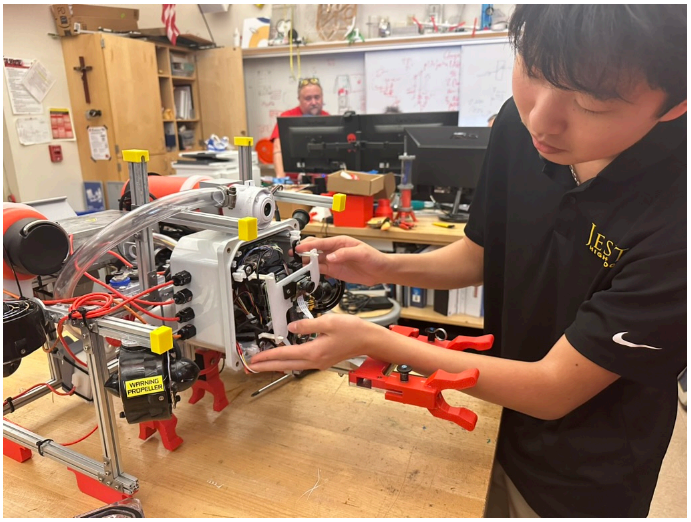
- When the ROV is powered off, disconnect the tether from the TCU and ROV.

- Coil the tether using the underhand-overhand method to avoid twists and tangles.

- Place the tether on the cart for storage and ease of transportation.

IV. Bottomside Electronics

Marlin's electrical system is simple and modular. ROVOTICS chose to divide the bottomside electronics into two distinct housings: the Main Electronics Housing (MEH) and the Power Systems Enclosure (PSE). This division capitalizes on the different properties of both housings. The MEH's clear lid offers operating and servicing advantages for control electronics, while the aluminum PSE dissipates heat from the power system. Additionally, dividing the electronics system allows the team to isolate variables when testing, simplify servicing, and balance buoyancy distribution across the ROV.

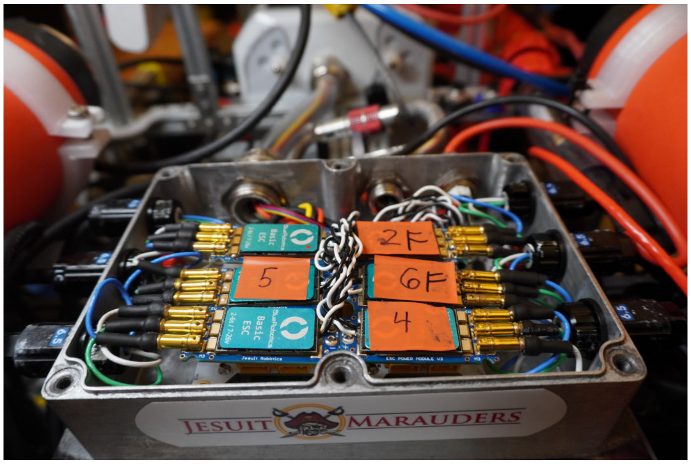


Ian Kim servicing the Main Electronics Housing (MEH)

A clear and flexible tube connects the electronics within the PSE and MEH. Through this tube, the power electronics provide power to control electronics, and control electronics communicate thruster data to power electronics. This tube is especially beneficial for maintenance because it allows both housings to be vacuum tested simultaneously to confirm water seals, reducing complexity and improving the reliability of testing. The tube is strategically positioned high enough on both enclosures to isolate each housing should a leak occur. After manufacturing, the housings are submerged and cycled in vertical profiles to stress test the seals and reveal faults that could cause leaks. This testing method simulates the mission environment where the ROV is profiling the area frequently. Before operating the ROV, ROVOTICS vacuum tests the enclosures to confirm they can hold a consistent pressure for at least 15 minutes, verifying the integrity of the watertight seals.

V. Power Electronics

Marlin's power electronics are contained in the PSE. Within this housing, a custom Power Board converts the 48V supply to lower voltages. This Power board features three voltage converters, two that provide 12V at 100A for thrusters, tools, and an Ethernet switch, alongside a third converter that supplies 5V for the Raspberry Pi 4, tools, and cameras. These converters were chosen due to their 96% conversion efficiency and their protection against overvoltage, undervoltage, overheating, and short-circuits. The thrusters are controlled by Blue Robotics ESCs, which are mounted to custom, low-profile, plug-and-play adapter plates. The custom PWM-I2C Board converts I2C commands from the Raspberry Pi 4 into Pulse Width Modulation (PWM) signals, which are then relayed to the ESCs that ultimately control the thrusters. A custom board was developed because commercial options didn't come with reliable signal capabilities.



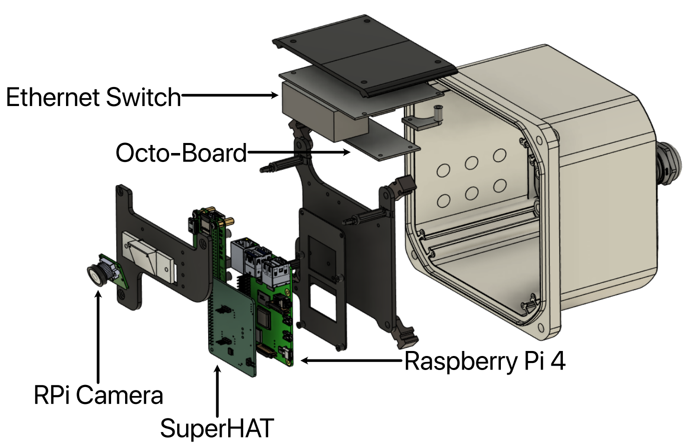
Electronics Inside The PSE (Power Systems Enclosure)

The voltage converters, which are responsible for generating the majority of heat in the PSE, attach to the aluminum interior of the PSE to maximize thermal transfer to the water. ROVOTICS chose to modify an off-the-shelf item because no commercial housing had the required thermal properties and the right size. Modifying an off-the-shelf housing provides the benefits of reduced cost, minimal fabrication time, and reliability compared to designing and manufacturing a custom enclosure.

VI. Control Electronics

The MEH contains *Marlin's* main computer, a Raspberry Pi 4 (RPi 4), which receives control input and communicates sensor and telemetry data to the TCU. A custom printed circuit board called the SuperHAT (Hardware Attached on Top) allows the RPi 4 to control high-power tools while interfacing with a depth sensor and a 9-axis Inertial Measurement Unit (IMU) that assists in orientation control. An eight-port Ethernet switch connects the RPi 4 and the Octo-Board to surface control via the tether. The Octo-Board then transmits power and ethernet connection to up to 8 cameras.

ROVOTICS chose to purchase this commercial enclosure because its clear lid allows for an unobstructed view for the internal camera and efficient inspection of electronics. Furthermore, the MEH's built-in rails allow electronics to be easily mounted on a sliding shelf system, providing easy access to internal components.



CAD Explosion of the MEH

ROV Housing: Build vs. Buy

ROV Housing Problem Statement:
Should ROVOTICS buy a commercial enclosure (the MEH) to house the control electronics, or design and build a custom housing?

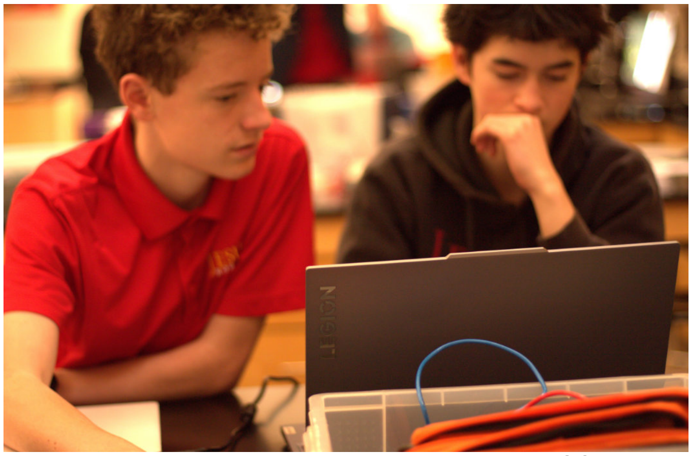
ROV Housing Decision:
Buy a commercial housing and modify it to adjust to ROVOTICS' specifications.

Buy Justification:

- The durable, polycarbonate housing has a clear lid that provides unobstructed camera views and quick inspection of electronics.
- The MEH housing has been used for several years, with its seals consistently proving to be watertight.
- The housing's built-in rails support a sliding shelf system, making it easy to mount electronics and access internal components.
- The housing provides a significant buoyant force for the ROV
- All these benefits outweigh the drawbacks of the housing's drag and cost.

SOFTWARE

ROVOTICS' software system allows for a smooth piloting experience while enabling rapid development for mission-specific tasks. The software is split into two subsystems: Topside and Bottomside. Topside consists of all the software that runs on *Marlin's* laptop, which transfers joystick input into thruster control, receives camera footage, and controls tools. Bottomside consists of all the software that runs on the ROV, specifically the Raspberry Pi 4B, which receives data and communicates over I2C with the thruster controllers. Topside and Bottomside integrate through ROS2, a middleware that allows for communication between programs over ROS topics. This year, ROVOTICS upgraded to ROS2 Jazzy, the newest stable version of ROS2. This transition allowed the team to record topics using the tool rosbag. When confronted with software issues over the development process, rosbag allowed ROVOTICS to analyze every piece of data communicated during multiple mission runs, easing the process of troubleshooting.



Jack Frings teaching Jonah Mayer about ROS

ROVOTICS also implemented two new software features to improve *Marlin's* ease of use. The thruster-control program now uses PID controllers (a real-time correction system) to lock in *Marlin's* angular orientation in a process known as yaw-lock and *Marlin's* depth in a process known as depth-hold. These programs mitigate the effects of drift in the water while allowing the pilot to move with increased precision.

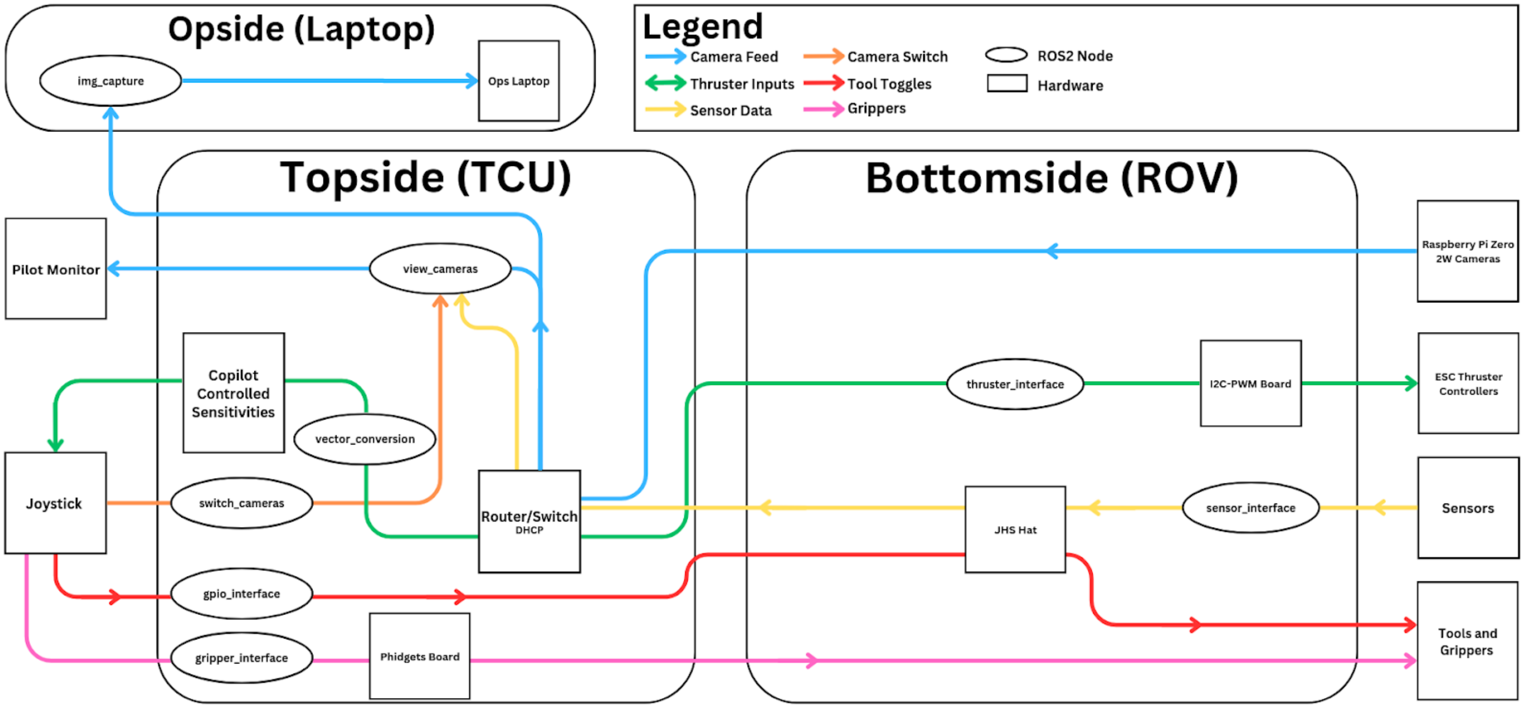
```python
# Implement separate logic for yaw control
# Use yaw-lock pid value unless pilot is moving on the axis
# Here, we only use the joystick angularZ value if the pilot has rotated at least self.yaw_deadzone degrees
if self.yaw_control_enabled and (abs(msg.angular.z) < self.yaw_deadzone):
    # This callback runs about 75x / second.
    # We want top speed to rotate the ROV 360 degrees in 1 second.

    # self.yaw_target += (msg.angular.z * 360 / 75)
    # self.yaw_target = self.yaw_target % 360
    self.yaw_pid.setpoint = 0
    self.yaw_effort_value = self.yaw_pid(self.yaw_error)
    self.log.info(f"yaw_effort: {self.yaw_effort_value} \n yaw_target: {self.yaw_target} \n yaw_error: {self.yaw_error}")

    angularZ = self.yaw_effort_value
else:
    self.yaw_target = self.yaw
    self.yaw_error = self.calculate_orientation_error(self.yaw)
    angularZ = msg.angular.z
```

PID software checks that the pilot isn't moving on an axis before automatically adjusting the ROV's orientation to remain constant using yaw values given by the IMU

VISION SYSTEM

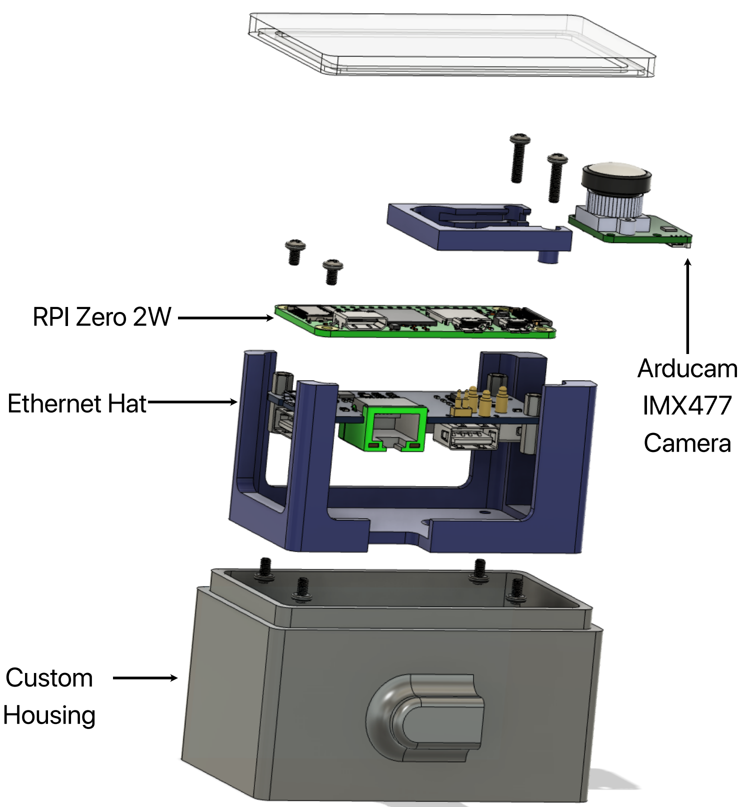
Marlin's vision system enables the pilot to effectively operate tools and navigate the ROV in aquatic environments. Rather than buying pre-built cameras, ROVOTICS chose to build the vision system to have more control over specific components, ensuring optimal performance, specifically low-latency streaming and high-quality video.

Each camera streams video at around 40 frames per second with a minimal 200 milliseconds of



Software Architecture Diagram

latency. These specifications create a smooth video feed with very little perceived latency, allowing the pilot to navigate with ultra-responsive feedback. The Arducam, an upgraded sensor, increases the diagonal field of view by 12.5% and improves color tracking, both of which are beneficial for piloting and photogrammetry. Additionally, the 1440p x 810p resolution provides high-definition visibility for the pilot and enhances capabilities for camera software tasks such as photosphere and shipwreck measuring. Ethernet cables reliably transmit camera data over TCP/IP to the TCU, where the operators have access to any of the camera views. With a press of a button, the pilot can easily switch camera views, significantly reinforcing *Marlin's* ease of use.



Custom Jesuit Camera CAD

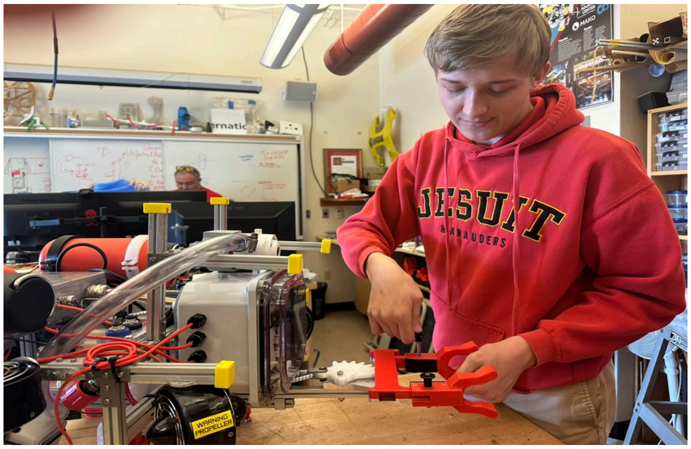
This year, the height of the external cameras was increased to make room for the larger optics of the Arducam camera sensor, which increased the diagonal field of view by 35 degrees. During the design modification to fit the higher-quality lens, ROVOTICS also decided to switch the manufacturing process of the camera housings to resin printing. As a result, there has been a 50% reduction in cost as well as a significant reduction in labor compared to the previous CNC process. These external cameras, with their new housings, can be quickly added, removed, or adjusted on the frame of the ROV using custom mounts, greatly enhancing *Marlin's* configurability for a wide range of mission tasks.

TOOLS

I. Cameras and Grippers

ROVOTICS' versatile tools allow the pilot to complete mission tasks with simple, reliable solutions for environmental conservation. To give the pilot complete perspectives of the tools and surrounding environment, *Marlin's* complete vision system features one internal camera and four external cameras strategically placed for optimal angles of view. The internal camera is contained within the MEH, which has a clear polycarbonate lid that is ideal due to its unobstructed view for cameras. The positions of the external cameras were tested through successive mission practices to provide the pilot with the best viewing angles for the tasks at hand. The under-view camera allows the pilot to view the vertical gripper, while the downward-facing camera provides a perspective for a top-down view of the seafloor. The two cameras mounted to the back of the ROV, angled upward and downward, are used to complete the photosphere task with a wide, unobstructed view. The top camera in the Photosphere array can be rotated to observe the Dual-Catch Tool. All these flexible placements of configurable external cameras enable a dynamic range of views for a multitude of tasks.

When operators switch to certain camera views with a simple push of a button, the operator can activate the gripper correlated with the camera, aiding the piloting experience. The multipurpose grippers are *Marlin's* most versatile tools. The ROV is equipped with both a vertical and a horizontal gripper, each strategically placed to improve piloting efficiency. This configuration allows the ROV to carry a greater payload while also reducing the number of necessary dives. Designed with modularity in mind, specialized fingers can be easily installed or removed from the grippers to accommodate different payloads, making the grippers easy to modify and able to accomplish many mission tasks. The grippers' versatility significantly increases the efficiency of the *Marlin's* operation.


Mark Weeden securing a gripper finger using a quick-release pin

II. Task 1

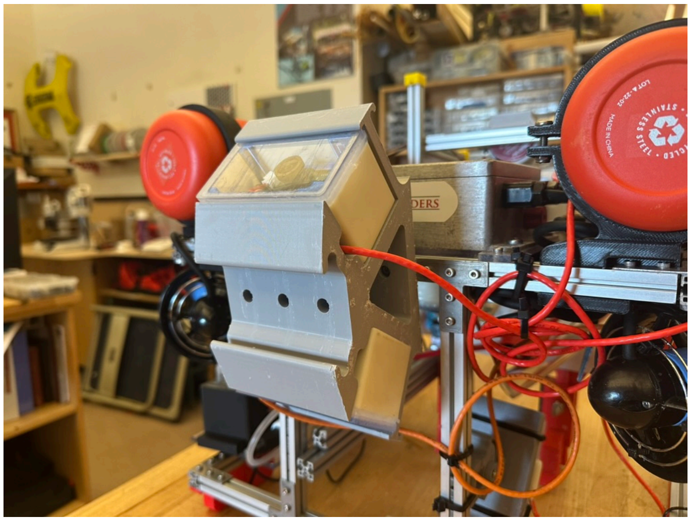
Advanced technologies play a crucial role in contributing to environmental conservation efforts, especially around the Great Lakes. As a result, *Marlin* is equipped with many tools—both mechanical and software—for addressing marine issues. Specifically in Mission Task 1, *Marlin* uses three specific technologies: photosphere, a fish modeling program, and buoys that measure ocean conditions.

The photosphere program is crucial for monitoring ecosystems and sites like shipwrecks. The tool is beneficial for its immersive visual models that successfully depict scale and perspective. The collected visuals are useful for understanding the histories of shipwrecks, documenting the wrecks, and exploring the sites with technology.

Marlin's fish modelling program is beneficial for monitoring species, like invasive carp in the Great Lakes. Invasive carp are dangerous because they compete with native fish for food and space. By digitally monitoring the invasive species, researchers can track their expansion to better understand the invasive species' impacts on the ecosystem.

The ROV's sensor that measures ocean conditions is instrumental for collecting data regarding rising ocean temperatures and acidification. The collected data, like pH and CO2 levels, are then transmitted to researchers for analysis to gain a better understanding of the health of marine ecosystems.

Photosphere: Visual data is essential for effectively monitoring and understanding marine ecosystems as well as historical sites like shipwrecks. Photospheres, in particular, allow for an immersive understanding of marine life with scale and perspective that's often lost in individual images. To capture photosphere data, ROVOTICS has developed a unique camera configuration within *Marlin*. This Photosphere camera setup consists of three cameras to allow for a collective 180-degree vertical FOV (Field of View) and a 50-degree horizontal FOV. To make the full photosphere, the program autonomously rotates the ROV in 50-degree intervals using the IMU (Inertial Measurement Unit) and the yaw-lock program to guarantee this angle. Once all these images have been captured, the images are stitched together using the OpenCV library. The high-resolution photosphere can then be exported and viewed through the Hugin Panorama Viewer.


Photosphere Rear Camera Configuration

Invasive Carp Model: The fish modeling tool visualizes the expansion of invasive carp over time. OpenCV image processing functions are used to load images, overlay text, and display the sequence of yearly data through CSV files. The visualization consists of six pre-edited images, each representing different stages of the carp's expansion. As the program reads the data, it overlays the corresponding year onto the appropriate image and displays it in a timed sequence, creating a dynamic representation that illustrates the carp's expansion.

```
def show_images(self):
  #Go through CSV file and show images
  with open("carp.csv") as file:
      for line in file:
              row = line.rstrip().split(",")
              image = cv2.imread(images[row[1]])
              image = addText(image)
              window_name = 'image'
              cv2.imshow(window_name, image)
              cv2.waitKey(1000)
              cv2.destroyAllWindows()
```

show_images() runs through an array of images corresponding to stages of the simulation and displays them with single second intervals

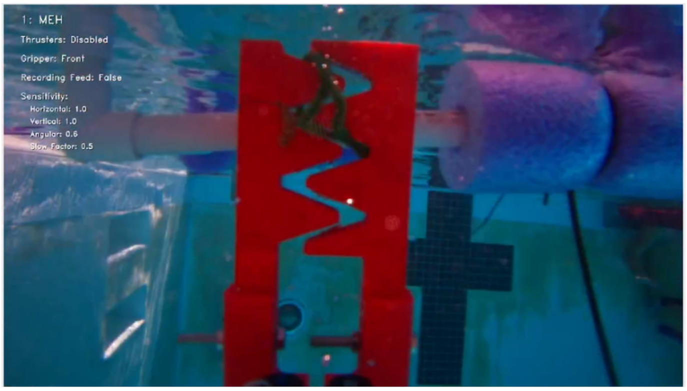
pH Sensor: The pH Sensor Tool retrieves water samples and accurately reads pH values to monitor the amount of ocean acidification. The tool uses a needle to puncture soft water containers, allowing a user-activated peristaltic pump to extract the solution into an external capsule. The capsule houses the electronic pH sensor, which integrates with *Marlin's* control systems, displaying real-time pH readings. This closed system prevents contamination of the sample. The sensor and capsule are visible through the camera system, ensuring reliable monitoring and verification of successful sample collection. The collected sample is then analyzed on the surface to read carbon dioxide levels of the environment.

III. Task 2

Marine renewable energy technologies, such as offshore wind farms and floating solar panel arrays, are vital for reducing reliance on fossil fuels, but they require frequent maintenance. Since submerged infrastructure faces corrosion from saltwater, ROVs are crucial for combating this. To resolve this, corroded materials are replaced with sacrificial anodes or uncorroded materials that reduce the rate of corrosion. ROVs also add epoxy patches to offshore structures to increase the longevity of the corrosible materials on the structures. In addition to maintenance, offshore infrastructure results in environmental challenges. The structures unintentionally attract marine life like jellyfish and fish species, but underwater noise from construction and operations disrupts these creatures. To research the impacts on these species, ROVOTICS collects these species to monitor changes in life cycles.

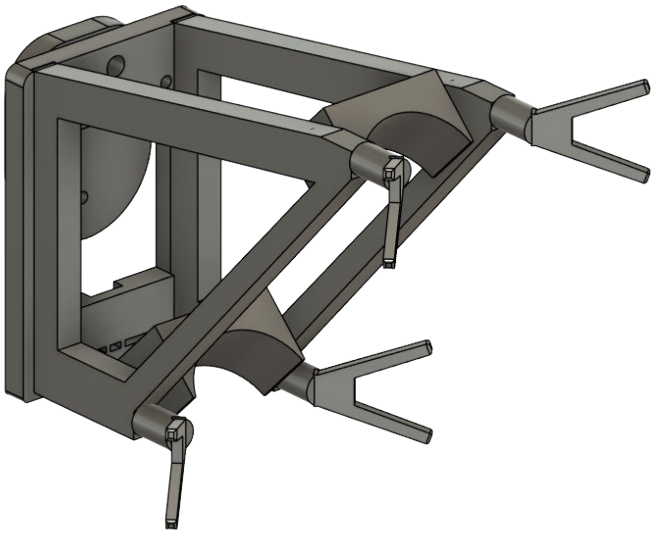
Dual Catch Tool: After many prototypes, the team decided to collect fish species and jellyfish by using a custom funnel design and a bilge pump, both of which keep the jellyfish and fish surrounded by water at all times without squeezing their bodies. To learn more about the design choices and the prototyping process for this tool, see pages 18-19 in Critical Analysis.

Custom Gripper Fingers: Each set of *Marlin's* 3D-printed gripper fingers is designed for a specific mission task; once a task is completed, the fingers can be swapped via quick-release pins to perform the next mission. The pins allow the deck crew to easily replace the fingers during operations, saving changeover time. The polyp-specialized fingers include precisely-fitted interlocking wedges that grasp the jellyfish without harming them. To replace sacrificial anodes, another set of specialized fingers has an imprint of the anode's handle, allowing the fingers to easily grasp the anodes.



Pilot's view of using custom gripper fingers

Epoxy Patch Tool: The Epoxy Patch Tool quickly and reliably attaches epoxy patches to corroded materials on underwater offshore wind farms, helping prevent damage to important underwater infrastructure. This tool uses a dual-axis rotating mechanism that automatically aligns the patch to the base structure regardless of the angle of approach, making the patch very easy to attach. Additionally, its simplicity adds to its reliability and eliminates nearly all the tool's maintenance. The tool is mounted to the frame using quick-release pins, allowing the deck crew to quickly add or remove it from *Marlin's* payload.



CAD of the Epoxy Patch Tool

IV. Task 3

GO-BGC floats are designed to create a worldwide network of chemical and biological sensors that help researchers record ocean health. The floats' sensors detect and record temperature, depth, and bio-geochemical data that is then routed to a global community of researchers, contributing to a better understanding of climate change's effects on the oceans.

GO-POD (peristaltic ocean device) is a GO-BGC-inspired float engineered to gather vital ocean data and vertically profile to targeted depths. It uses a peristaltic pump to alter buoyancy. This design conserves battery life. The float's operations are managed by an ESP32 microcontroller paired with custom PCBs, allowing it to interface with various sensors and transmit depth data via Wifi. The pressure relief cork is greater than 2.5 cm in diameter, ensuring the safety of operators and wildlife while complying with MATE safety specifications. To comply with the provided fuse diagram, GO-POD's power lines are fused to 5A. For power, GO-POD relies on rechargeable 9V Ni-MH batteries, reducing waste.

GO-POD's features don't come at the cost of serviceability. Its flange-sealed enclosure can be taken apart in seconds, and an electrical spring contact interface that separates the top and bottom sections facilitates easy disassembly for maintenance, as no connectors need to be unplugged.

GO-POD (Peristaltic Ocean Device)

Float Housing: Build vs. Buy

Float Housing Problem Statement:
Should ROVOTICS make a custom float housing(s), or purchase a commercial design?

ROV Housing Decision:
Buy a commercial housing and modify it to adjust to ROVOTICS' specifications.

Buy Justification:

- Buying the Blue Robotics tube allowed ROVOTICS to spend more time developing the custom components of the float, testing in the water, and troubleshooting.
- Designing a custom bayonet seal would be very difficult because the dimensions require high-level precision.
- The waterproof housing is beneficial for serviceability, as the float can be easily serviced with screws and flanges

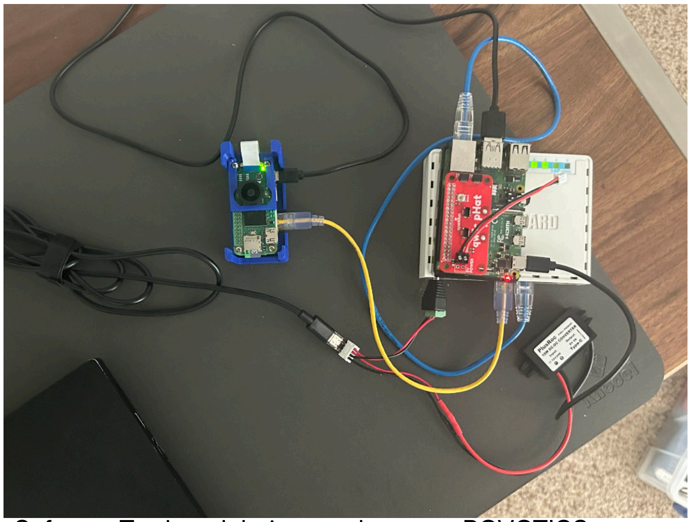
Critical Analysis

To ensure safe and reliable systems, ROVOTICS emphasizes systematic testing and troubleshooting in all departments throughout the development process. For example, portable software testbenches are used to verify code functionality before integration, ensuring ROV stability. Furthermore, whenever a system or a design malfunctions, ROVOTICS doesn't just look for quick fixes. For instance, when thrusters were behaving erratically, the team used a systematic debugging methodology, which involved isolating components to find root causes. Resolving these issues resulted in valuable electronics testing processes for future years; ROVOTICS now has a dedicated ESC-thruster test tank and electronics testbenches to rigorously and efficiently test the electrical system on land. Furthermore, all of ROVOTICS' designs undergo digital and physical prototyping. A prime example of this is the Dual-Catch Tool. Through extensive prototyping and testing, the team was able to evaluate which design would be the simplest, the most reliable, and the most cost-effective. Like all tools, the design was implemented on the ROV after it was proven to be safe and reliable.

SOFTWARE TESTBENCH

At ROVOTICS, developing new software requires efficient resource management. Given that multiple team members work on different software components simultaneously, allowing everyone to test their code directly on *Marlin* is not feasible. To address this, software development follows a structured process.

In the initial stage, developers write a draft version of their code, which they test on individual testbenches. Each testbench includes a USB-C power adapter, a wireless router, and a Raspberry Pi 4 to simulate *Marlin's* environment. Additional testing modules, such as cameras, hats, and thruster testbenches, are shared among team members to refine their code further. After all this hardware has been thoroughly tested, the testbench acts as a proven piece of hardware, allowing for software to be tested as an isolated variable.



Software Testbench being used to test a ROVOTICS camera

Once the code runs successfully on a testbench, it moves to the second stage, where developers test it on *Marlin*. If the code functions as expected, the final step is documenting it on GitHub, ensuring future team members can easily build on the existing work.

THRUSTER TROUBLESHOOTING

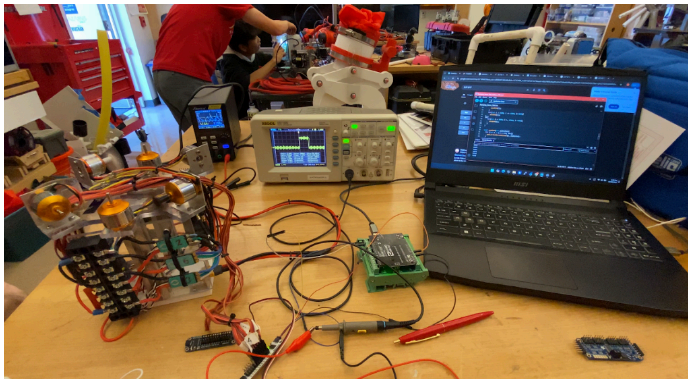
To resolve last year's thruster issues—sudden brownouts, resets, and erratic spinning—ROVOTICS initiated a systematic troubleshooting process. This strategy has been crucial in preventing similar problems from recurring and improving the overall reliability of *Marlin*.

The electronics team began troubleshooting with a methodical approach based on the thruster system's control hierarchy: mechanical is controlled by electronics, and electronics are controlled by software.

ROVOTICS started by analyzing the mechanical components and looking for worn parts, misalignments, obstructions, corrosion, or missing pieces, but nothing seemed to be wrong. Even though no issues were found at this stage in the process, the electronics team did confirm that the mechanical aspects of the thrusters were not the source of the problem. ROVOTICS then began testing the electronics system. Since there is no way to test the thrusters' electrical capabilities independently of the ESCs, and vice versa, the team built an ESC-thruster test tank. The control electronics were placed on a dry, accessible surface, making it easy to measure voltage, current, and signal frequencies. Meanwhile, the thrusters were submerged in a water-filled bucket, replicating the underwater environment.

To effectively test the electrical functionality of the ESC-thruster system, a verified PWM Servo Controller was used to provide a reliable signal. This way, any faults detected would be isolated to the ESC-thruster system. After testing, the team found no issues, leading to the conclusion that the erratic behavior could only be caused by a faulty signal. Thus, the next step was to find the source of the faulty signal. ROVOTICS began by testing the custom I2C-PWM Board. When this component was added to the verified ESC-thruster test tank, the thruster started behaving erratically, confirming that the I2C-PWM Board was the source of the problem. After analyzing the board with an oscilloscope, the team saw that the voltage being fed to the PCA9685 chip—an integrated circuit that converts I2C signals from the MEH to PWM signals for the ESCs—occasionally dropped below the minimum operating voltage. To determine the source, ROVOTICS reviewed the custom board's schematic and found a critical power supply issue: one linear voltage regulator was being powered by another identical regulator. This configuration produced an additional voltage drop because the second regulator received an input voltage below its minimum requirement leading the PCA9685 to brown out and send corrupted signals.

Luckily, the solution to this problem was simple: remove the problematic linear voltage regulator. This ensured that the PCA9685 chip received a proper supply of voltage, resolving the thruster issues. Through this methodical troubleshooting process, ROVOTICS was able to pinpoint the root cause and effectively resolve the issue, improving *Marlin's* overall dependability.



Thruster Testbench

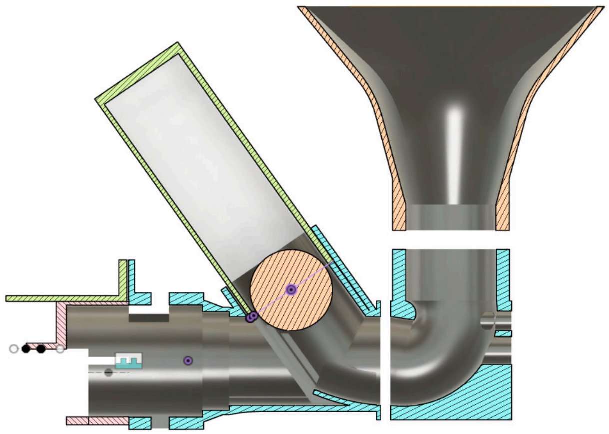
DUAL CATCH TOOL

When brainstorming about how to safely collect fish and medusa-stage jellyfish, ROVOTICS considered a funnel design to safely draw marine species into a container by using a suction force. To power this suction force, there were two options:

1. A powerful but complex Diamond Dynamics thruster

2. A simple bilge pump.

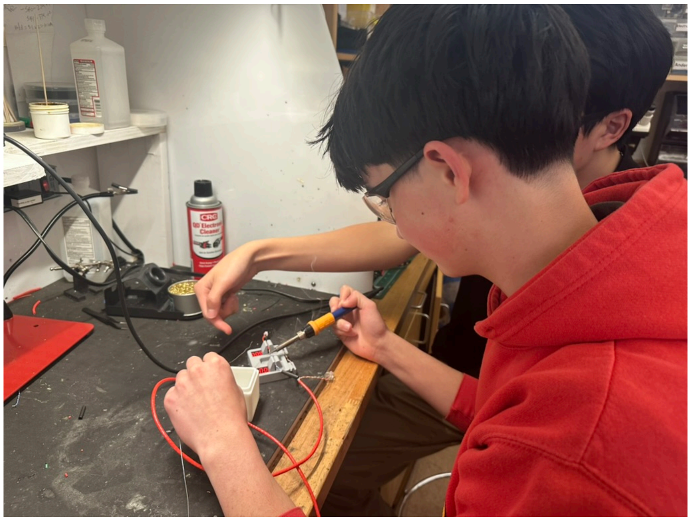
Having no experience with either, the team prototyped the bilge pump first because a simple yet effective design was preferable. After digitally modeling and prototyping a 3D-printed funnel, extensive testing revealed that the design could overcome a ping pong ball's buoyant force—a critical requirement. The success of this simple bilge pump design eliminated the need for a more complex thruster approach, saving significant development time and resources. Next, ROVOTICS prototyped a cylindrical ball storage reservoir. Testing revealed a critical flaw: trapped air bubbles prevented balls from entering. After adding holes for air to leak out, the issue was resolved. After further testing, ROVOTICS guaranteed that marine species would be surrounded by water at all times without harming them with the tool. This systematic prototyping approach allowed ROVOTICS to evaluate each component and issue, ultimately reducing both cost and development time.


CAD of the Dual Catch Tool

SAFETY

The safety features on *Marlin* and GO-POD ensure non-hazardous operations at all times. All thrusters have visible metal guards that protect operators and wildlife by preventing anything the size of a finger or larger from coming into contact with the propellers, adhering to IP20 protection Standards. On the frame, smooth end caps remove sharp edges, preventing scratches, cuts, and environmental damage. For protecting operators and wildlife, the grippers are equipped with shielded gears and surface padding to prevent trapping or crushing accidents when servicing subsurface spotter buoys, collecting environmental DNA (eDNA), and more. If safety issues arise, operators can quickly cease operation by turning an Emergency Shut-off Switch. The deck crew can then safely bring the ROV to the surface for inspection. To protect all electrical connectors, secure strain relief attachments connect the ROV and the TCU while protecting vital cabling from damage and allowing the ROV to be safely lifted by the tether without damaging connections. To adhere to safety regulations, GO-POD has a pressure release plug that vents pressure in case the internal pressure reaches an unsafe level, preventing explosions and keeping wildlife and employees safe. In addition, the float's voltage and current regulation ensure that electronics operate within safe levels and automatically shut down before dangerous levels are met.

To maintain safe practices, ROVOTICS emphasizes the importance of training so that all members can adhere to team protocols and procedures. The team's peer-to-peer training system includes upperclassmen, alongside experienced coaches, who mentor and supervise underclassmen. When coaches confirm that new members consistently demonstrate safe operating practices with tools and machinery, members update the Equipment Authorization Sheets listing those who are qualified to use specific equipment. To ensure that everyone uses materials, safely, ROVOTICS maintains Material Safety Data Sheets (MSDS) that clearly show the properties of different materials and how to properly use them. During both the manufacturing process and the operation of products, wearing safety glasses is mandatory to prevent injury to eyes.


Ian Kim training Jonah Meyer to solder safety while wearing safety glasses.

To enhance operational safety, ROVOTICS has developed a scripted communication protocol. When the ROV's pneumatics and power are disabled, the pilot notifies the tether managers so they know when it's safe to handle *Marlin*. Additionally, ROVOTICS' lab facility features a roof-mounted vent hood so that members can solder electronics with proper ventilation. For more details about safety protocols and procedures, see the Operations and Safety Checklist on page 21.

Budget & Accounting

ROVOTICS receives its income from funding at Jesuit High School, donations, and dues from the families of team members. At the beginning of each season, ROVOTICS prepares a budget with estimated costs based on the prior year's actual costs. Since the ROV is based on a standard design, it is easy to forecast the budget. The team starts by referencing previous costs that are documented in BOMs (Bills of Materials), and then, ROVOTICS accounts for inflation and price differences in certain components. After this, the team focuses on estimating the costs for *Marlin's* enhancements and tools. To ensure adherence to the projected budget, ROVOTICS submits BOMs for purchases that coaches review. All purchase receipts are tracked in a Project Cost Sheet, which undergoes a monthly review to track spending. The 2024-2025 Project Cost Sheet can be found on page 25. It is important to note that expenses related to transportation, travel, and meals are estimated but listed separately because members are responsible for paying these costs themselves.

Acknowledgments

- MATE Center and Marine Technology Society - Sponsoring this year's competition
- Oceaneering International - Their support of the MATE competition
- Jesuit High School - Their generous donation of funding and pool access
- Our Coaches (Jay Isaacs, Cheryl Kiyama, Steve Kiyama, Michael Sharp, Aimin Wang) - Their dedication, guidance, and time
- MacArtney Underwater Technology - Providing connectors at a reduced rate
- GitHub - Providing complimentary private code repositories
- Autodesk - Supplying a quality CAD software for 3D modeling
- KiCad EDA - Providing a free, open-source software environment to design PCBs
- TAP Plastics - Donation of stock plastic
- Our Families - Their continued support and encouragement

Appendix

Operations & Safety Checklist

Pre-Power Procedure (Pilot, Co-pilot & Deck Crew)

- Area clear and safe (no tripping hazards, items in the way)
- Verify power switches and circuit breakers on TCU are off
- Tether flaked out on the deck and free from damage
- Tether connected to TCU and secured
- Tether connected and secured to ROV
- Tether strain relief connected to ROV
- Verify the electronics housing sealed
- Visually inspect electronics for damaged wires, loose connections
- Fasteners are tight on the electronics housing
- Thrusters free from obstructions
- Power source connected to TCU
- Vacuum test electronics housing (see vacuum test procedure)
- Verify vacuum check port is securely capped

Vacuum Test Procedure (Deck Crew)

- Verify MEH housing fasteners are secure and visually inspect front cover seal.
- Verify PSE screws are secure.
- Verify screw caps on all cameras are secure and o-ring seal is properly seated.
- Connect vacuum hand pump to ROV electronics housing
- Pump electronics housing to -35 kPa (vacuum), this is 10 inches of Hg on the gage.
- Verify electronics chamber holds -35 kPa (vacuum) for 5 minutes
- Remove vacuum pump and securely cap vacuum check port
- Stow vacuum hand pump back in case

Power-Up Procedure (Pilot, Co-pilot & Deck Crew)

- Verify TCU receiving 48V nominal
- Control computers up and running
- Ensure deck crew members are attentive
- Call out, "Power On"
- Power on TCU
- Call out, "performing thruster test"
- Perform thruster test/verify thrusters are working properly (joystick movements correspond with thruster activity)
- Switch between each camera to verify video feeds and proper camera positioning.
- Test any electrical or pneumatic tools that require pilot control

Launch Procedure (Pilot, Co-pilot & Deck Crew)

- Place ROV in water
- Visually check for bubbles
- If there are bubbles from the electronic housings, remove ROV from water immediately and call out "electronics leak". Proceed with Leak Detection Protocol
- If no issues are observed, the deck crew calls out "ready to launch"
- Co-pilot calls out, "Prepare to launch"
- Deck crew members handling ROV call out "hands off!"
- Co-pilot calls out "thrusters engaged" and pilot begins mission

ROV Retrieval (Pilot, Co-pilot & Deck Crew)

- Pilot calls "ROV surfacing"
- The deck crew calls "ROV on the surface. Disable thrusters"
- Co-Pilot disables thrusters and calls out "Thrusters disabled"
- The deck crew calls "Hands On", and removes ROV from the water
- After securing the ROV on deck, the deck crew calls out "ROV secured on deck"
- Co-Pilot powers down TCU if the team is demobilizing from deck.

Leak Detection Protocol (Pilot, Co-pilot & Deck Crew)

- Power down system and remove ROV from water if running a mission. Recover ROV by pulling to the surface using the tether if required.
- Visually Inspect to determine source of leak. Do not disassemble any part of the ROV until the leak is located.
- Install pressure testing equipment and use soapy water to verify the leak source.
- Create a plan to repair the leak and check all systems for damage and proper operation.

- Document the cause of the leak and implement corrective action or design changes as required

Loss of Communication (Pilot, Co-pilot & Deck Crew)
- Cycle power on TCU to reboot ROV
- If no communications, power down ROV, retrieve via tether
- If communication restored, confirm there are no leaks, resume operations
- If communication is not restored, begin troubleshooting procedures, Isolate the issue. Is there a hardware or software cause? Proceed to analyze/ isolate cause
- Document the cause of the failure and implement corrective action or repair as required

Pit Maintenance (All Team members)
- Pit is organized and free of garbage.
- Verify all tools and cables are neatly stored and there are no trip hazards.
- Check electrical cords and correct any possible electrical hazards
- Clean Thrusters with Deionized Water
- Inspect Tether Power and Network Connectors
- Check supplies and organize a shopping list if anything is needed for repair or upkeep.
- Verify TCU, ROV and tether are clean, dry and properly stored. Protective caps for electrical connectors should be in place
- ROV, TCU and tether have been readied for use on the next mission run

Inspect and Test Pneumatic System (Pilot, Co-pilot & Deck Crew)

- Verify all pneumatics lines are properly connected to the air source, TCU, and ROV
- Verify that the compressor is switched on
- Activate pneumatics system and open main valve
- Verify there are no leaks and pneumatic lines are securely connected while under pressure
- Activate any pneumatic tool and verify the pressure returns to 2.75 Bar (40PSI) after the tool is shut off. Adjust pressure regulator to 2.75 Bar (40PSI) if required and repeat the test until 2.75 Bar (40 psi) is achieved

Buoyancy Calculations

Item	Quantity	Mass (g)	Volume (cm^3)	Net (g)	Net Force (N)
Core ROV[1]	1	-12,450	8,910	-3,540	34.7
Static Buoyancy[2]	1	-1,180	4,420	2,540	-24.9
Modular Buoyancy[3]	6	-20.4	864	843.6	-8.3
Total		-14,350	14194	-156	1.5

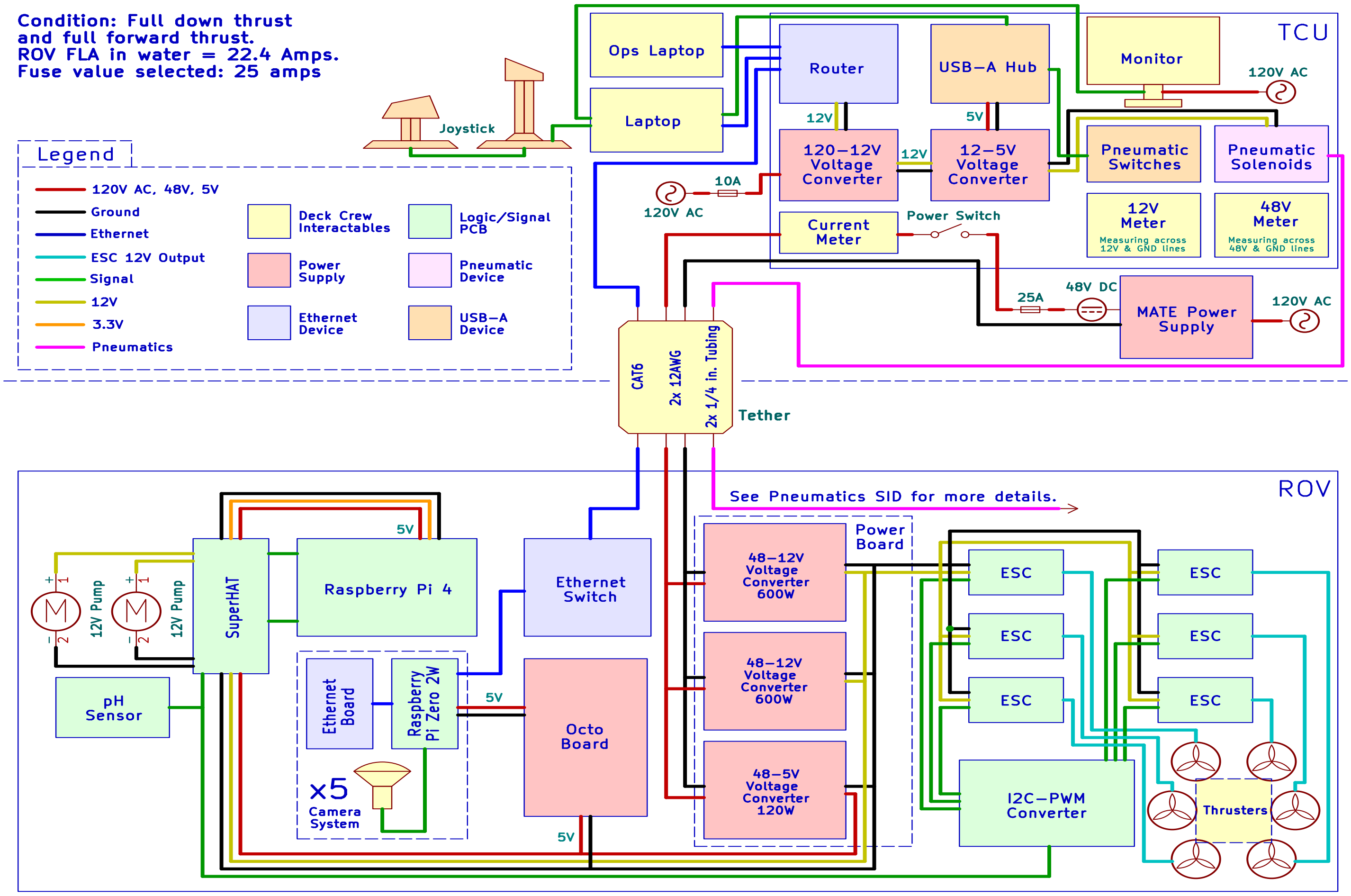
[1]Core ROV: Cameras, thrusters, tether, aluminum extrusions, brackets, and screws

[2]Static Buoyancy: Main Electronics Housing (MEH), Power Systems Enclosure (PSE), and Nacelles

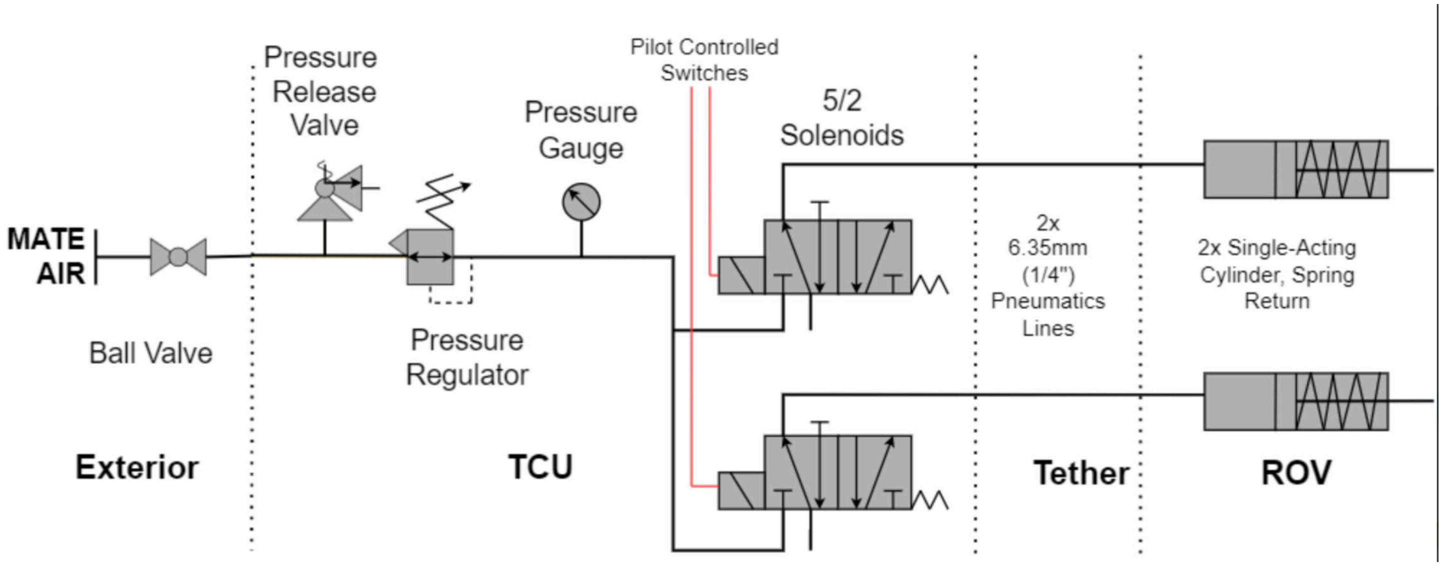
[3]Modular Buoyancy: Hydrostatic Foam Squares

The added ballast of tools is not included in these calculations.

ROV SID

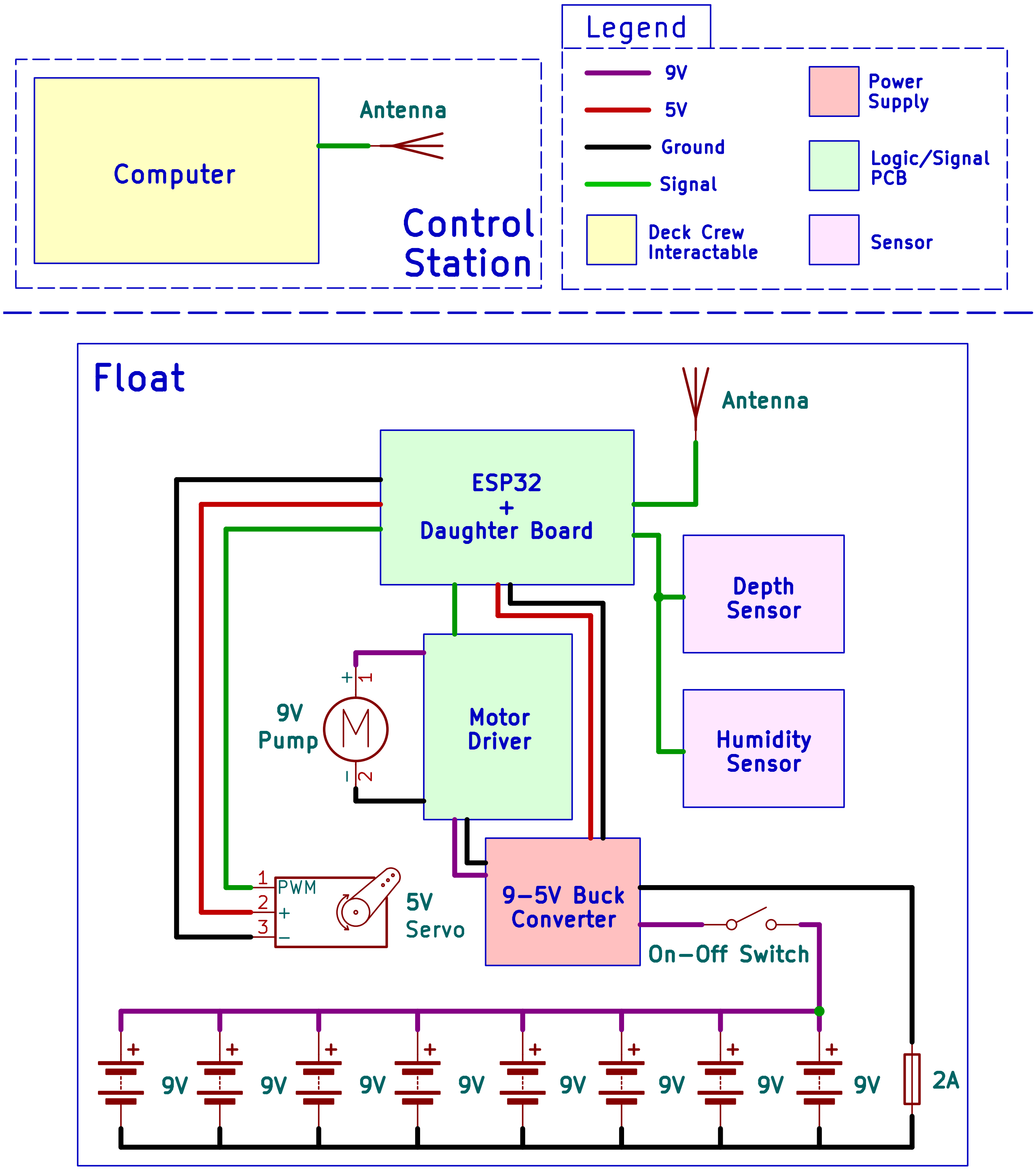


PNEUMATICS SID



FLOAT SID

FLA Measurements
Waiting mode: 0.2A
Buoyancy change mode: 1.6A
Fuse value selected: 2A



BUDGET & COST ACCOUNTING SHEET

Income	Budget	Type
Jesuit School Funding	$ 12,000.00	Income
Student Fund Raising	$ 3,250.00	Income
Donations	$ 5,000.00	Income
MATE Competition Awards	$ 300.00	Income
Employee Dues	$ 4,250.00	Income
Total Income	$ 24,800.00	
Production Expenses	**Budget**	**Type**
Frame & Housing	$ 500.00	Purchased
Thrusters & ESCs	$ 850.00	Purchased
TCU	$ 542.41	Re-used
Tether & Connectors	$ 450.00	Re-used
Electronics & Connectors	$ 1,500.00	Purchased
Electronics Rework	$ 500.00	Purchased
Pneumatics	$ 100.00	Re-used
Mission Tools	$ 600.00	Purchased
Mission Control Center	$ 1,350.00	Purchased
Raw materials	$ 500.00	Purchased
Production Budget	$ 6,892.41	
R&D Expenses	**Budget**	**Type**
Elegoo Resin Printer	$ 500.00	new
Bambu A1 mini 3d printers	$ 600.00	new
Test Benches	$ 750.00	new
R&D Budget	$ 1,850.00	
Operations Expenses	**Budget**	**Type**
Lodging	$ 7,000.00	Purchased
Mission Props	$ 300.00	Purchased
MATE Entry Fee	$ 450.00	Purchased
Power Fluid Quiz Fee	$ 25.00	Purchased
Printing	$ 500.00	Purchased
Operations Budget	$ 8,275.00	
Employee Paid Expenses	**Budget**	**Type**
Competition Meals	$ 3,600.00	Purchased
Transportation & hotel subsidy	$ 3,250.00	Purchased
Estimated Employee Fees	$ 6,850.00	

Production & Operations Budget & Cost Analysis	Project Cost	Difference
Available Income	$ 24,800.00	
Total Budget		$ 17,017.41
Production ROV Costs	$ 7,338.32	$ (445.91)
Research & Development Costs	$ 1,768.17	$ 81.83
Operations Costs*	$ 8,551.49	$ (276.49)
Capital Costs	$ -	$ -
* Budget overage due to increased fees		$ 125.00
Funds available for next season	$ 7,142.02	
Description	**Project Cost**	**Difference**
Polycase Housings, 15mmx15mm aluminum extrusio	$ 745.80	$ (245.80)
(6) T100 Blue Robotics thrusters & ESCs + 2 spares	$ 820.80	$ 29.20
Case, Monitors, Electronics, Pneumatics, joystick	$ 702.41	$ (160.00)
Si wire, CAT5e, coax cable, sheathing, connectors	$ 611.28	$ (161.28)
PCB Board Fab, components, connectors, cameras	$ 1,516.20	$ (16.20)
PCB revisions and components	$ 352.18	$ 147.82
Valves, fittings, tubing	$ 100.00	$ -
Gripper Fingers, Jelly fish tool, ph sensor, expoxy	$ 768.34	$ (168.34)
Lenovo Laptop 16"	$ 1,326.29	$ 23.71
Plastics, metals, hardware, 3D filament, consumables	$ 395.02	$ 104.98
Total ROV Production Cost	**$ 7,338.32**	**$ (445.91)**
Description	**Project Cost**	**Difference**
Elegoo Resin Printer (Donated)	$ 500.00	$ -
Bambu printers	$ 645.84	$ (45.84)
SW test benches (3)	$ 622.33	$ 127.67
R&D Project Cost	$ 1,768.17	**$ 81.83**
Description	**Project Cost**	**Difference**
11 hotel rooms for team/2 per room	$ 6,875.00	$ 125.00
MATE mission props supplies, materials	$ 468.00	$ (168.00)
MATE entry fee	$ 650.00	$ (200.00)
MATE power fluid quiz	$ 25.00	$ -
Report, display, brochure printing	$ 533.49	$ (33.49)
Operations Project Cost	**$ 8,551.49**	**$ (276.49)**
Description	**Project Cost**	**Difference**
Cash collected for competition meals;14 people	$ 3,600.00	$ -
Cash contribution for car rental, gas, & hotel subsidy	$ 3,250.00	$ -
Actual Employee Fees	**$ 6,850.00**	**$ -**

REFERENCES

- **Standard BOM Format:** https://www.projectmanager.com/blog/bill-of-materials
- **Jesuit GitHub Repository:** https://github.com/jhsrobo
- **Rosbag Feature Documentation:** https://docs.ros.org/en/jazzy/Releases/Release-Jazzy-Jalisco.html#rosbag2
- **Arducam Specs:** https://www.arducam.com/12-3mp-477m-hq-camera-module-for-raspberry-pi-with-135d-m12-wide-angle-lens.html
- **GO-BGC Floats:** www.go-bgc.org/floats