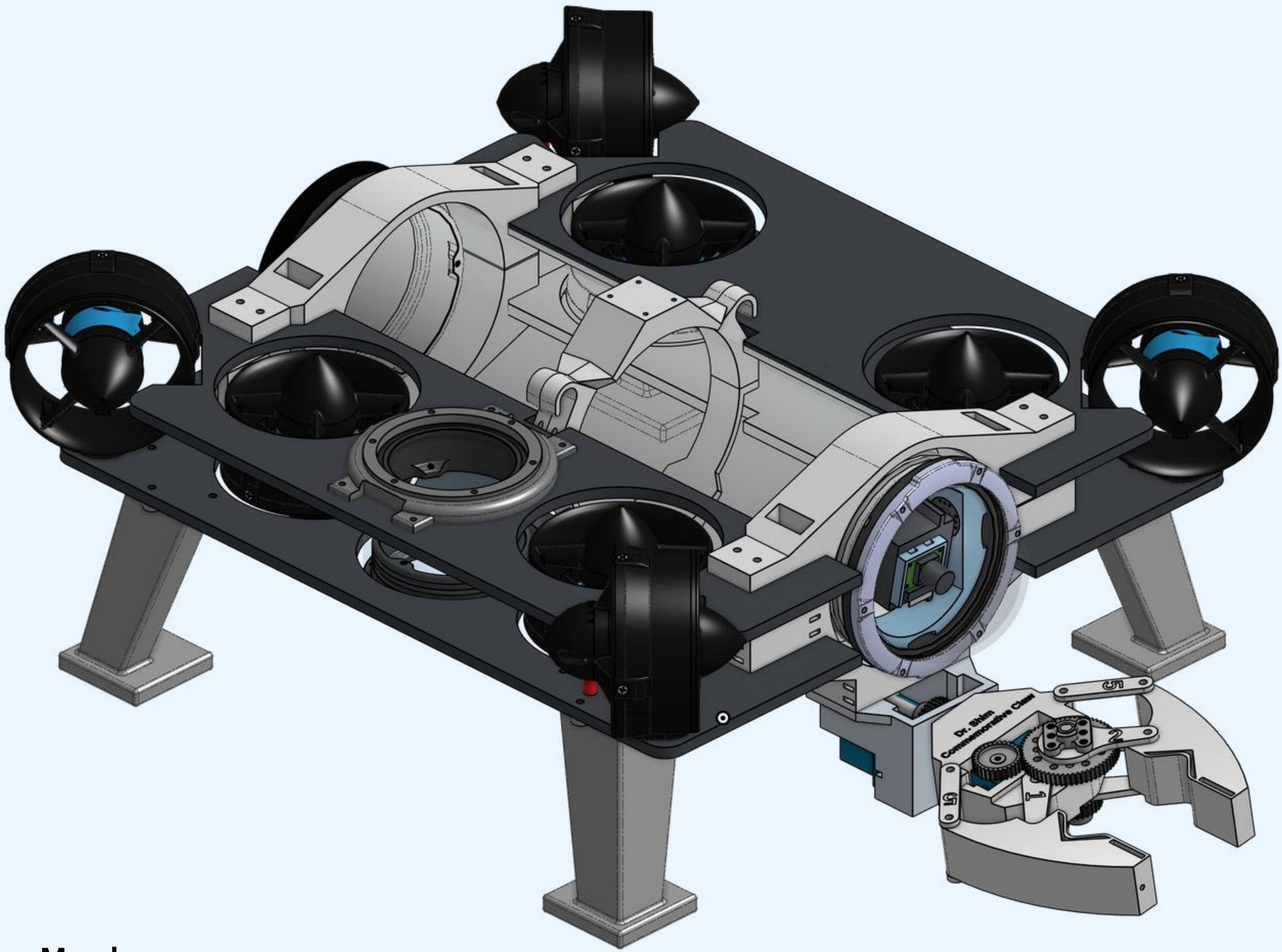
# WARRIORTIDES

VALLEY CHRISTIAN HIGH SCHOOL
SAN JOSE, CALIFORNIA, USA

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# ABSTRACT

WarriorTides is an entirely student-run company based in San Jose, California, specializing in underwater Remotely Operated Vehicle (ROV) design and deployment. This eight-person company is innovating cutting-edge products capable of addressing today's oceanic issues, including research data collection, SMART cable deployment, coral and sturgeon restoration, and working in tandem with a GO-BGC float. WarriorTide's newest innovation is *Panini*, which is more technically sophisticated and reliable than any previous products. Meticulously manufactured through prototyping, testing, and troubleshooting, *Panini* can efficiently perform a wide range of mission tasks.

The fifth ROV produced by WarriorTides, *Panini,* features eight T200 thrusters configured to support all six degrees of freedom. This agility, coupled with a two-point rotation manipulator and a low-latency dual-stream vision system, creates the optimal driving experience. Additionally, *Panini's* highly serviceable interconnecting PCB and modular laser-cut Delrin frame facilitate easy maintenance and adaptability. Equipped with multiple specially designed mission tools, including a Gatling float, *Panini* is capable of advancing the United Nations' Sustainable Development Goals.

Beyond technical innovation, WarriorTides is committed to making an impact in the community. This season, WarriorTides mentored Warrior Waves, a Navigator-level team, led a week-long engineering camp for students from low-income families, organized underwater robotics education events, and participated in a local beach cleanup.

Amidst transformative changes in design philosophy, team structure, and management, this year has marked a significant milestone for WarriorTides. As the company continues to push boundaries, *Panini* exemplifies WarriorTide's breakthrough innovation and continued passion for preserving aquatic environments for the next generation.

*Figure 1: WarriorTides team photo (Shivaan Patel & Kashish Kapoor not pictured)*
*Taken by Melissa Chacon*

# ROV OVERVIEW

To begin the season, WarriorTides identified key issues in last year's ROV and brainstormed possible improvements that would allow *Panini* to complete mission tasks more effectively. Drawing upon the team's collective expertise, key design choices (discussed in more detail later in this document) were made to maximize *Panini*'s capability.

**Key Mechanical Design Choices:**

- Returned to cylindrical acrylic electronics enclosure from aluminum box due to waterproofing issues
- Electronics enclosure sandwiched between in-house laser cut Delrin sheets with custom mounting points for rotating parallel gripper (claw), external camera, thrusters, and buoyancy
  - Simple form-factor enabled early season testing, and new components could be added to the ROV as they were designed
  - Enables the ROV to maintain all 6 degrees of freedom
  - Lightweight and sleek for increased speed and reduced drag

**Key Electrical Design Choices:**

- Designed an interconnecting printed circuit board (PCB) system rather than a power distribution PCB for improved serviceability, modularity, and wire management
- Ethernet network was selected for communication, allowing for HD, low latency video stream and isolation with the camera and control systems
- Returned to Fathom-Slim tether due to ethernet communication and the lightweight tether properties
- Addition of an “Emergency STOP Button” to the topside station as a safety measure

**Key Software Design Choices:**

- Development of proportional-integral-derivative (PID) controllers and pilot graphical user interface (GUI) to improve the driving experience
- Focus on computer vision algorithms and programs specific to mission tasks
- Developed failsafe code that initiates automatic restarts if a component crashes or fails to respond

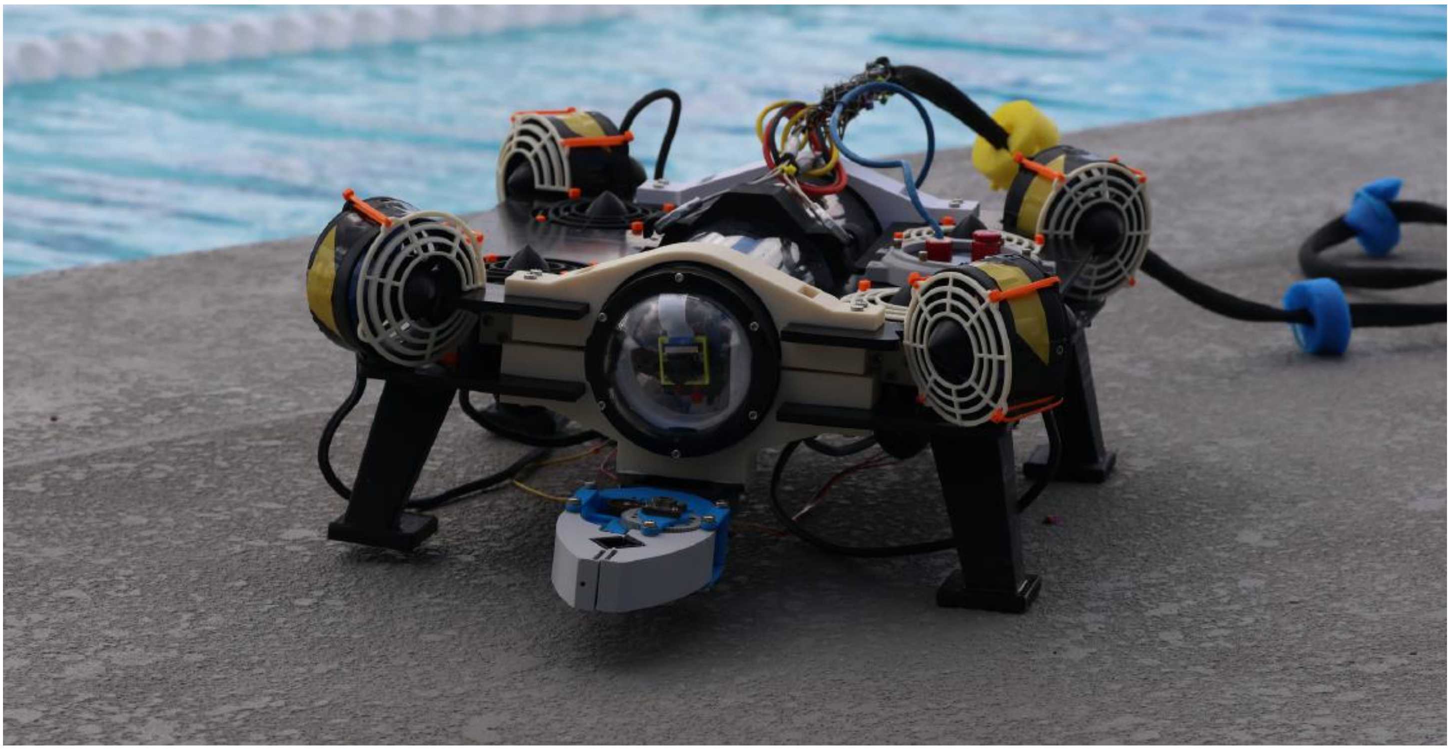


*Figure 2: Panini by the poolside*
*Taken by Jonathan Lim*

# PROJECT MANAGEMENT

## Company Structure

WarriorTides is an entirely student-run company of eight engineers. The six-year-old company is organized into three subteams: software, electrical, and mechanical. Each subteam is managed by a more experienced leader responsible for delegating tasks within the subteam and making design decisions.

The company is run by an executive leadership team consisting of one CEO and two co-presidents. The CEO is responsible for managing overall team progress, setting deadlines, supervising the budget, and advising final design decisions. The CEO consults the co-presidents for alternative opinions on decisions or for assistance in running day-to-day operations at the company. The executive leadership team works in conjunction with subteam leads to ensure that the company runs as one cohesive unit.

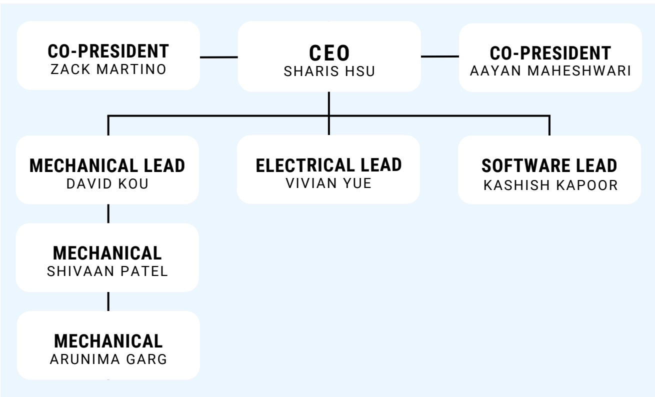



*Figure 3: WarriorTides organizational chart*
*By Sharis Hsu*

## Day-to-Day Operations

WarriorTides employees meet from 3 to 6 pm on Mondays and Wednesdays for a total of six hours per week. In March, just over a month before the regional, the company switches to meeting every day of the week to increase the amount of pool testing and work time possible.

WarriorTides communicates via Microsoft Teams as it is an organized environment for company announcements and discussions. Additionally, Microsoft Teams enables friendly but professional communication between employees and mentors.

The executive leadership team strives to schedule at least one formal team bonding event every two months. These are intended to boost morale within the company, enable employees to form a community, and establish a collaborative atmosphere. WarriorTides strongly believes that a good team dynamic between all employees enables productive learning and collaboration. Consequently, WarriorTides has held team bonding events such as a beach cleanup, laser tag, and a Christmas party. Similarly, at every meeting, different team members bring in snacks to share so employees can have a relaxing break together halfway through meetings. The positive team culture of this company and the lifelong friendships between employees are a direct reflection of WarriorTides' commitment to team bonding.

*Figure 4: The team celebrates Christmas together*
*Taken by Howard Ding*

## Scheduling

Upon encountering significant failures in the 2022-2023 season, WarriorTides was forced to take a serious re-evaluation of the company's approach to project management and scheduling. This reflection led executive leadership to work more closely with subteam leads, follow a schedule readily available to all company members, and create overtime meetings to maintain timely progress.

During the 2023 summer, executive leadership and subteam leads came together to brainstorm for the year. At this meeting, deadlines for key components were set, like when the PCB needed to arrive or when the ROV CAD needed to be completed. These were placed into a running Gantt Chart (Appendix A) where more minute deadlines were gradually added, such as "silkscreen completion."

This year, every working week began with the CEO reviewing where the company was in the year and what tasks needed to be completed by the end of the week. After this initial meeting, subteam leads were responsible for enforcing the completion of these tasks with their team or breaking down these tasks into multiple smaller parts. At the end of every week, subteam leads were responsible for reporting their task status to the CEO This consequently enabled all subteams to stay on track for big-ticket events like the initial pool test.

## Decision Making

WarriorTides shifted its decision-making approach to involve all employees from all subteams. Utilizing decision matrices as a framework, WarriorTides systematically evaluated options ensuring that they were feasible across all subteam areas. The company also took into consideration this season's design philosophy that was established before the season started (explained on page 7 of this document).

For example, when selecting thruster configurations, the company considered mounting feasibility for mechanical, programming complexity for software, and PCB compatibility for electrical. The combination of inputs allowed WarriorTides to select design choices that maximize the performance of *Panini*.

## Peer-to-Peer Mentoring

WarriorTides has three mentors who are adept in different technical fields. These mentors can be sought out for advice but do not participate in any day-to-day operations because WarriorTides is entirely student-run. Therefore, the company relies on peer-to-peer mentoring to educate the next generation of engineers.

At the start of the season, veteran employees host educational workshops on their areas of expertise. Some of these workshops include "Electrical 101," "CAD Basics," and "ROV Basics." These workshops help to jumpstart employees' knowledge. Throughout the season, rookie employees shadow subteam leads who help guide them through technical challenges. WarriorTides is tremendously proud of how the majority of employees begin working with no technical skills but graduate able to design PCBs, write complex code, or 3D model intricate parts due to peer-to-peer mentoring.


*Figure 5: Electrical Lead Vivian Yue holds a workshop*
*Taken by Sharis Hsu*

# BRAINSTORMING

WarriorTides' brainstorming methodology centers around evaluating the strengths and weaknesses of previous ROVs and prototypes to develop new ideas. Since WarriorTides begins research and development in July, time can be devoted to prototyping and experimentation, which has proven to be largely successful. As the team begins to narrow down to several ideas, decision matrixes are created to determine the best option.

## Design Philosophy

As part of the WarriorTides design philosophy, the team follows a new tenet each season that guides decision-making. These team tenets are selected by WarriorTides leadership during the summer and continue to be referenced throughout the year. Implementation of this guiding philosophy unifies WarriorTides as all employees work together underneath an overarching mission. This year's team tenet is *"Pressure Creates Diamonds,"* encouraging employees to experiment with something new, even if it is uncomfortable. The hope is that these explorations will generate unique outcomes that allow WarriorTides to continue growing.

- **Mechanical.** *Unity and Performance.* This tenet encourages the mechanical subteam to emphasize communication among its members, preventing time-wasting miscommunication. This principle prompted a companywide shift to Onshape for easier collaboration and continues to support synergy among all employees.
- **Electrical.** *Vision into Voltage.* This tenet inspires the electrical subteam to consider complex electrical system designs as a reality instead of writing them off as too difficult or time-consuming to attempt. This mindset is the primary reason for this season's successful attempt at a 4-board interconnecting PCB.
- **Software.** *What's the Worst that Could Happen?* This tenet motivates the software subteam to try and further programs instead of stopping at the bare minimum. This mentality inspired programs like multi-directional thrust, as the team had confidence they could return to regular drive code if anything went wrong.

# VEHICLE DESIGN

## Frame

A prominent goal for WarriorTides's ROV design this year was simplicity. This idea is reflected in *Panini's* frame—composed of a 4-inch (101.6 mm) Blue Robotics enclosure that houses electronics, four laser-cut Delrin sheets that compose most of the ROV's structural layout, plus 3D-printed pieces that hold the enclosure and Delrin together. WarriorTides chose Delrin over acrylic due to its high strength-to-weight ratio and neutral buoyancy, making *Panini* more lightweight and hydrodynamic than any previous ROV.

This focus on simplicity, alongside other intentional design choices, made future upgrades simple and efficient. Although WarriorTides considered using aluminum extrusions due to the modularity of moving mounts along the railing, the ability to drill and cut holes of any size anywhere in *Panini's* Delrin sheets is a more versatile means of attachment. Screw mounting parts were also implemented throughout 3D-printed parts of the frame for easy attachment of new pieces like the buoyancy mount. Because these screw-in points are inherent to the design of *Panini*, WarriorTides was able to quickly prototype and modify mission-critical components like the claw manipulator to meet task requirements without having to worry about the forward compatibility of existing parts.

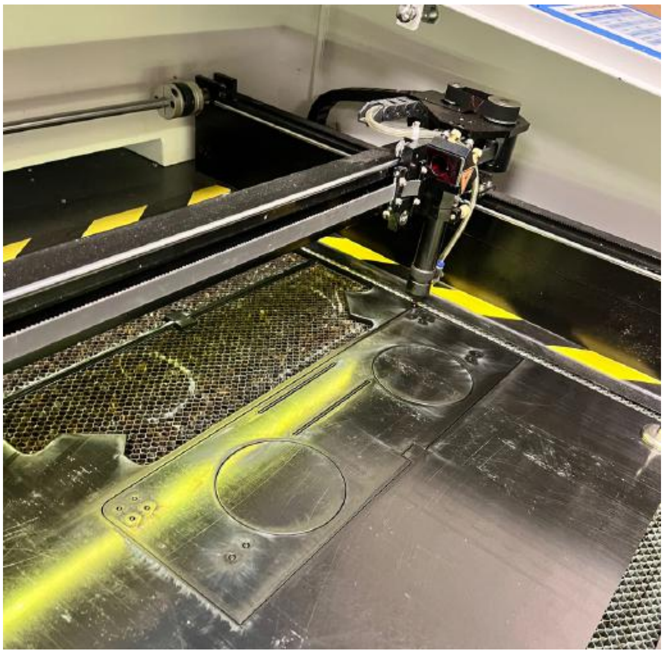


*Figure 6: Delrin frame laser-cut in-house*
*Taken by Sharis Hsu*

## Propulsion

*Panini* is propelled by eight Blue Robotics T200 thrusters, four of which are vectored while the other four are oriented for vertical thrust. This setup was selected rather than last season's six T200 thrusters design because it allows *Panini* to achieve all 6 degrees of freedom. Although this does reduce the power budget for each thruster, the increased ROV maneuverability to navigate tasks is a worthy trade-off. Additionally, by selecting Delrin for the frame, *Panini* is incredibly lightweight (only 10.2 kgs on land), so a slightly lower thrust still enables the ROV to move at a competitive speed.

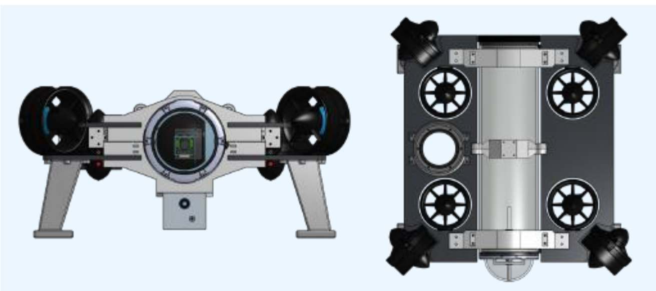


*Figure 7: Thruster mount locations*
*By David Kou*

## Buoyancy

*Panini* is designed to be slightly positively buoyant, ensuring it will resurface during an emergency. This slight positive buoyancy also aids in lifting heavy props to the surface during mission tasks.

| Part | Water Displacement ($cm^3$) | Mass (g) | Displaced Water Mass (g) | Net Buoyancy (N) | Unbalanced Buoyant Force (N) | Force of Gravity (N) |
|---|---|---|---|---|---|---|
| Delrin Sheets | 908.9 | 1232 | 908.9 | -3.17 | 8.92 | 12.09 |
| Legs (ABS) | 621.5 | 652 | 621.5 | -0.3 | 6.1 | 6.4 |
| Thrusters (w/o wires) | 1561.8 | 2055 | 1561.8 | -4.84 | 15.32 | 20.16 |
| Thruster Wires (~70cm each) | 180.2 | 488 | 180.2 | -3.02 | 1.77 | 4.79 |
| 3D-Printed Racks | 650.1 | 684 | 650.1 | -0.33 | 6.38 | 6.71 |
| Strain Relief Mount | 101.9 | 107 | 101.9 | -0.05 | 1 | 1.05 |
| Claw Wrist Mechanism | 101.8 | 198 | 101.8 | -0.94 | 1 | 1.94 |
| Claw Gripper Mechanism | 327.7 | 501 | 327.7 | -1.7 | 3.21 | 4.91 |
| Bottom Cam (w/ wires, PCB, cam) | 511.84 | 2500 | 511.84 | -19.51 | 5.02 | 24.53 |
| Enclosure (w/ flange, cam, PCB) | 4450.1 | 1000 | 4450.1 | 33.85 | 43.66 | 9.81 |
| Washers & Nuts | 4.5 | 35.3 | 4.5 | -0.31 | 0.04 | 0.35 |
| Screws | 77.2 | 615 | 77.2 | -5.27 | 0.76 | 6.03 |
| Total | 9497.54 | 10067.3 | 9497.54 | -5.59 | 93.18 | 98.77 |

*Figure 8: Buoyancy calculation spreadsheet*
*By David Kou*

A system of weights and foam is used to achieve positive buoyancy. Initially, buoyancy blocks were mounted on the Delrin plates of *Panini;* however, after practicing Task 2, WarriorTides realized that external buoyancy foam served as places where the SMART cable could catch onto. This then prompted a change to sandwiching buoyancy foam between *Panini's* Delrin sheets to maintain a sleek profile. Pieces of foam were milled to fit around the T200 thrusters and bottom camera enclosure located between two of the wing plates. Additional weights are distributed among *Panini's* four legs to ensure that the center of mass stays below the center of buoyancy and that a large metacentric height is maintained for stability.

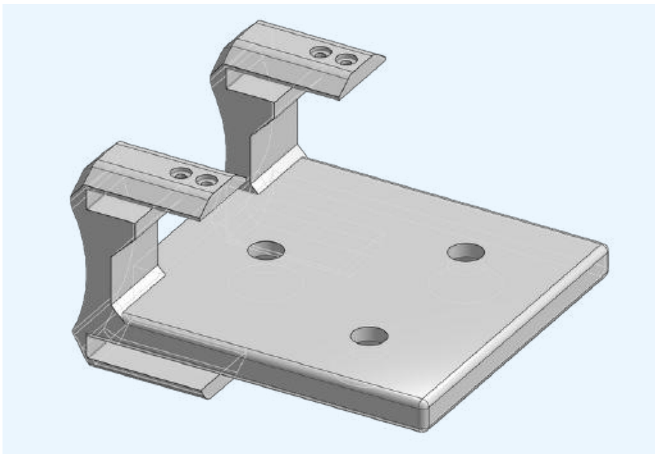


*Figure 9: Buoyancy foam mount*
*By Shivaan Patel*

# CONTROL SYSTEM

## Onboard Electronics

The core of *Panini's* electronics system is four interconnecting PCBs, successfully making the electronics enclosure more serviceable and preventing clutter. This year, WarriorTide's electrical team considered two possible designs: a two-layered power distribution PCB (utilized in 2022-23) or an interconnecting PCB system. Despite the simplicity and reliability of a two-layered power PCB, the interconnecting system was selected as it dramatically improves wire management issues involving ESCs, a key problem noted. Utilizing an interconnecting system allows WarriorTides to connect the entire electrical system simply by plugging in two connections, significantly less than the standard 10+ connections present in most designs. This novelty makes it possible to unplug a single board, perform a necessary fix, and then plug it back in without wasting any time by having to rewire. Additionally, this design challenged employees to innovate beyond the realm of previous designs. *Panini's* PCB system is separated into four boards: 1) Passthrough, 2) ESC, 3) Raspberry Pi (RPi), and 4) Spacer.

The Passthrough board is the centerpiece of this electrical system. This board connects perpendicularly to the ESC and RPi Boards, both of which plug into the Passthrough board. This board contains all wire connections to the flange as well as a Blue Robotics I2C Level Converter. As the name suggests, the ESC board houses all ESCs and an Arduino Mega Pro. The Arduino is responsible for generating PWM signals for the ESCs which are routed into the Passthrough Board and to the thrusters. With the theme of serviceability in mind, the ESC board uses screw terminals to attach all components rather than solder pads enabling rapid switching of ESCs. The RPi Board is home to an RPi 4, Fathom-X, and a mini ethernet switch. This architecture allows *Panini* to communicate with the topside station via Ethernet. Although this does require additional space, WarriorTides can remotely access the RPi 4 and upload new code to the Arduino Mega Pro over the tether. This once again improves *Panini's* serviceability as the code can be modified on the fly without having to open the electronics enclosure.

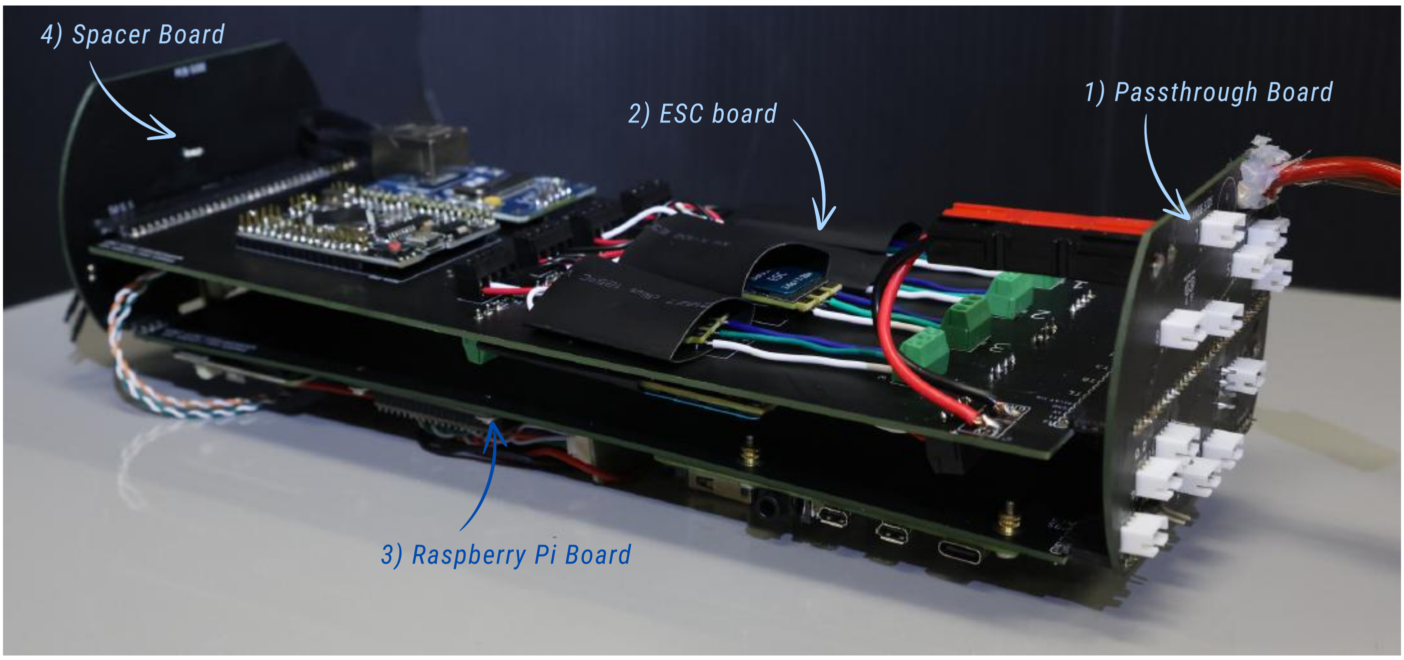



*Figure 10: 4-board interconnecting PCB system*
*Taken by Jonathan Lim*

All of *Panini's* PCBs were designed by employees using Autodesk EAGLE, first by creating an SID for the overall architecture, followed by schematics and layouts. At each step, designs underwent technical review by fellow team members, mentors, and WarriorTides alumni. All PCBs were manufactured by PCBWay but assembled in-house by employees. This allowed WarriorTides to save money and provide employees with valuable experience.

Due to the large number of intricate connections present in the PCB system, prototyping was key to WarriorTides' success. CADs of all PCBs were generated, allowing the system to be assembled in OnShape to ensure successful integration. Following this, the PCB shapes and through holes were laser cut into thin sheets of acrylic. Thus, a physical prototype was assembled to test that all mounted components fit their custom footprints and that all boards had precise connections.

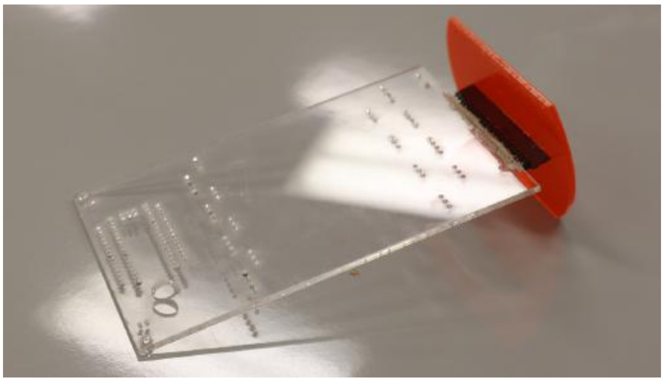


*Figure 11: Laser cut PCB prototype to test drill hole fits and connection between boards*
*Taken by Jonathan Lim*

After a fully functional electronic system was assembled and tested for several weeks, WarriorTides decided to make small revisions to the initial PCB design based on flaws noticed in performance. These revisions include the addition of board four, a spacer board that maintains the distance between the ESC board and RPi Board, reducing stress on the connections to the Passthrough Board. These revisions have allowed WarriorTides to produce a durable PCB system that is incredibly serviceable and successful.

# Tether

*Panini's* tether consists of a 12-volt 9-AWG silicon power and ground wire pair alongside a Blue Robotics Fathom Slim Tether. The Fathom Slim Tether was selected as it is a single twisted pair, making the tether easier to manage and preventing excessive tether drag as it is lighter and more neutrally buoyant than other alternatives. The wire pair in the Fathom Slim Tether is used for communication and data transfer and enables the Fathom-X to act as a transparent ethernet connection between topside and the ROV. These cables are enclosed in a mesh sheath to prevent tangles and lacerations.

# Tether Management

**Before ROV Launch**

- Inspect the tether for any damage
- Ensure strain relief is attached on both sides of the tether

**ROV in Water**

- One employee stands on the poolside letting tether in our out
- Pilot calls for more or less tether

**Following Pool Test**

- Tether is dried and inspected
- Tether is re-coiled using velcro straps

# Tospide Station

WarriorTide's topside station houses a Fathom-X Tether Interface board, two laptops, an Ethernet switch, a PlayStation controller, and two 22-inch (56 cm) LCD monitors. The Fathom-X board, Ethernet switch, and RPi-powered router allow multiple devices on topside to connect to the ROV, enabling seamless communication. Through this Ethernet network, both computers can receive video feed from the RPis which are then displayed on the monitors. The right monitor is for the pilot and displays video feeds in HD while also sending the pilot's driving data to the onboard Arduino. The left monitor is for the co-pilot and runs the copilot GUI to perform tasks such as Task 3.3 (3D Coral Modeling).

These topside electronics are housed within a Pelican Storm iM3220 Case with 44" x 14" x 8.5" interior dimensions. This case features press-and-pull latches and rugged in-line wheels for easy and safe transport. Brass hinges were added to restrict the case lid's maximum open angle. Two acrylic panels were installed to safely isolate cables underneath and provide a flat surface for the keyboard, mouse, and PlayStation controller. Alongside this, an "Emergency STOP button" was added, enabling the pilot to cut power to *Panini* instantaneously in an emergency.

*Figure 12: Topside station set up with co-pilot on the left side and pilot on the right side*
*Taken by Jonathan Lim*

## Sensors

For the first time in company history, WarriorTides implemented sensors within *Panini*. Sensors were deemed necessary because they improve the overall driving experience by keeping the ROV stable, and a temperature reading is crucial to completing Task 2.1 (Verify SMART cable sensor readings).

*Panini* utilizes a multifunctional Blue Robotics Bar02 sensor that records temperature readings while simultaneously reading depth, allowing the creation of a PID controller. This enables the ROV to maintain a constant depth within 2 cm accuracy even when picking up heavy props. This is incredibly helpful for intricate tasks like Task 1.1 (pull a pin to release float). The depth sensor is also used to alert the pilot of any rapid change in depth caused by external factors.

## Software Control Code

WarriorTides takes pride in developing all software control code in-house, utilizing open-source projects such as OpenCV, Pygame, and ReactJS as the backbone of the control system.

A key component of *Panini's* control system is an Arduino running locally onboard. This Arduino is responsible for generating PWM signals for thruster control and servo actuation. It also receives data from *Panini's* depth sensor via I2C and implements a PID controller. The Arduino communicates with the topside station via an ethernet module, allowing bidirectional communication with user datagram protocol (UDP) packets.

The topside station runs a Python script that acts as a bridge between the ROV and GUI. It manages UDP communication, hosts a WebSocket Server, and handles joystick input. Topside also hosts React-based web GUI by connecting to the WebSocket server. Thus, metrics from the depth and temperature sensors, camera feed, and the state of all processes currently running (PID, system test, autonomous driving, or system failures) can be displayed.

WarriorTides also developed a power optimization code to ensure that each thruster on *Panini* produces the maximum amount of thrust while keeping the 25-ampere limit in mind. This code dynamically adjusts individual thruster power based on the driver inputs from the PlayStation controller by utilizing efficiency, current draw, and thrust data of the T200 published by Blue Robotics.

Finally, a multi-directional driving algorithm was also developed by WarriorTides employees to improve the driving experience. Combining both the linear and angular directions of the X, Y, and Z axes, this program allows *Panini* to move in any direction the pilot desires.

# CAMERA SYSTEM

## Camera Placement

The camera system onboard *Panini* aims to optimize the number of perspectives for the pilot while minimizing the number of cameras required. The first camera is positioned at the front of *Panini's* central enclosure providing the driver with a view of the manipulator and any object they may be trying to grab during a task. This camera is also the primary navigation camera and increases the driver's situational awareness. To allow the pilot to view both the manipulator and in front of the ROV, this camera is mounted on a tilt servo, enabling field of view adjustments by the pilot.

The second camera is housed within an external enclosure located on the left wing of *Panini*. WarriorTides chose to situate this camera on the left wing rather than a more central location to decrease the side-on profile of the ROV and prevent the camera from scraping on the pool bottom or catching on props. The tradeoff was having to rebalance the ROV laterally using weights. This secondary camera is strategically angled to observe the area directly below the ROV which is particularly helpful for Task 3.3 (3D Coral Modeling), to complete the autonomous photogrammetry and measuring.

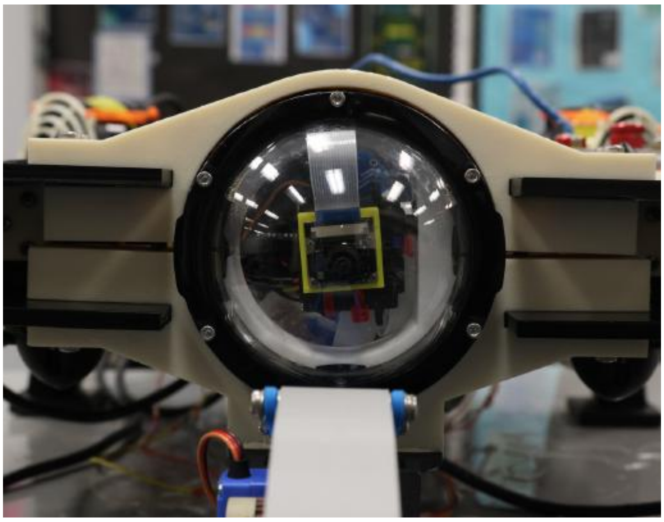


*Figure 13: Front camera mounted to servo*
*Taken by Jonathan Lim*

## Camera Enclosure

The front-facing camera is located within *Panini's* main enclosure so no additional enclosure is necessary. The bottom camera is housed inside a three-inch (76.2 mm) Blue Robotics enclosure that was cut down in-house to fit snuggly in the wing. The enclosure holds the bottom camera and an RPi. WarriorTides chose to utilize a purchased enclosure instead of 3D printing them like in previous years due to significant leak issues and the inability to open the camera enclosure safely. By customizing a purchased enclosure, the external camera enclosure fits *Panini's* main frame, is not at risk of leaking, and is easily serviceable by simply removing an endcap.

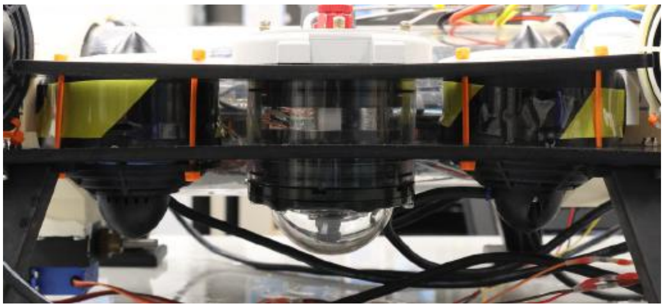


*Figure 14: Bottom camera located in the left wing*
*Taken by Jonathan Lim*

## Electronics & Code

*Panini's* camera system is composed of RPis connected via an ethernet network. Each camera module consists of an RPi connected to a wide-angle 5-megapixel camera via a CSI ribbon cable, allowing HD video streams at 24fps. Thus, the pilot has a clear and smooth view of the ROV's surroundings.

The front camera utilizes an RPi 4 to achieve a latency of only 0.1s. This RPi is connected to the Arduino in the central electronics enclosure, allowing code to be uploaded to the Arduino even when the enclosure is closed, enabling rapid modifications during testing.

For the bottom camera, WarriorTides utilizes an RPi Zero for its convenient size. This RPi is connected to the ROV with a single CAT-5 insulated ethernet cable and utilizes the 100BASE-TX standard for transmission. This communication standard requires only two twisted pairs (instead of the conventional four), allowing the other two pairs to power the RPi, streamlining the connection. This system produces a latency of 0.24s.

Each RPi runs a script that streams the camera feed over HTTP and accepts multiple connections. This allows the driver to complete movement-dependent tasks while the copilot uses the camera feed to complete processing-heavy tasks on another computer, such as Task 3.2 (autonomous brain coral) and Task 3.3 (photogrammetry 3D modeling of coral). This networked system maintains visual fidelity.

# MISSION TOOLS

## Claw

Panini's claw is designed with durability and torque in mind so that it will succeed with both delicate missions, such as Task 1.1 (pulling a pin for float release), and strength-related missions, like Task 3.1 (moving heavy probiotic irrigation system). The claw is centered around two parallel four-bar linkage systems, one for each gripper. The parallelogram system allows the grippers to stay parallel while opening and closing, making it easy for the ROV driver to visualize and execute mission tasks where precise claw movements are necessary. To drive the linkage system, an IP57 waterproof servo is used in conjunction with a metal gearbox that generates a 2:1 mechanical advantage between the servo input and the grip strength of the claw. This additional torque ensures the driver has a firm grip on heavy props, a capability crucial to performing tasks effectively and quickly.

To maximize performance, the claw's grippers were specially optimized to meet mission requirements. They are precisely contoured to grip on a 1/2-inch (12.7 mm) PVC pipe (most common in this year's missions) and have an integrated hook to latch onto thin materials like cable present in Task 2. This claw has maintained its performance through 40+ hours submerged in the pool without swapping servos, demonstrating the longevity of this design.

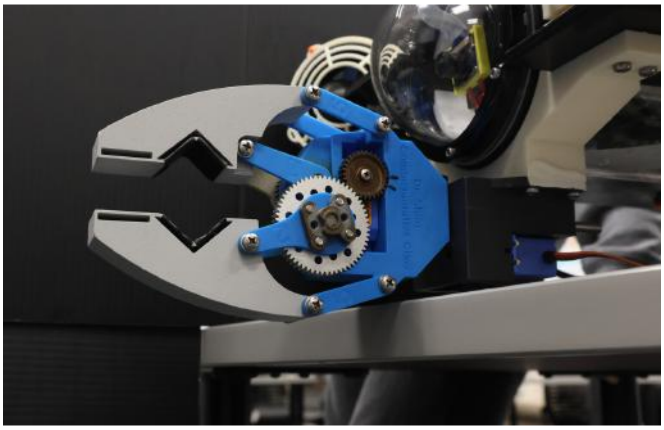


*Figure 15: Panini's claw*
*Taken by Jonathan Lim*

## Recovery Line Tool

To assist with part of Task 1.1 (attaching a carabiner onto a U-bolt), WarriorTides developed a custom 3D-printed part. This piece is a 20mm x 20mm square to fit within the claw, and the carabiner is glued into the piece. This prevents the carabiner from twisting into the wrong position when *Panini* exerts strong force onto the carabiner to clip it onto the U-bolt.

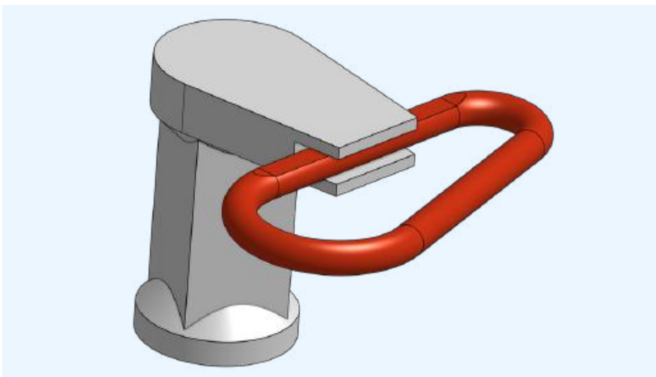


*Figure 16: CAD of Recovery Line Tool*
*By David Kou*

# Gatling Float

Alongside *Panini*, WarriorTides developed *Geoff*, a vertical profiling float. *Geoff* centers around a buoyancy engine that uses a large syringe to simultaneously draw in water and compress the air within the enclosure, rendering the float negative buoyant. This causes the float to sink for the first half of the profile. To complete the profile, the water is pumped out of the syringe, restoring the float to positive buoyancy. To keep *Geoff* vertical during profiling, a 3D-printed “halo” is attached to the top of the float and filled with flotation foam. *Geoff’s* batteries are in a separate enclosure that can release pressure in the event of an emergency.

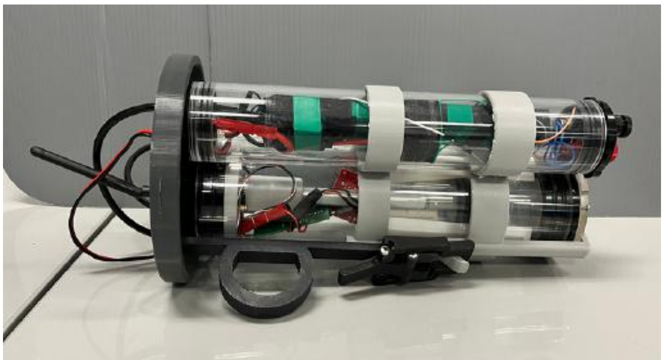


*Figure 17: Geoff the GO-BGC float*
*Taken by Sharis Hsu*

*Geoff* is controlled by a Wemos D1 Mini Pro (D1 Mini) microcontroller, a development board for the ESP8266 microcontroller. Alongside this, onboard *Geoff* is a BarO2 depth sensor, an external antenna for communication, a voltage converter, and an H-bridge that enables bidirectional control of the actuator. All of these electronics are connected to a custom PCB, which simplifies servicing and reduces the risk of shorts or wires getting caught on moving parts. *Geoff* is powered by eight AA batteries.

The topside station also houses an identical D1 Mini that communicates with the float using Wi-Fi. This is connected to the topside laptops via a Python script that handles all communication and plots the necessary depth vs time data.

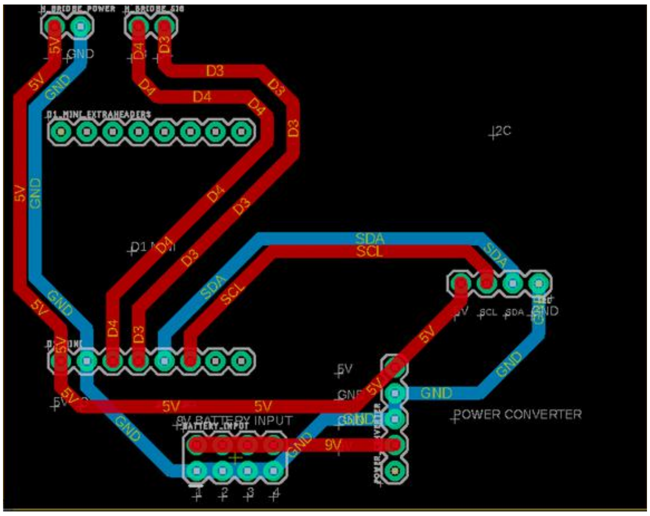



*Figure 18: Geoff’s PCB layout in Eagle*
*By Sharis Hsu*

# Co-Pilot GUI

WarriorTides co-pilot GUI is built upon the already powerful React-based Pilot GUI. As a networked approach is present in *Panini’s* system design, the co-pilot GUI can also connect to the Python backend WebSocket server to control the ROV. Thus, the co-pilot can also adjust joystick sensitivity, thruster power, record the camera feed (essential for image processing tasks such as photogrammetry and object measurement), run autonomous driving tasks, and disable any part of the ROV in the event of an issue. WarriorTides also developed a sleek user interface for the co-pilot to quickly assist the driver in completing mission tasks. This year’s interface used ReactJS because running many Python scripts for different tasks, as previously done, is slow, inefficient, and prone to error.

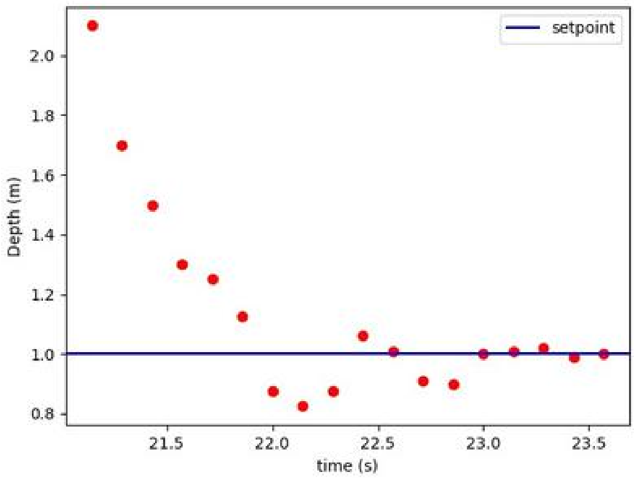



*Figure 19: Depth vs time graph for PID calibration*
*By Aayan Maheshwari*

## Computer Vision

For the software-heavy and autonomous mission tasks, WarriorTides utilizes custom PID controllers, the OpenCV library, and the MacOS Object Capture API. For Task 3.2 (autonomously transplanting brain coral), The PID controllers are utilized to allow the ROV to maintain a constant depth while an OpenCV-based Python script runs color and contour analysis on the video feed to guide the ROV to the restoration area.

For Task 3.3 (3D coral modeling), OpenCV is used to capture images of the coral restoration area before feeding the images to Photocatch, a lightweight app that uses the macOS Object Capture API to create 3D Models. The model is then exported and scaled to size using 3D modeling software. To calculate the scale, WarriorTides uses the known size of the PVC connectors present in the prop.

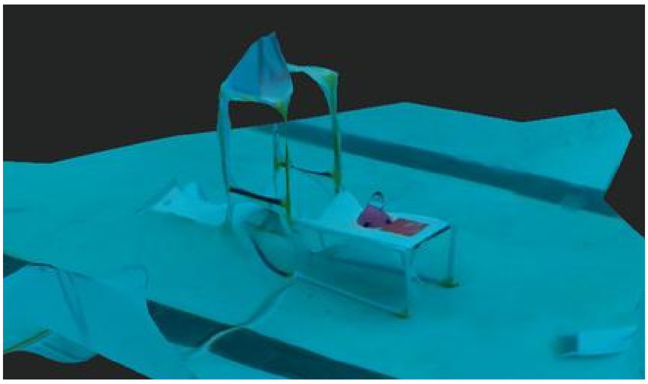
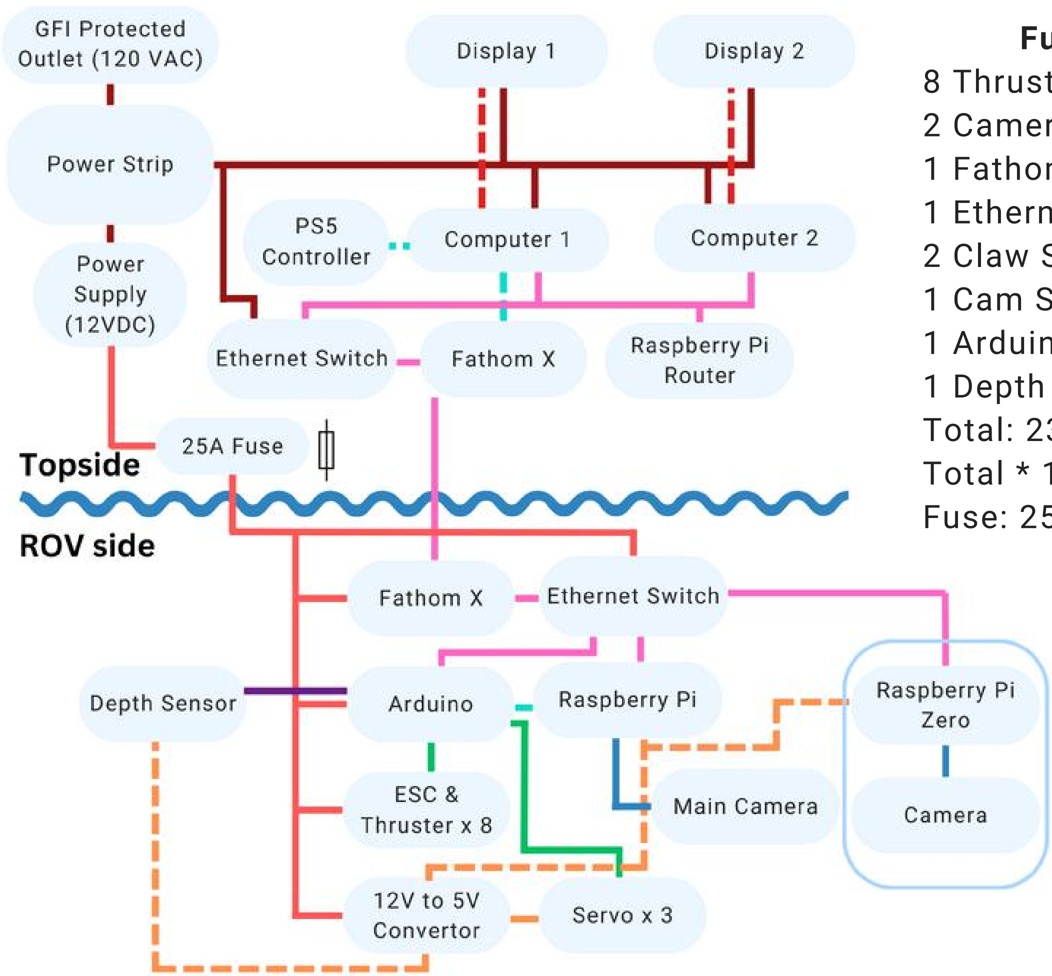


*Figure 20: Successful photogrammetry of the coral restoration area at the 2024 Monterey Regional By Sharis Hsu*

# ROV SID



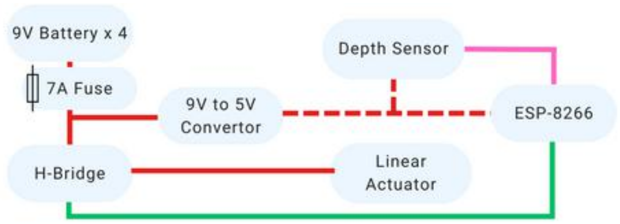

**Fuse Calculations**

8 Thrusters: 2.5A*8 = 20A
2 Cameras: 0.4A*2 = 0.8A
1 Fathom X: 0.2A
1 Ethernet Switch: 0.06A
2 Claw Servos: 0.6A*2 = 1.2A
1 Cam Servo: 0.3A
1 Arduino: 0.6A
1 Depth Sensor: 0.001A
Total: 23.161A
Total * 150%: 34.7415A
Fuse: 25A

**Legend**

12 VDC
5 VDC
120 VAC
Ethernet
HDMI
I2C
PWM
Serial
CSI
USB

# FLOAT SID




**Legend**

- 9 VDC
- 5 VDC
- Digital Sig
- I2C

**Fuse calculation**

1 Actuator: 0.3
1 ESP-8266: 0.2A
1 Depth Sensor: 0.001A
Total: 0.501A
Total * 150%: 0.7515A
Fuse: 7.5A

# TESTING & TROUBLESHOOTING

## Prototyping

A central part of WarriorTides' development process is prototyping. This year, WarriorTides assembled a prototype *Panini* to evaluate the feasibility of major shifts happening in the innovation process: a new enclosure, a new frame material, and an incredibly complex electrical system. The prototype ROV was assembled in December of the season and put through pool testing. Following testing, all subteams were able to make necessary improvements. Mechanical opted into designing new Delrin wing plates that had more screw holes for additions like legs and buoyancy mounts. Electrical also chose to add a fourth PCB to the system to reduce stress on connectors. This prototyping process displays weaknesses in the theoretical designs that WarriorTides initially develops, enabling *Panini* to be the most competitive ROV possible.

## Troubleshooting

When troubleshooting, WarriorTides strives to remain calm and systematically explore the situation. Power to *Panini* is initially cut to ensure that all employees are in a safe situation while inspecting the error. In the case of an electrical issue, test code is run to narrow down where the issue is, followed by a visual inspection and going through with multimeters. In the case of a software issue, the team works together to read each line of code and spot bugs. In a mechanical issue, the team attempts to visibly observe the issue, regrouping to identify failures in the design.

## Testing

WarriorTides tests the integration of individual components in stages throughout the season to prevent a buildup of errors at the end of the development process. WarriorTides has built custom test code for the thrusters, Arduino, and cameras to evaluate the functionality of these components. Before pool testing, WarriorTides completes a dry run where the entire system is powered, and all code is run. On the pool deck, code can be uploaded to *Panini* without opening the enclosure, so changes can be made on the fly during testing to maximize pool time.

*Panini* has undergone forty-one hours of pool testing to date. These pool tests are recorded in the pool log, along with what was accomplished, to identify how much more testing is necessary and where.

| Date | Hours in Pool | Goals of Practice |
|---|---|---|
| 12/06/2023 | 2 hours | Inital drive testing of ROV. Establish thrust limits and areas for improvement |
| 12/13/2023 | 1 hour | Test drive functionality of core ROV |
| 01/16/24 | 1 hour | Buoyancy testing to ensure most stable ROV |
| 02/02/24 | 2 hour | Claw testing. Practice loading props onto the claw |
| 03/18/24 | 1 hour | Test camera functionality in the pool. Establish the ideal angles for camera servo |
| 03/20/24 | 2 hours | Pilot practice on Task 1. Testing carabiner tool |
| 03/25/24 | 2 hours | PID tuning to maintain a constant depth |
| 03/27/24 | 2 hours | Test PID integration with regular driving commands |
| 04/01/24 | 3 hours | Pilot practice on Task 2 |
| 04/03/24 | 3 hours | Pilot and co-pilot practice on Task 3 |
| 04/05/24 | 2 hours | Co-pilot testing photogammetry |
| 04/08/24 | 3 hours | Full 15 minute mission runs, modifying the task order as necessary. |
| 04/10/24 | 3 hours | 15 minute mission runs with set up and takedown. |
| 04/15/24 | 3 hours | 15 minute mission runs with set up and takedown. |
| 04/17/24 | 3 hours | 15 minute mission runs with set up and takedown. |
| 04/22/24 | 2 hours | 15 minute mission runs with set up and takedown. |
| 04/24/24 | 2 hours | 15 minute mission runs with set up and takedown. |
| 04/29/24 | 2 hours | 15 minute mission runs with set up and takedown. |
| 05/08/24 | 2 hours | 15 minute misison runs with new camera angles |
| 05/18/24 | 2.5 hours | 15 minute misison runs and testing autonomus code |

*Figure 21: Pool Log*
*By Sharis Hsu*

# BUDGET

WarriorTides began this season with a budget of $6,000 generously provided by Valley Christian High School. This budget was split into the categories of mechanical, electrical, software, and miscellaneous. Re-used items from last season include topside materials, T200 thrusters, prop-building supplies, and previously purchased tools. Additionally, Valley Christian High School provided 3D printers, filament, and materials transportation to the Regional and World Championship.

To avoid unnecessary spending, WarriorTides chose to continue implementing a justification requirement for purchases, a process first piloted last season. When employees put in purchase requests for products over $30 they were required to write a short memo answering the following questions:

- Why is this part necessary?
- Why are we building over buying?
- Why are we buying this part over cheaper alternatives?
- How does this improve the ROV?
- How does this further the subteam's tenet?

These memos encouraged employees to think deeply about the part they ordered, facilitating budget management and reducing wasteful spending culture.

All memos and requests for purchases are reviewed by the CEO, co-presidents, and mentors. The budget is continually referenced throughout the year to ensure that the development of *Panini* stays within the budget.

Both budget and cost accounting for this season can be viewed as Appendix B and C on pages 24-25 of this document.

**Employee memo for a Blue Robotics ESC:**

*This part is the Blue Robotics ESC, which is responsible for controlling our vehicle's propulsion via our electrical control system. These controllers allow us to utilize Blue Robotics T100s and T200s, the most common, safest, reliable, and powerful consumer thrusters on the market.*

*While the ESCs, or their first revision, are open source and thus possible to independently fabricate, we will be buying them because we won't be producing them at scale. Independent fabrication is costly and time-consuming, not to mention potentially unsafe. Cheaper alternatives include regular, similar-amperage ESCs. However, those are configured for drone firmware and will need to be flashed with Blue Robotics software. Again, not something open source and a time-consuming endeavor.*

*Figure 22: Co-presidents Aayan Maheshwari and Zack Martino review order requests*
*Taken by Sharis Hsu*

# PROCESS & ANALYSIS

## Build VS Buy

WarriorTides believes building in-house is the best way for company members to learn engineering skills and also for the company to customize systems. All components related to specific mission tasks are built in-house to maximize performance. For example, *Panini's* manipulator was built by employees instead of buying one, as a contour could be designed into the pincers for optimal grasping geometry around 1/2 inch (12.7 mm) PVC pieces present in multiple mission tasks. However, some components are not practically feasible to build because they are costly, dangerous, or impractical to fabricate in-house.

**Electrical**

- Bought components such as ESCs, RPis, and Arduinos as these components are too expensive and time-consuming to create
- Built a custom PCB to interconnect electronics and made modifications to purchased components like ESCs to interface them with the rest of the ROV

**Mechanical**

- Bought two new Blue Robotics T200 thrusters as safe, tested, characterized PWM-controlled thrusters are prohibitively expensive to manufacture
- Bought Delrin sheet material for the frame as it is not feasible to build in-house. However, WarriorTides laser cut the sheet into frame pieces in-house
- Bought *Panini's* enclosure due to the need for precise machining to maintain a repeatable, disassemblable, watertight seal
- Built and 3D printed custom mounts to hold Delrin sheeting to the enclosure
- Built claw and 3D printed the majority of pieces in-house for mission task specifications
- Built and 3D printed custom mounts within *Panini's* enclosure to hold our camera and electronic system

## New VS Reused

WarriorTides strives to be as environmentally conscious as possible. The company is aware that discarding any function parts or materials may add to the global aquatic pollution crisis, an issue *Panini* is attempting to remediate. Thus, a significant amount of components are reused between years; however, systems are never reused wholesale as they are modified and improved yearly.

**Electrical**

- The Topside Pelican Case and monitors were re-used as there is no increase in usability by replacing them, and all are still in excellent condition
- New ESCs were purchased as ESCs from previous years were soldered to PCBs and unusable, plus some had significant water damage
- Commonly used components such as loose wires, crimps, connectors, and heat shrink continued to be used from last year's inventory; however, more were purchased on an as-needed basis throughout the season
- Tools such as heat guns, soldering irons, and hand crimpers were re-used as they were in good condition

**Mechanical**

- Six Blue Robotics T200 Thrusters were reused as they showed no significant drop in thruster output or signs of wear. However, two new thrusters were also purchased to replace older ones that were no longer functioning
- Penetrator blanks and o-rings were re-used unless they showed leakage issues
- A new enclosure was purchased as previous ones were too small to fit this year's electrical system
- Tools such as vacuum pumps, screwdrivers, drill bits, and hammers were re-used as they were still in good condition

# SAFETY

## Safety Philosophy

WarriorTides approaches safety with the philosophy that safety is a continual process of improvement. The company takes pride in maintaining the safety and health of its employees in all situations. WarriorTides has a dedicated Safety Captain responsible for answering safety questions and ensuring all members follow safe practices.

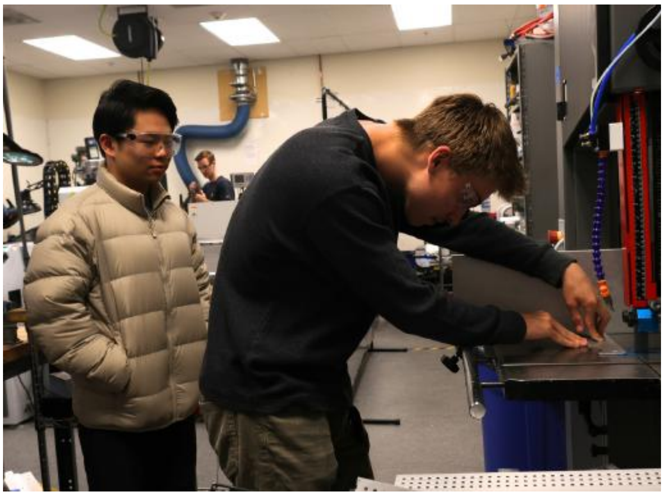


*Figure 23: Mentor Jonathan Lim supervises Zack Martino using the bandsaw*
*Taken by Sharis Hsu*

Existing safety practices, such as requirements for adult mentor supervision, continued this season. Concurrently, in alignment with this year's philosophy, WarriorTides considered situations where new safety measures might be applicable. For example, after realizing the dangerous possibility of tools like soldering irons being left unattended, the company instituted a new policy. At the end of a meeting, the CEO, Safety Captain, and mentors are responsible for completing a full rundown of all work areas to ensure no equipment is carelessly left on. This proactive stance of recognizing shortcomings in existing team policies and making corresponding changes enables WarriorTides to maximize safety in all aspects of operation.

## ROV Safety Features

Intentional design choices were made during *Panini's* construction to maximize safety including:

- Rounded Edges: All edges are either designed rounded, chamfered, or sanded down to prevent *Panini* from snagging props (tangling in the wires of Task 2) or causing injuries
- Thruster Shrouds: All T200s are fitted with 3D printed shrouds that meet IP-20 to prevent debris (mission props such as pins or ropes from Task 1) and fingers from getting caught in thruster blades
- Emergency Stop Button: Present on the topside station is a highly visible and easy-to-reach emergency stop button to cut ROV power instantly
- Eye-catching Labels: Neon yellow hazard labels are present on any parts that could be a safety risk, such as T200s
- Desiccants: Moisture-absorbing desiccants are always present in the ROV's electronic enclosure. These desiccants change colors when exposed to water indicating a leak and also reducing the chance of short circuits by absorbing a significant amount of water
- Fuse: In accordance with the MATE ROV competition guidelines, a 25-amp fuse is installed on the positive power line of the ROV, next to the power supply


*Figure 24: Emergency stop button*
*Taken by Jonathan Lim*

# SAFETY

## Operational Safety

- Safety glasses are worn when soldering, when using drills/dremels/bandsaw, and when thrusters are on
- Fume extractor and ventilation are turned on when soldering
- Team members always wear closed-toed shoes
- No running in the workspace or on the pool deck
- No food/drink in the workspace
- Employees must be trained and certified on machinery by mentors before using it
- JSA is accessible at all times

## Construction Safety

- ROV has no exposed wiring
- ROV has no sharp edges
- Tether has proper strain relief
- A fuse with overcurrent protection is connected to the power supply

## ROV Operation Safety

**Before Leaving Workspace**

- Insert desiccants into the enclosure
- Vacuum test for fifteen minutes, ensuring that the reading stays constant at fifteen mmHg
- Check that vent plugs on all enclosures are tightly fastened
- Ensure that strain relief is fastened to both the ROV and topside station
- Coil tether safely to prevent tangling during transportation to the pool

**Before ROV Launch**

- Ensure that the pool deck is clear of all possible hazards
- All swimmers must be out of the pool or separated by a bulkhead
- Plug into a GFCI-protected power outlet. Pilot must call “POWER ON”
- Test connectivity between topside and ROV. Run thruster, camera, and claw code to confirm that all components are working as intended

## ROV Operation Safety

**ROV in Water**

- Poolside team calls “ROV IN”
- Poolside team maintains a grip on tether at all times, and is prepared to pull out of the water in an emergency
- Poolside team watches for bubbles exiting the ROV
- Drive team calls out changes in the mission plan, and requests for more or less tether
- Drive team informs everyone on deck that the mission has ended and that they are returning the surface
- Pilot disables ROV control and poolside team calls “ROV OUT”

**Following ROV Launch**

- Poolside team checks for any moisture within the second O-ring and any color change to the desiccants
- ROV is thoroughly dried with towels to prevent rusting and corrosion of components and buildup of chlorine and other pool chemicals
- Poolside and drive team regroup to discuss the mission run and any optimizations for future runs

*Figure 25: Panini’s topside strain relief*
*Taken by Jonathan Lim*

# CORPORATE RESPONSIBILITY

At WarriorTides, corporate responsibility is highly emphasized. Though intellectual growth is essential to the company, WarriorTides believes it is equally important to give back to the community and environment.

## Volunteering

WarriorTides has taken the initiative to get involved in the health of waterways beyond the scope of engineering. The company partners with Save Our Shores and Keep Coyote Creek Beautiful to collect litter and harmful substances at local beaches and creeks respectively. These trash collection sessions allow employees to witness firsthand the significant impact of human actions on aquatic ecosystems.

*Figure 26: The team volunteering a beach cleanup in Santa Cruz*
*Taken by Sharis Hsu*

## Mentoring

To continue the MATE ROV mission of engaging students in using marine technology to remediate environmental challenges, WarriorTides founded Warrior Waves, another company that competes in the MATE ROV Navigator class. WarriorTides employees take on the significant responsibility of mentoring this team by hosting workshops, providing design advice, and offering technical training. Under the steadfast guidance of WarriorTides, WarriorWaves has grown to reach new levels of success and continues to create opportunities for many students.

*Figure 27: Members of Warrior Waves learn to solder*
*Taken by Sharis Hsu*

## Engaging Community

This year, for the first time, WarriorTides ran a “Dreams to Designs” week-long engineering camp for students from low-income families. During this week, campers created rockets, catapults, windmills, and many other projects. They also got to hear words of wisdom from successful engineers and drive *Panini*. This camp brought in 25 students and inspired them to pursue engineering.

*Figure 28: Dreams to Designs Campers*
*Taken by Jonathan Lim*

WarriorTides also continues to host annual Drive Days, inviting members of the community to learn about marine environmental concerns and have the opportunity to drive an ROV. This year, WarriorTides held an ROV education and drive session for kindergarten students from Valley Christian Elementary School. The company has also continued to underscore the significance of underwater robotics by delivering presentations at the Valley Christian High School Open House and International Student Fair.

# REFLECTIONS

## Major Challenges

This year, WarriorTides prioritized proactive planning and allocating leeway time to avoid having major setbacks that could derail the company. This strategy has proven to be successful, although there were some pitfalls. The company struggled significantly with the external camera enclosure due to hard-to-identify waterproofing issues that were later attributed to an uneven cut when shortening the enclosure. Software and electrical also faced many challenges in the integration process of their work. The complexity of an interconnecting PCB system proved to be more challenging and time-consuming than initially anticipated. Thus, it became a large bottleneck for the entire team as testing and development were halted until a working electrical system was produced.

## Future Improvements

Although *Panini* is an exceptional work of technical innovation, WarriorTides does plan to further enhance its performance. Throughout the season, WarriorTides did experiment with the addition of an IMU. Future goals include completing the integration of an IMU in conjunction with PID controllers to introduce stability in the roll and pitch directions. Additionally, WarriorTides hopes to improve *Panini's* PCB design by incorporating a 3D support along the connections between boards to prevent bending of the connectors during removal. Finally, WarriorTides aims to develop a more sophisticated external wire management system for long thruster wires that shift *Panini's* distribution of weight backward. This will most likely be accomplished by cutting slits in the Delrin frame to thread the wires through.

## Lessons Learned

In reflection, WarriorTides has learned the significance of a shared team vision and including every team member in the design process. Clear communication of the team's goals and objectives has proven instrumental in ensuring that all team members are motivated to continue innovating and overcoming obstacles. Additionally, by including employees of all subteams in all parts of the design process, WarriorTides proactively ensured that designs were feasible across subteams, preventing unwanted confusion and chaos when parts of the ROV came together later in the season. Creating an environment where all team members are included and empowered to contribute their unique perspectives has allowed WarriorTides to create more robust designs, improved company efficiency, and allowed employees to collaborate seamlessly.

## From the CEO...

It has been a privilege to lead WarriorTides for one final season, producing our strongest ROV to date and cultivating a positive team culture that speaks for itself. As a team, we have tackled challenges well beyond our helm from experimenting with a Delrin frame ROV, creating an elaborate interconnecting PCB system, to implementing sensors within our ROV for the first time. But beyond our technical success, we all have had plenty of fun turning our "company" into a family. It is exceptionally difficult to say goodbye to this team, but I am confident that WarriorTides will continue to grow following this outstanding season. I am incredibly proud of every employee who has continued to give their all to WarriorTides. Thank you for all your hard work, dedication, and passion.

**-Sharis Hsu, WarriorTides CEO 2023-2024**

# ACKNOWLEDGMENTS

WarriorTides would like to thank the program manager, Mr. Reese, for his never-ending support and guidance this season. WarriorTides would also like to thank Jonathan Lim and Dr. Okoro for their technical mentorship and assistance. Thank you to Valley Christian High School for providing WarriorTides with funding, a workspace, and numerous opportunities to educate the community about underwater robotics. WarriorTides is grateful to Blue Robotics for being the supplier of numerous ROV components. WarriorTides would also like to like team mascot Rick-the-Brick for his unwavering emotional support. Thank you to the MATE ROV team for hosting the annual MATE ROV competition and challenging WarriorTides to build an ROV capable of remediating global environmental concerns. Finally, WarriorTides thanks the MATE Center for striving to improve marine technical education and providing the company with the opportunity to learn and compete.

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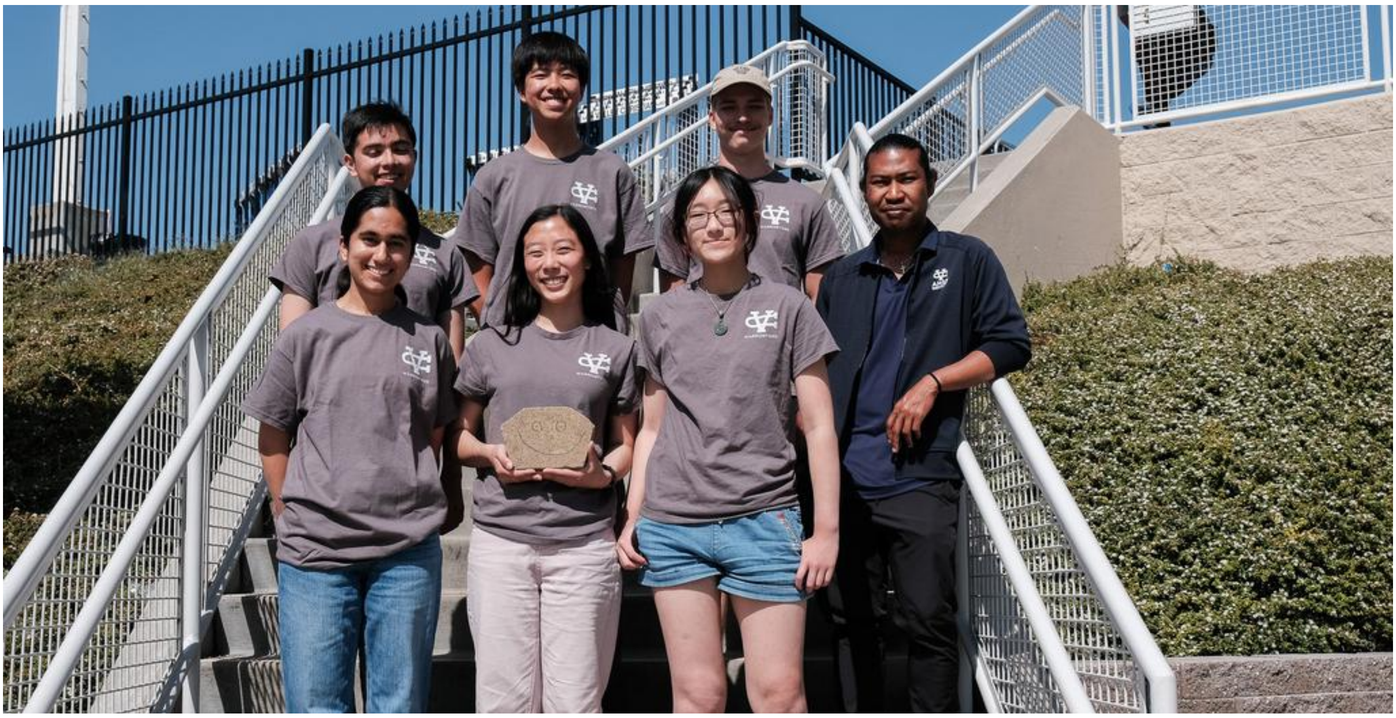

*Figure 29: WarriorTides team photo with mascot Rick-the Brick (Shivaan Patel & Kashish Kapoor not pictured) Taken by Melissa Chacon*

# APPENDICES

## Appendix A: Portion of 2023-2024 Gantt Chart

| | | | | | | | 7 SUMMER WEEKS | | | | | | | 6 INDIVIDUAL WORK WEEKS | | | | | | 4 TE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TASK NUMBER | TASK TITLE | TASK OWNER | START DATE | DUE DATE | WEEK DURATION | PCT OF TASK COMPLETE | 7/17 | 7/24 | 7/31 | 8/7 | 8/14 | 8/21 | 8/28 | 9/4 | 9/11 | 9/18 | 9/25 | 10/2 | 10/9 | 10/16 |
| **Mechanical** | | | | | | | | | | | | | | | | | | | | |
| MECH.1 | Frame Design | David | 7/17/23 | 8/7/23 | 3 | 100% | | | | | | | | | | | | | | |
| MECH.2 | Frame CAD | David | 8/7/23 | 8/21/23 | 2 | 100% | | | | | | | | | | | | | | |
| MECH.3 | Frame Laser Cut | David | 8/21/23 | 8/28/23 | 1 | 100% | | | | | | | | | | | | | | |
| MECH.4 | Frame Assembly | Shivaan | 8/21/23 | 9/4/23 | 2 | 100% | | | | | | | | | | | | | | |
| MECH.5 | Strain Relief | Lucas | 9/18/23 | 10/23/23 | 5 | 100% | | | | | | | | | | | | | | |
| MECH.6 | Bottom Camera Mount | Zack | 8/21/23 | 9/25/23 | 5 | 100% | | | | | | | | | | | | | | |
| MECH.7 | Internal Camera Mount | Shivaan | 8/7/23 | 8/21/23 | 2 | 100% | | | | | | | | | | | | | | |
| MECH.9 | Claw | David | 8/28/23 | 10/2/23 | 5 | 100% | | | | | | | | | | | | | | |
| MECH.10 | Leak Testing | Shivaan | 8/28/23 | 9/11/23 | 2 | 100% | | | | | | | | | | | | | | |
| MECH.11 | Buoyancy & Weighting | Shivaan | 9/11/23 | 10/2/23 | 3 | 100% | | | | | | | | | | | | | | |
| **Software** | | | | | | | | | | | | | | | | | | | | |
| SOFT.1 | Camera testing | Aayan | 7/17/23 | 9/18/23 | 8 | 100% | | | | | | | | | | | | | | |
| SOFT.2 | IMU Research | Allison | 7/17/23 | 8/21/23 | 5 | 100% | | | | | | | | | | | | | | |
| SOFT.3 | IMU Testing | Allison | 8/21/23 | 9/18/23 | 4 | 100% | | | | | | | | | | | | | | |
| SOFT.4 | GUI Design | Aayan | 9/4/23 | 9/25/23 | 3 | 100% | | | | | | | | | | | | | | |
| SOFT.5 | PID Research | Allison | 8/21/23 | 9/25/23 | 5 | 100% | | | | | | | | | | | | | | |
| SOFT.6 | PID Testing | Aayan | 9/25/23 | 10/23/23 | 4 | 100% | | | | | | | | | | | | | | |
| **Electrical** | | | | | | | | | | | | | | | | | | | | |
| ELEC.1 | PCB Schematic | Sharis | 7/17/23 | 8/7/23 | 3 | 100% | | | | | | | | | | | | | | |
| ELEC.2 | PCB Layout | Sharis | 8/7/23 | 9/4/23 | 4 | 100% | | | | | | | | | | | | | | |
| ELEC.3 | PCB Prototyping | Sharis | 9/4/23 | 9/18/23 | 2 | 100% | | | | | | | | | | | | | | |
| ELEC.4 | PCB Review | Sharis | 9/18/23 | 10/16/23 | 4 | 100% | | | | | | | | | | | | | | |
| ELEC.5 | Source Parts | Sharis | 10/16/23 | 10/23/23 | 1 | 100% | | | | | | | | | | | | | | |

## Appendix B: Budget

| Income | Type | Description | | Amount |
|---|---|---|---|---|
| School Funding | Grant | Valley Christian High School Funding Grant | $6,000.00 | $6,000.00 |
| **TOTAL Income** | | | | **$6,000.00** |
| **Expenses** | **Type** | **Description** | **Projected Cost** | **Budgeted Value** |
| Mechanical | Purchased | Frame Materials | $300.00 | $300.00 |
| | Purchased | Enclosures & Endcaps | $600.00 | $600.00 |
| | Purchased | Weights | $50.00 | $50.00 |
| | Purchased | Float Supplies | $40.00 | $40.00 |
| | Purchased | Claw Gears | $55.00 | $55.00 |
| | Purchased | T200 Thrusters | $400.00 | $400.00 |
| | Donated | Printer Filament | $118.89 | N/A |
| Electrical | Purchased | PCB Manufacturing & PCB Components | $750.00 | $750.00 |
| | Purchased | Electrical Consumables | $20.00 | $20.00 |
| | Re-Used | 6 T200 Thrusters, Pelican Case, 8 ESCs | $1,829.95 | N/A |
| | Purchased | Ethernet Switches, Fathom-Xs, Arduinos, ESCs | $1,200.00 | $1,200.00 |
| | Purchased | Power Supplies | $300.00 | $300.00 |
| | Purchased | Acrylic for Topside | $60.00 | $60.00 |
| Software | Purchased | SD Cards & Readers | $80.00 | $80.00 |
| | Purchased | Sensors | $300.00 | $300.00 |
| | Purhased | Camera System | $435.00 | $435.00 |
| | Purchased | Rapberry Pis | $150.00 | $150.00 |
| | Purchased | Ethernet & USB Hub | $150.00 | $150.00 |
| Miscellaneous | Purchased | Team Bonding | $200.00 | $200.00 |
| | Purchased | Prop Building Supplies | $120.00 | $120.00 |
| | Re-Used | Prop Building Supplies | $166.32 | $166.32 |
| | Donated | Regional MATE Entry Fee | $250.00 | N/A |
| | Donated | Worlds MATE Entry Fee | $100.00 | N/A |
| Travel | Donated | Transportation to the Regional | $70.00 | N/A |
| | Donated | ROV and materials transportation to Worlds | $900.00 | N/A |
| | Employee Paid Expense | Worlds transporation, accomodation, and meals | $1,200.00 | N/A |
| **TOTAL Expenses** | | | **$9,845.16** | **$5,376.32** |
| | | | **Total Income:** | $6,000.00 |
| | | | **Total Expenses:** | $5,376.00 |
| | | | **NET Profit:** | **$624.00** |
| | | | **Total Fundraising Needed:** | $0.00 |

# APPENDICES

## Appendix C: Cost Accounting

| School Name: Valley Christian High School | | | | | | | From: 8/28/2023 |
|---|---|---|---|---|---|---|---|
| Instructor: Robert Reese | | | | | | | To: 5/20/2024 |
| **Date** | **Type** | **Category** | **Expense** | **Description** | **Quantity** | **Amount** | **Running Balance** |
| 8/28/2023 | Purchased | Electrical | Electrical Connectors | JST & Magnetic Connectors, Anderson Powerpoles | 1 | $298.79 | $298.79 |
| 9/20/2023 | Purchased | Software | Ethernet Hats & Shields | Ethernet Hats/Shields for Raspberry Pis & Arduinos | 12 | $171.76 | $470.55 |
| 8/29/2023 | Purchased | Software | SD Cards & Reader | Used to store code | 2 | $72.99 | $543.54 |
| 8/29/2023 | Purchased | Software | Sensors | Humidity Sensor, Depth Sensor, IMU | 8 | $279.88 | $823.42 |
| 9/11/2023 | Purchased | Mechanical | Delrin Sheets | Used to create ROV frame | 1 | $270.00 | $1,093.42 |
| 9/18/2023 | Purchased | Software | Adaptors | Various USB, Ethernet & USBC Cables and Adaptors | 15 | $86.79 | $1,180.21 |
| 9/19/2023 | Purchased | Software | Cameras | Multiple camera types for testing | 12 | $196.91 | $1,377.12 |
| 9/22/2023 | Purchased | Mechanical | Enclosure & Endcaps | ROV, Camera, & Float Enclosures & Endcaps | 9 | $595.00 | $1,972.12 |
| 10/2/2023 | Purchased | Software | Ethernet & USB Hub | Multiple port hub for Topside | 3 | $141.97 | $2,114.09 |
| 10/2/2023 | Reused | Electrical | Reusable Components | 6 T200 Thrusters, Pelican Case, 8 ESCs | 1 | $1,829.95 | $284.14 |
| 10/4/2023 | Purchased | Mechanical | Waterproofing | O-Rings | 2 | $6.00 | $290.14 |
| 10/6/2023 | Purchased | Electrical | Electrical Consumables | Wire, solder, flux, crimps, casings | 1 | $17.99 | $308.13 |
| 10/9/2023 | Purchased | Mechanical | T200 Thruster | Two new thrusters with extended cables | 2 | $400.00 | $708.13 |
| 10/11/2023 | Donated | Mechanical | Printer Filament | Donated from Valley Christian High School for printers | 4 | $118.89 | $589.24 |
| 10/11/2023 | Purchased | Mechanical | Linear Actuator | Used for the float | 1 | $35.99 | $625.23 |
| 10/11/2023 | Purchased | Hardware | D-Shaft | Used for strain relief | 4 | $6.36 | $631.59 |
| 10/16/2023 | Purchased | Electrical | PCB Parts | Relay, SMD Components | 1 | $65.95 | $697.54 |
| 10/17/2023 | Purchased | Electrical | Ethernet Switch | 5-port Ethernet switch | 2 | $350.00 | $1,047.54 |
| 10/17/2023 | Purchased | Electrical | Fathom-X Board | Pair of boards for Topside and ROV communication | 2 | $480.00 | $1,527.54 |
| 10/17/2023 | Purchased | Electrical | ESCs | Electronic speed controllers to run thrusters | 8 | $288.00 | $1,815.54 |
| 10/18/2023 | Purchased | Electrical | Arduinos | Arduino Mega Pro, Arduino Uno | 11 | $169.68 | $1,985.22 |
| 10/20/2023 | Purchased | Electrical | Power Supplies | 12V-5V Convertor, 9V Batteries | 11 | $282.91 | $2,268.13 |
| 10/23/2023 | Purchased | Software | Camera Cables | Ribbon cables for ROV vision system | 4 | $38.96 | $2,307.09 |
| 10/23/2023 | Purchased | Business | Team Bonding | Supplies for bi-monthly team bonding | 1 | $67.66 | $2,374.75 |
| 10/24/2023 | Purchased | Electrical | PCB | Manufactured by PCBWay | 1 | $264.15 | $2,638.90 |
| 11/13/2023 | Purchased | Electrical | Acrylic | Opaque Acrylic for Topside Station | 2 | $56.88 | $2,695.78 |
| 11/13/2023 | Purchased | Software | Transceiver Module | Extras bought for testing | 4 | $33.96 | $2,729.74 |
| 11/15/2023 | Purchased | Mechanical | Claw Gears | Gear for claw design | 6 | $52.53 | $2,782.27 |
| 12/6/2023 | Purchased | Misc. | Pool Towels, Tool Boxes | Towel for ROV, Organizational Boxes | 2 | $61.97 | $2,844.24 |
| 12/8/2023 | Purchased | Mechanical | Weights | Different sizes and mounts | 2 | $44.98 | $2,889.22 |
| 12/15/2023 | Purchased | Software | Rasberry Pis | Rasberry Pi 5, 4B, and 3B+ | 3 | $155.05 | $3,044.27 |
| 1/8/2024 | Reused | Misc. | Prop Building Supplies | Reused PVC and connectors | 1 | $166.32 | $2,877.95 |
| 2/22/2024 | Purchased | Misc. | Prop Building Supplies | Mission specific items | 1 | $117.51 | $2,995.46 |
| 3/11/2024 | Donated | Misc. | MATE Entry Fee | Monterey Regional competition registration | 1 | $250.00 | $2,745.46 |
| 5/7/2024 | Purchased | Mechanical | Pelican Case | Additional Pelican Case for safe ROV transporation | 1 | $405.95 | $3,151.41 |
| 5/10/2024 | Donated | Misc. | MATE Entry Fee | World Championship competition registration | 1 | $100.00 | $3,051.41 |
| | | | | | | **Total Donated/Reused** | $2,465.16 |
| | | | | | | **Total Spent** | $5,516.57 |
| | | | | | | **Final Balance** | $3,051.41 |