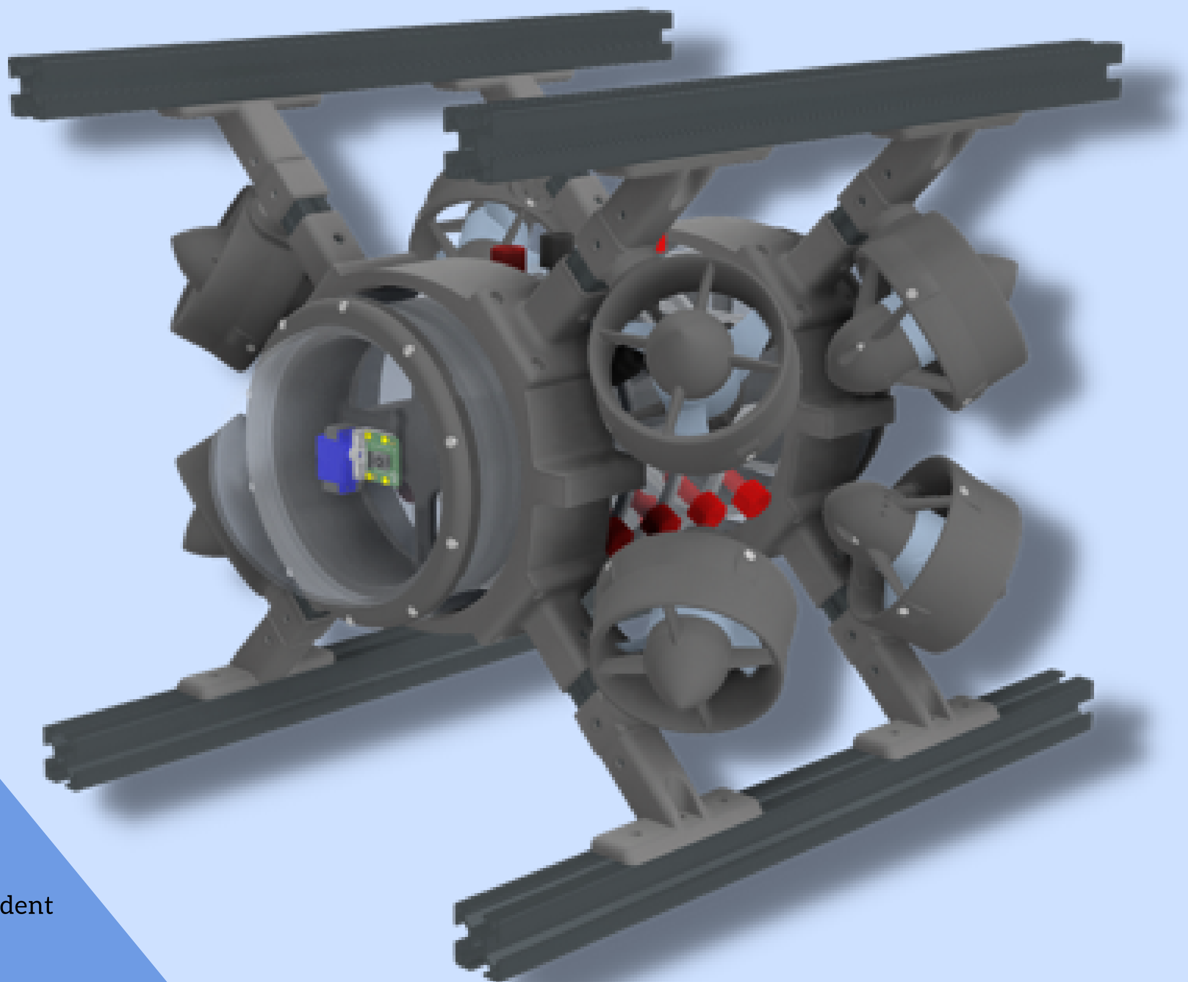
# WARRIORTIDES

## Valley Christian High School
## San Jose, California, USA



**Members:**
George Sousa | Mentor
Sheryl Hsu | CEO
Jonathan Lim | President
Geoffrey Vander Veen | President
David Bai | Safety captain
Raj Khera | Mechanical lead
Ryan Chiou | Mechanical
Zach Martino | Mechanical
Connor Stone | Mechanical
Ryane Li | Electrical lead
Sharis Hsu | Electrical
Nathan Weng | Electrical
Brayden Tam | Software lead
Aayan Maheshwari | Software
Marcus Lee | Software
Ananya Maheshwari | Business lead & CFO
Rhea Virk | Business

# TABLE OF CONTENTS

# ABSTRACT


WarriorTides is an entirely student-led company specializing in underwater technologies. It is our mission to construct ROVs capable of solving global environmental concerns by accomplishing tasks involving marine renewable energy systems, aquaculture, carbon sequestration, and marine life. This year, WarriorTides proudly presents its third ROV, Black Flounder, to support such efforts to combat the challenges prevalent in the ocean.

Our ROV features a reliable claw manipulator, 8 T200 thrusters with the ability to move in all 6 degrees of freedom, an HD through Ethernet multi-camera system, a student-designed custom PCB, and a sleek dual-display topside station. The claw manipulator is able to deploy hydrophones, remove morts, and farm seagrass while the Ethernet-based camera system provides high-quality images enabling the Black Flounder to measure shipwrecks, and inspect fish pens, and pilot into a docking station. All of these aspects combined make Black Flounder a versatile and powerful ROV.

*Figure 1: Black Flounder*

*Figure 2: WarriorTides Team*

Along with the technical aspects of the company, the team at WarriorTides has prioritized corporate responsibility by using their resources to give back to the community. WarriorTides is blessed to have the opportunity to mentor a Navigator team, invite members of the community to learn about underwater robotics, host engineering workshops for underprivileged youth, and participate in beach cleanups.

Overall, this year was an invaluable learning experience for WarriorTides. Thanks to the sheer amount of time spent developing the ROV and each member's contributions, Black Flounder is our most innovative ROV to date. We are confident that it will be an invaluable asset in helping keep our earth's oceans sustainable for generations to come.

# PROJECT MANAGEMENT

## Company Description

Warrior Tides is a company of 16 engineers. We have one CEO, two Presidents, and four subteams all working together toward the goal of creating our mobile and versatile ROV. The CEO oversees the entire team, while the Presidents help the CEO make crucial decisions. All three leaders are responsible for recruiting talent, mentoring employees, and assigning tasks.

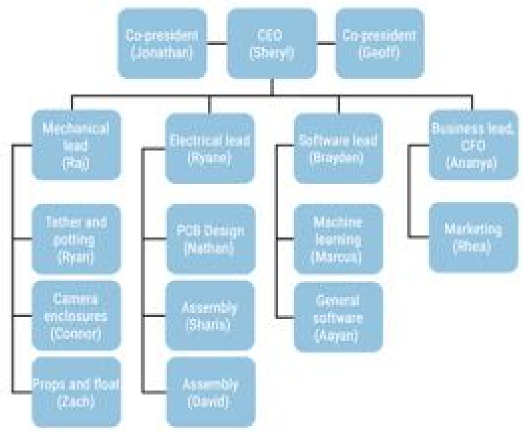


*Figure 3: Organizational chart*

The four subteams are Mechanical, Software, Electrical, and Business. Each department has a team lead that keeps members organized and delegates tasks. Members of each team generally work on projects such as mounts or mission task programs depending on their interests and the team's needs. We meet twice a week to collaborate and fabricate our ROV. All our meetings are supervised by our mentor, who is freely available for consultation. All team-wide decisions related to the MATE competition and the design of the ROV are made during group meetings with all team members present.

## Scheduling

The overall plan for the season was to spend the first semester building a new frame, PCB, and control system. The second semester was to be spent working on competition-specific manipulators, computer vision algorithms, and drive practice. We created a Gantt chart as seen on the right. Unfortunately, due to PCB design and manufacturing delays, we fell behind schedule and have thus been required to approach the rest of the season with adaptability and flexibility.

*Figure 4: Gantt Chart for 2021 scheduling*

## Decision Making

Though each specific process was different, we made overall decisions through team discussions and took a holistic approach to the vehicle's systems. We encouraged all engineers from various technical backgrounds to propose their ideas and utilized decision matrices to reach our final decisions. We made decisions by setting criteria and then talking through each of the options until we came to a gradual consensus. One example of this was when we were deciding whether to have a 4, 6, or 8 thruster configuration. We considered the criteria of feasibility, ease of programming, compatibility with the PCB, speed, and weight. After talking through each configuration, we all agreed to use the 8 thruster configuration.

# Day-to-Day Operations

For most of the season, WarriorTides meets on Mondays and Wednesdays from 2:45 - 5:45 for a total of six hours per week. As we approach the competition, we meet daily, focusing on the subteams that need the most time. Each work session begins with an all-hands meeting where we discuss updates and provide announcements.

To manage the budget, we organize all purchase requests in a Google sheet. We keep track of the remaining budget after every purchase. We use Slack as our primary platform for communication as it provides an organized environment for company announcements and discussions.

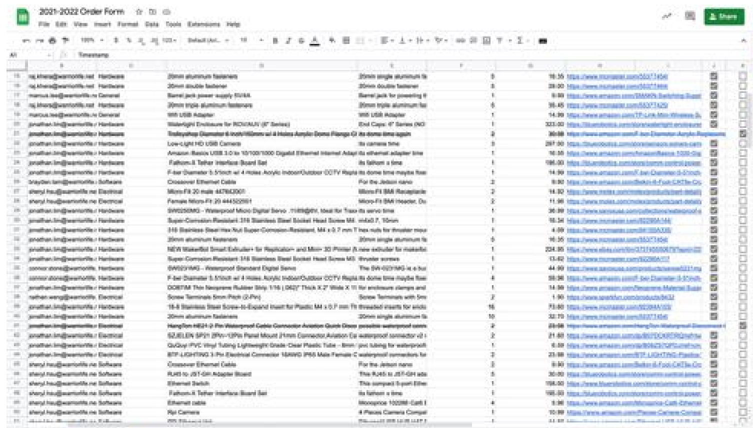



*Figure 5: WarriorTides Order Form*

While WarriorTides takes pride in our professionalism and technical excellence, we also recognize that we want to create an open company atmosphere and promote a sense of community. In order to boost team morale, we created a snack schedule where team members were assigned to bring food on certain days. This gave the team a chance to mingle as a community and build friendships during our four o'clock break time.

*Figures 6, 7,8: Team Bonding Activities*

WarriorTides has additionally held multiple team bonding events that have not only created a fun way to interact with other employees but have also established the communicative atmosphere we strive for. We truly believe that a good team dynamic between all members helps us build a company that enables learning and collaboration in the process of developing a product.

# ROV OVERVIEW

## Vehicle Overview

Going into the season, we identified key issues in last year's ROV and brainstormed possible improvements that would allow Black Flounder to more effectively complete mission tasks. After reading the competition manual, we decided that a redesigned frame and claw were crucial improvements for the mechanical team to accomplish. New Ethernet communication, refined camera systems, and PCB design were tasked to the electrical team. Software chose to focus on developing a measurement system and image recognition tasks.

Mechanically, our design is similar to an X-wing from Star Wars, with a central electronics enclosure and four aluminum extrusion mounting rails for our rotating pincer claw manipulator and external camera. Although this made assembly more complex, we decided the advantages of such a frame outweigh the disadvantages. This idea came from a need for a more flexible mounting system, especially after a brainstorming session concerning last year's ROV. The decision was made with all team members' input and opinions. This starship design enables Black Flounder to move quickly through the water and creates space for a six-inch acrylic enclosure. The topside control station is built to store two 22" monitors in a Pelican case. This is where the control computer is housed alongside the power supply for the ROV.

## Brainstorming

Our brainstorming process consisted of members throwing out ideas. A lot of times we already had existing ideas that we observed in other ROVs or even Star Wars. As we began to discuss ideas, we combined aspects of multiple ideas before deciding on a couple to prototype.

Black Flounder's onboard electronic system consists of two PCBs. These PCBs allow for improved wire management and serviceability. Black Flounder utilizes an Ethernet network for communication, allowing for 1080p, low latency video streams.

Black Flounder's control code consists of a Python script on the topside that sends joystick data to the onboard Arduino. The software team also developed a co-pilot GUI, computer vision algorithms, and programs to perform specific mission tasks.

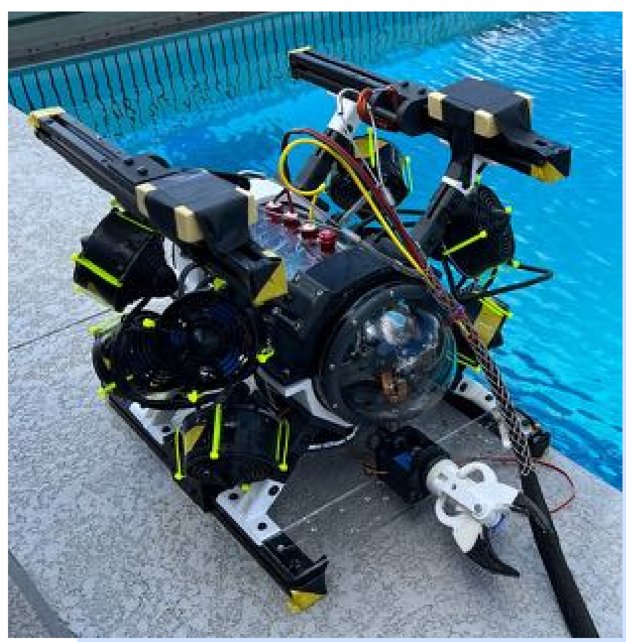


*Figure 9: Black Flounder*

# VEHICLE DESIGN

## Frame

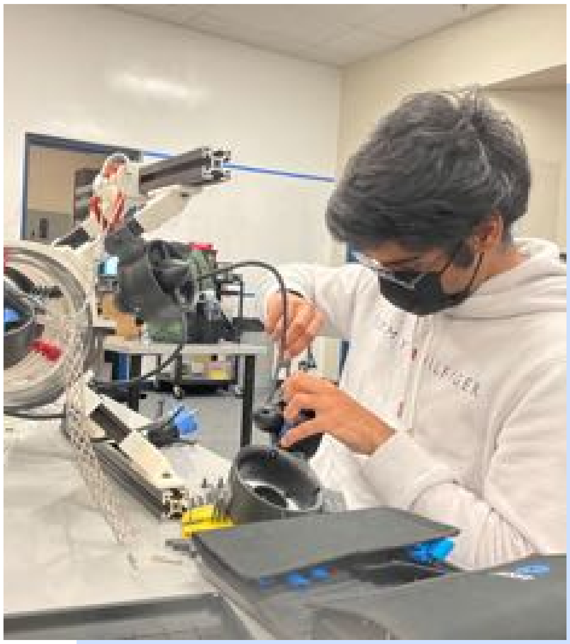


*Figure 10: Mech lead Raj works on frame*

The ROV's frame features an X-shaped design that enables mounting flexibility with many available thruster and manipulator attachment points. It is made of aerospace-grade aluminum extrusion and utilizes 3D printed parts to connect the various spars. 316 stainless steel corrosion-resistant bolts are used to secure it without fear of rust. We chose to use aluminum extrusion because of the rails which allowed for modular attachment points and easy balancing of the ROV. The frame is symmetrical and has radially drilled penetrators, which keeps the center of gravity approximately in the ROV's middle, below the center of buoyancy, and frees up the rear of the ROV so custom domes and retaining rings can be mounted on either end of the enclosure to support tilt cameras. It also features four rails to mount the rotating claw, strain relief mechanism, and an external camera.

## Buoyancy

A significant benefit to using a 6" electronics enclosure was the added buoyancy. Despite aluminum being relatively heavy, our acrylic enclosure ensures that the ROV stays positively buoyant in the water. To offset the positive buoyancy, 1 oz adhesive weights were added to the bottom of the ROV in locations that would fix the imbalances caused by the claw and bottom camera, keeping the center of buoyancy above the center of gravity and ensuring the ROV would remain stable and stay nearly neutrally buoyant while completing tasks.

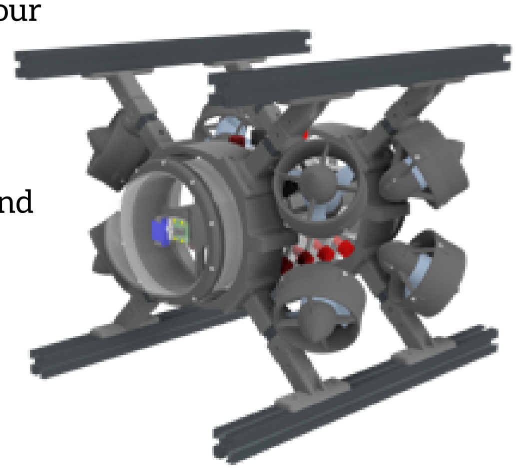


*Figure 11: CAD of the ROV's frame*

## Propulsion

The ROV has eight T200 thrusters in a vectored configuration. This position allows for motion in all six degrees of freedom, increased stability, and more complex movements like surge and heave simultaneously. The trade-offs of using eight vectored T200 thrusters are power consumption, cost, and movement inefficiency. Running one of the thrusters at full power would pull more current than the required 25A, so we had to lower the current provided to each T200.

We arrived at our current design of eight thrusters after much deliberation and prototyping. We brainstormed many designs at the beginning of the season, such as four thrusters mounted on servos, six thrusters, and eight thrusters. We prototyped the thrusters mounted on servos. We then held a full-team discussion with electrical, software, and mechanical members. Considering the software team's concerns about the complexity of programming the servos, the mechanical team's concerns about the servos moving fast enough to allow for smooth motion, and the electrical members' power calculations, we choose to go with the eight thruster design. Using the data from Blue Robotics on the thrust from T200s versus amperage, we calculated that eight thrusters would provide the most thrust. We decided to budget 20A for the thrusters, with 5A for other systems onboard the ROV. Since the system runs at 12V, we used the technical data graphs on the BlueRobotics' website and calculated that when performing the most power-intensive and inefficient maneuver, surge, and heave at full power, four upward thrusters run at 2.5A produced 4kgf of thrust versus two at 5A produced only 3.3kgf. We applied this same theory to the horizontal thrusters, so each plane of thrusters would be allowed 10A to meet our total of 20A.

We believe that the benefits of extra thrust, stability, flexibility in thruster placement, and thrust vectoring capability greatly outweigh the excess weight, mounting hardware, and electrical systems required. We were also able to reuse the thrusters from the previous competition season, resulting in significant cost savings.


*Figure 12: Thruster current performance chart*

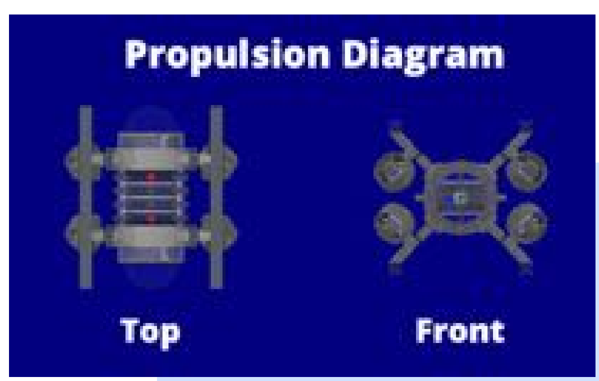



*Figure 13: Propulsion Diagram*

# CONTROL SYSTEM

## Onboard Electronics

Our ROV electronics system consists of a custom PCB designed by WarriorTide employees. The board consists of an Arduino MEGA, eight ESCs, one Fathom X, an ethernet switch, and a Raspberry Pi. Our system architecture allows the topside to communicate with the ROV over Ethernet, which our PCB facilitates with a Fathom-X and ethernet switch. The board also includes an Arduino with an Ethernet shield that sends PWM signals to the ESCs, whose output is then routed to the organizer board and the thrusters. We also included a Raspberry Pi Zero connected to the Arduino via USB. Although this took up additional space on our PCB, it allows us to remotely access the Raspberry Pi and upload new code to the Arduino over the tether. This improves the serviceability of our robot as it eliminates the need to take the ROV out of the pool, unseal the enclosure, remove the board, and plug in a USB cable every time we need to modify a snippet of code.

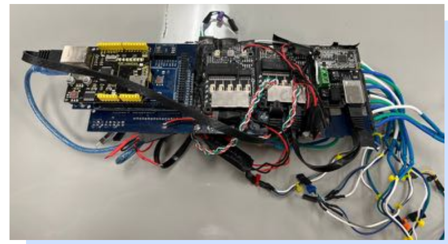


*Figure 14: Top side of custom PCB*

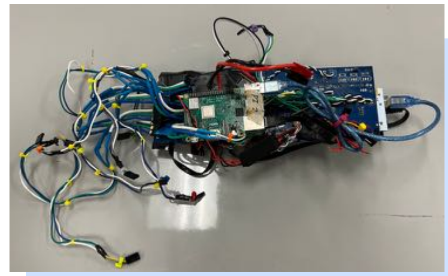


*Figure 15: Bottom side of custom PCB*

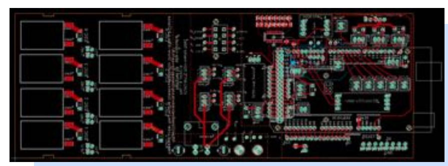


*Figure 16: Layout of PCB*

The PCB was designed using Autodesk EAGLE. We began the design process by creating a SID of the overall architecture. We then created schematics for both boards. We reviewed the schematics with our mentor before designing the PCB. After the design was finished, we solicited feedback on the PCB from our mentor, WarriorTides alumni, and others. After creating revisions based on our design reviews, the PCBs were ordered and then assembled in-house, saving money and allowing members to gain valuable experience working with surface-mounted components

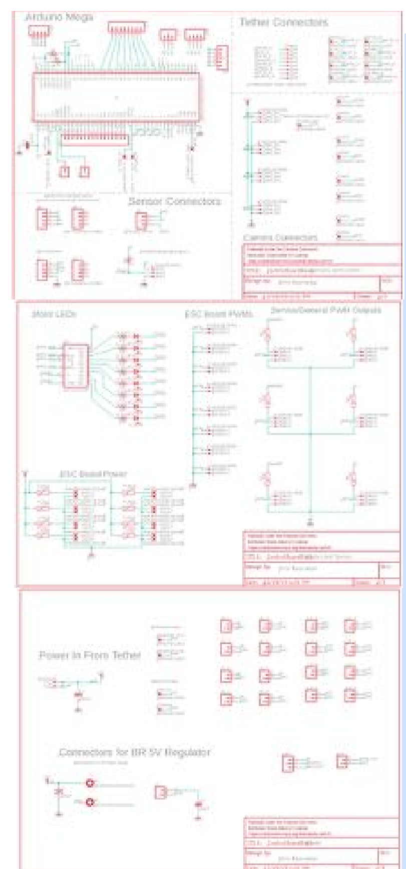


*Figure 17: Schematic of PCB*

We arrived at our current PCB after making quite a few difficult decisions. The electrical team actually spent over half the year designing and building a different two-board PCB system. However, the system was plagued with many problems, from components that did not fit, to traces that didn't align between the two boards. Even after reordering the boards, we still had many issues with intermittent connections between the boards. In the end, after hearing input from all members of the electrical team, based on the criteria of reliability, cost, and time we decided to stop working on the two-board system and instead modify last year's PCB.

## Sensors

Black Flounder does not feature any sensors besides the three cameras. We are able to perform all of the mission tasks by simply using camera input and thus did not include additional sensors. While at some point we did experiment with PID using other sensors such as an IMU and depth sensor, after driving the Black Flounder around we felt that it was stable enough to successfully perform tasks without additional PID controllers.

## Topside Station

Our topside electronics include a Fathom-X Tether Interface board, two laptops, an Ethernet switch, an Xbox controller, and two 22" LCD monitors. The Xbox controller is used to direct the ROV's movements. The Fathom-X board and Ethernet switch create an Ethernet connection between the topside laptops and the ROV's microcontrollers. Both computers receive video feed from the Raspberry Pis through the Ethernet network.

Each laptop is connected to an LCD monitor. The leftmost monitor is for the driver and displays all three video feeds at 1080p and also sends Xbox data to the onboard Arduino. The rightmost monitor is for the co-pilot and runs various scripts to perform tasks such as mort identification or shipwreck measurement.

Our topside station is housed within a Pelican Storm iM3220 Case with 44" x 14" x 8.5" interior dimensions. It features press-and-pull latches and rugged in-line wheels for easy and safe transport. We installed brass hinges to help support the case's lid when open. Two acrylic panels safely isolate cables underneath, provide a flat surface for the keyboard, mouse, and Xbox controller, and add a sleek look to the topside station.

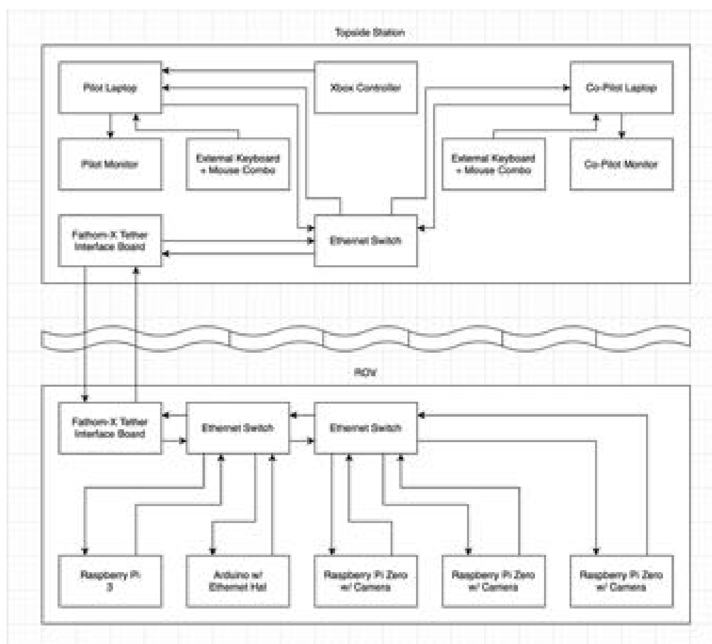



*Figure 18: Topside station diagram*

*Figure 19: Topside station setup*

*Figure 20: Piloting the ROV from the topside*

## Tether

Our tether comprises a 12-volt power and ground wire pair and the Blue Robotics Fathom Slim ROV Tether, which contains a single pair of wires, making it easy to manage. The wire pair in the Fathom tether is used for communication and data transfer and enables the Fathom-X to act as a transparent ethernet connection between the topside and the ROV. Waterproof cable connectors that allow for quick disconnections between the topside and ROV were also implemented into the tether design for short maintenance and convenience.

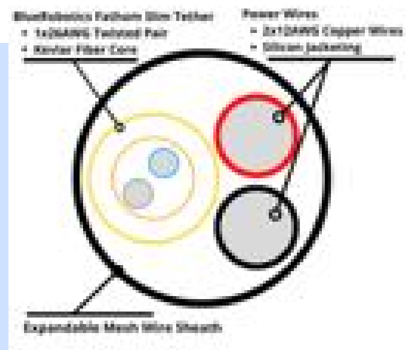



*Figure 21: Black Flounder Tether Diagram*

## Tether Management Protocol

WarriorTides's developed protocol for tether management is that one employee stands by the poolside, taking in or letting out the tether. In addition, the driver can communicate with the poolside employee by vocal commands. For safe transport, we use a set of velcro straps to wind up our tether into a manageable bundle.

## Software Control Code

Our control system code consists of Arduino control software run locally on the ROV. The Arduino communicates directly with the topside computer via ethernet. The Arduino is responsible for generating PWM signals for thruster control and servo actuation. We chose to use an Arduino because it allowed us to reuse a portion of our code from last year and had a more reliable PWM signal than a Raspberry Pi.

We also chose to implement fine and coarse modes. Fine mode is used for small, slower movements such as removing algal marine growth while coarse mode allows the driver to quickly move the ROV.

On the topside, a Python-based script handles the bidirectional communication between the ROV and the pilot on the topside station, compiling and transmitting video to our GUI and sending joystick inputs to the ROV.

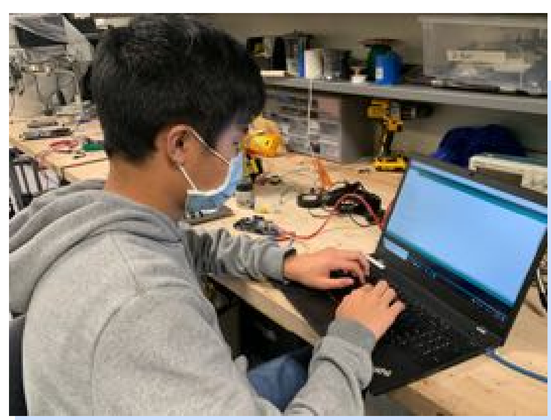


*Figure 22: Software Lead Brayden coding*

# CAMERA SYSTEM

## Placement Rationale

Black Flounder is equipped with three Raspberry Pi Ethernet cameras. Two cameras are mounted on servos in the main enclosure's front and rear domes, while one is placed in an individual externally-mounted enclosure positioned downwards. The front camera provides the driver with a view of the claw, while the rear camera can be used to capture images for AI tasks such as measuring fish as well as give the driver additional information about the ROV's location. The bottom camera is used for navigation, capturing images for habitat and wreck inspection, and flying a transect line. This particular placement was used to give the driver all the camera angles needed to complete the competition tasks and orient the ROV in the pool.

## Camera Enclosure

Black Flounder has a 4-inch waterproof BlueRobotics enclosure cut to accommodate the Raspberry Pi, Pi ethernet shield, and a BlueRobotics RJ45 to JST-GH adapter, as well as the camera itself. Using a BlueRobotics flange and an endcap allowed us to pass wires through the watertight penetrators. We also included a vent plug which enabled ease of testing and serviceability; we paired the flange and endcap with an acrylic dome. Finally, we 3D printed a mount for the camera connected to the flange by M3 bolts along the edges.

*Figure 23: Camera enclosure*

## Electrical and Software

Black Flounder's camera system consists of Raspberry Pis connected via an ethernet network. Each camera module consists of a Raspberry Pi zero connected to a camera via a CSI ribbon cable. We use an Ethernet converter so that the Raspberry Pi's ethernet connection is converted to 4 wire JST, making it easier to run cables and pot penetrators.

Each Raspberry Pi runs a Python script that creates a server where the camera is streamed on the software side. The topside computer can then view the camera stream from the server. This camera system streams three cameras at a resolution of 1080p at 30 fps with about 0.2 seconds of latency.

We first brainstormed many different options to come to this design, such as using USB cameras plugged into a Jetson Nano, USB cameras plugged into a Raspberry Pi, and multiple Raspberry Pi cameras. Our primary research methods included referring to other companies' technical documentation from previous years, ROVs observed at the regional, and our school's FIRST robotics team. Following the brainstorming process, we began prototyping and testing the different options using the metrics of latency, video resolution, power consumption, and size before finalizing our current system of multiple Raspberry Pi cameras. Although this year's camera system required considerable time and effort to develop since it is drastically different from last year's, we felt that making the switch to an ethernet-based video feed would allow us to get the higher resolution images necessary for image recognition tasks such as measuring the shipwreck, measuring fish, creating the photomosaic, and inspecting the fish pen.

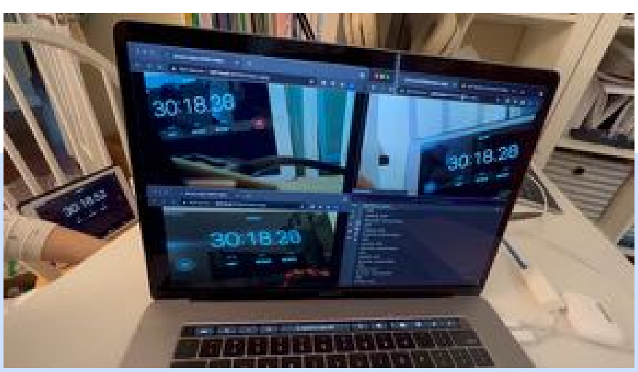



*Figure 24: Testing the latency of camera system prototype*

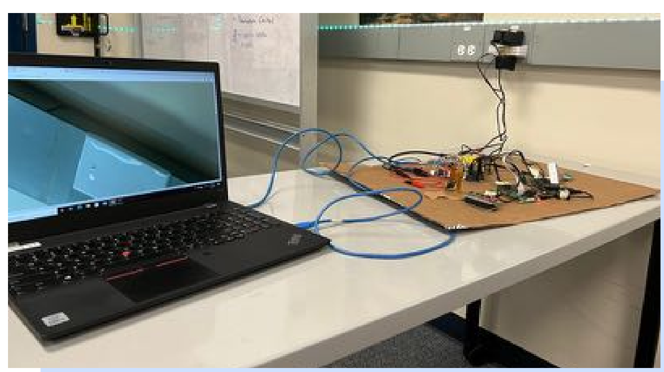


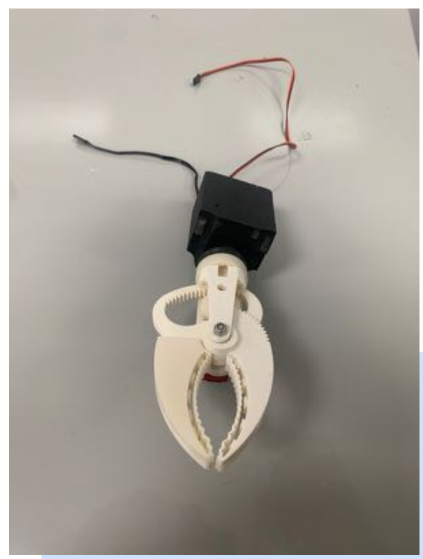
*Figure 25: Figure Bench test setup of camera prototype*

# MISSION TOOLS

## Claw

This season, WarriorTides' single manipulator is a two-pincer claw driven by a waterproof servo (IP-67 rated and tested multiple times in the pool). It was 3D printed and assembled in-house. Last season, we struggled with slipping gears and loose connections on the previous claw, which was more complicated than it was worth. As a result, we selected our claw design based on the criteria of simplicity, feasibility, ability to complete mission tasks, and cost. This design favors simplicity over strength, which we figured was acceptable considering the relatively light loads the robot would be handling this competition season. It only has three moving pieces, making it much more robust and easier to repair in case of failure.

Black Flounder also has a rotating mount that gives the claw roll. It is designed to rotate 360° around its center axis, although it will only be rotating 90° from vertical to horizontal during competition runs. We chose to include this because it allows us to perform tasks such as recovering the GO-BGC float and removing encrusted marine growth.



We chose to use a servo-driven claw as opposed to a pneumatic or hydraulic claw because we do not have experience with either, and this covers our needs well.

*Figures 26 and 27: Claw top view and side view*

## Specific Missions

This gripper was chosen to help deploy the hydrophone, remove marine and algal growth, collect the mort, prune the seagrass bed, plant a new seagrass bed, recover the float, and deploy our Gatling Float. The claw can open to any width between fully open and fully closed, making it ideal for both grabbing loops, such as the algal growth or the mort, and pipes, such as the hydrophone and the seagrass.

## The Gatling Float

WarriorTides began the development of a float for completing vertical profiles of the ocean in 2022. This design utilizes six syringes arranged in a circle, sandwiched between two acrylic plates to adjust buoyancy. The compression of the plates is driven by an electric motor powered by an onboard alkaline nine-volt battery and controlled by an onboard Arduino Nano connected to a motor controller.

*Figure 28: CAD of the float*

*Figure 29: Float prototype*

## Measurement System

WarriorTides developed a novel measurement program to measure the length of the shipwreck and fish. Since the length of certain sections of the shipwreck and fish is constant, we created a program that captures a photo of the shipwreck or fish. The user is then instructed to click on the start and end of the known section and the start and end of the unknown section. Our program can then compute the needed length.


*Figure 30: Measurement system being tested on sample shipwreck prop image*

## Photomosaic System

We developed a script that is able to take 8 photomosaic images and arrange them in the specified order. Before the product demonstration begins, the pilots discuss the optimal way to capture the images and update the script to the order in which the photos will be taken.

## Float Location System

WarriorTides developed a program to determine where the float will next surface. Our program consists of a grid where the user can select the square in which the float was last seen in. The user also provides additional information like speed and angle. The program then highlights the square on the grid where the float will next appear.

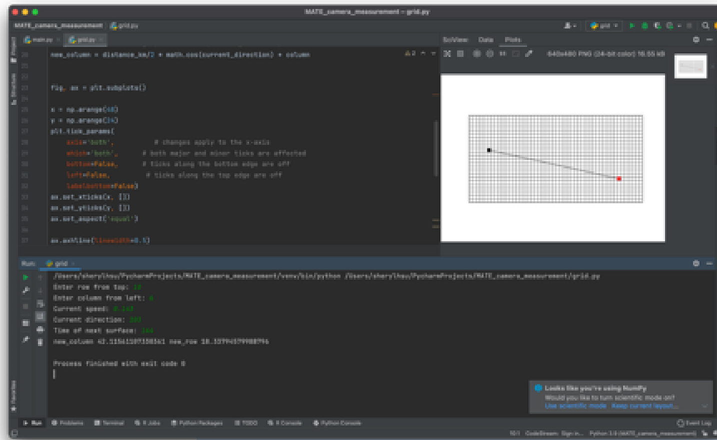


*Figure 31: Testing the float location system with provided data*

## Co-Pilot GUI

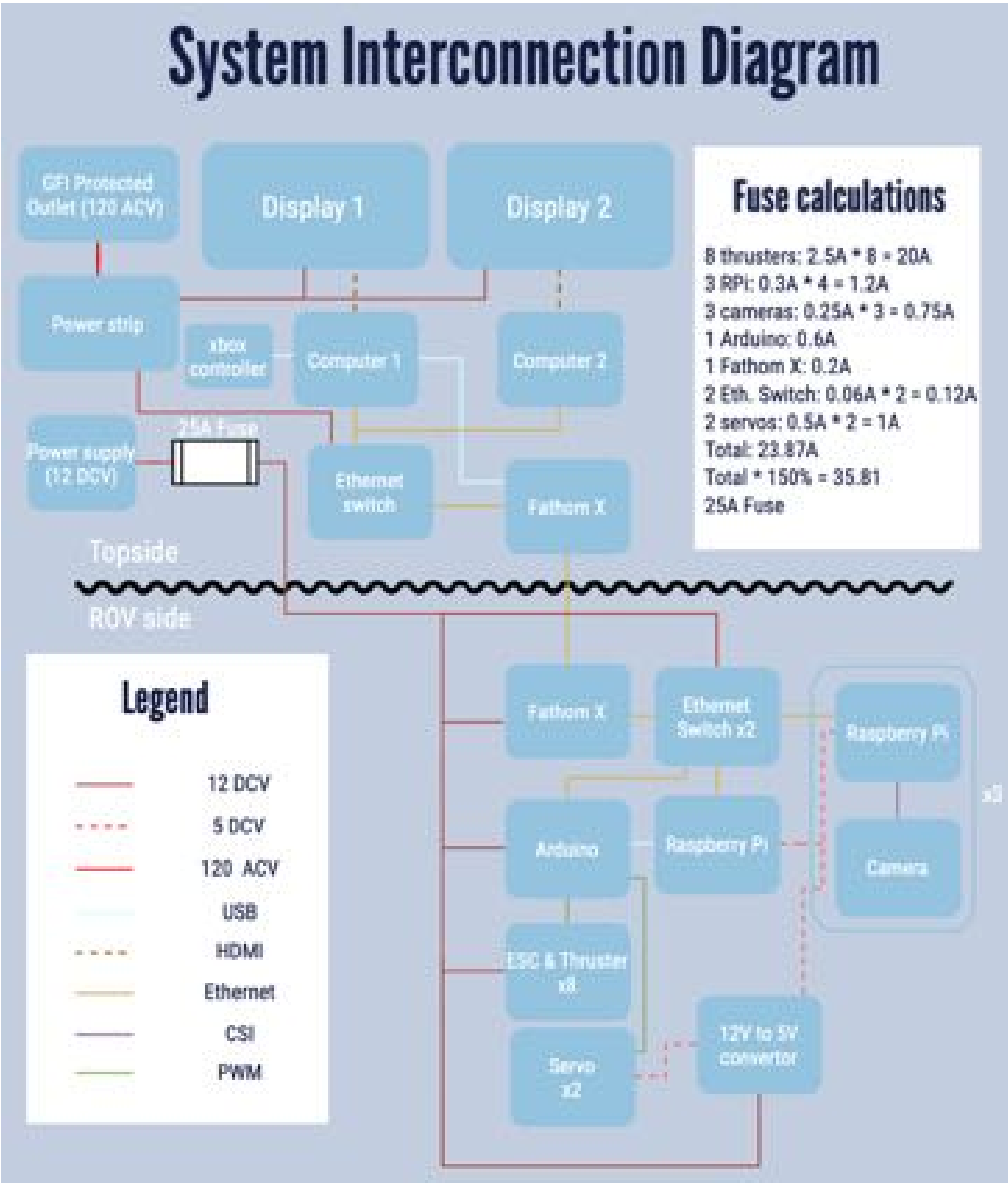
Our co-pilot GUI is a React-based web application that utilizes web sockets and a Django Python backend server to handle requests. The co-pilot will be able to view camera feed, read sensor and thruster data, view ROV orientation, adjust joystick sensitivity (ex: high sens means more abrupt and coarse movements), run software-based mission tasks (like run autonomous tasks or image processing tasks), and more. We created a sleek and elegant UI interface for the co-pilot to quickly assist the driver in completing mission tasks. We used ReactJS because our old solution, PyGame, was slow, inefficient, and restricting.

## Autonomous Mort Detection

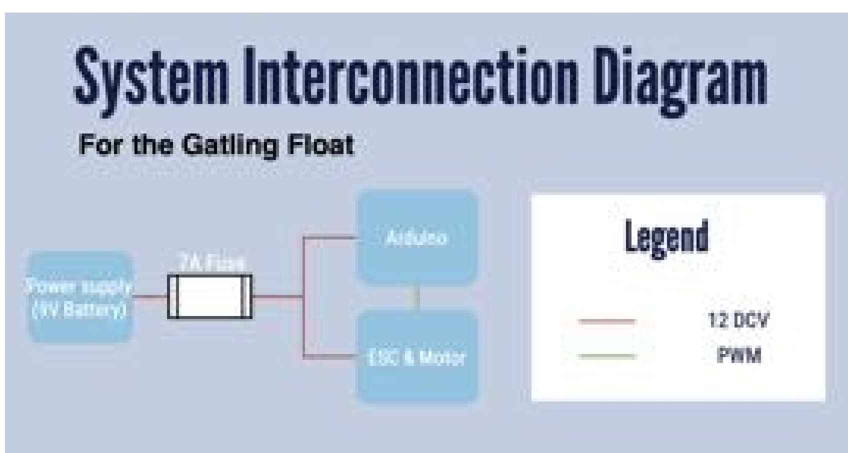

*Figure 32: Screenshot of mort detection algorithm output*

To complete the Mort detection task, our system utilizes color filtering. We decided to use this after noticing that the Mort fish are resting on the netting and reflect the light coming from the sun. This causes the fish to appear white. To filter out the fish, we create a mask of the image that only allows a specific range of whites to be visible, and we place bounding boxes around the objects. Although placing bounding boxes around white objects will cause other objects to be detected, we can minimize this by limiting some of the bounding boxes based on size, shape, and location.

# SID



System Interconnection Diagram
GFI Protected Outlet (120 ACV)
Display 1
Display 2
Power strip
xbox controller
Computer 1
Computer 2
Power supply (12 DCV)
25A Fuse
Ethernet switch
Fathom X
Fuse calculations
8 thrusters: 2.5A * 8 = 20A
3 RPi: 0.3A * 4 = 1.2A
3 cameras: 0.25A * 3 = 0.75A
1 Arduino: 0.6A
1 Fathom X: 0.2A
2 Eth. Switch: 0.06A * 2 = 0.12A
2 servos: 0.5A * 2 = 1A
Total: 23.87A
Total * 150% = 35.81
25A Fuse
Topside
ROV side
Legend
12 DCV
5 DCV
120 ACV
USB
HDMI
Ethernet
CSI
PWM
Fathom X
Ethernet Switch x2
Raspberry Pi
Camera
x3
Arduino
Raspberry Pi
ESC & Thruster x8
Servo x2
12V to 5V convertor

System Interconnection Diagram
For the Gatling Float
Power supply (9V Battery)
7A Fuse
Arduino
ESC & Motor
Legend
12 DCV
PWM

# PROCESS & ANALYSIS

## Build vs Buy

At WarriorTides, we believe that building gives us more opportunities to teach our newest team members and allows for flexibility amongst each module. However, we understand that sometimes items may not be possible to build, so we must buy them. For example, we purchased our 6-inch enclosure, but we machined penetrator holes in the side ourselves. This was done to reduce unequal drag and weight distributions when managing the tether. We also decided to build the claw and 3D print claw components instead of buying one.

For the electrical side of Black Flounder, we chose to design our custom PCB and assemble it in-house. The WarriorTides electrical team even attempted to build a reflow oven from a toaster oven. On the other hand, we decided to buy ESCs, Fathom X boards, Ethernet switches, and Raspberry Pis, given the effort, technical knowledge, and time that would have been required for us to build those ourselves. Even with these bought components, we would often make modifications such as swapping pin headers with stacking ones to work with our PCB and Ethernet shields.

*Figure 33: Teammate assembles reflow oven*

## New vs Re-used

WarriorTides attempted to reuse as many components as possible to save money and prevent unnecessary waste. However, there were several occasions when parts were simply too outdated to be reused. All of the T200 thrusters on our ROV are reused from last year, saving us a considerable amount of money. On the electrical side, many of the tools used to create our board — including a soldering oven, soldering irons, AutoDesk EAGLE, spare wires, and connectors — were reused from previous years, so the cost spent on new tools was low. Given the abundance of tools used, we provided many opportunities for team members to gain experience working with PCBs and design tools. We also chose to reuse most of the components in our topside station: our Pelican case, monitors, keyboard, mouse, and acrylic panels. Considering the high expense of the monitors and Pelican case, we had originally purchased these items to use them for multiple years. In addition to saving money, this also allowed us to save time and focus our efforts on other aspects of our ROV, such as the Ethernet camera system and new frame.

## Testing Procedure

Throughout the development of Black Flounder, there were several instances where we had to test and troubleshoot issues. Prior to every pool test, we ran a thruster test before sealing the electronics enclosure. The electronics enclosure was then vacuum pumped to ensure that it was watertight. The electrical team tested individual components such as cameras and ESCs before testing the overall board. Although testing was at times cumbersome, we felt that considering the consequences of something failing, taking the time to test was well worth it.

*Figure 34: Prototype enclosure being vacuum tested*

## Troubleshooting

When troubleshooting, the team does its best to remain calm and systematically explore the situation to find the problem. For the electrical sub-team, this means turning off power and disconnecting unnecessary components; then, we probe with multimeters to find the error. The software team would often isolate certain pieces of code and focus on fixing them. When faced with the problem of 3D-printed thruster mounts snapping, the mechanical team assessed the failures of the broken design before creating an improved version.

*Figure 35: Team member identifies points of leakage in the submerged ROV at a given depth*

## Prototyping

We also created and tested many prototypes before arriving at our final design. For example, the mechanical team first created a prototype frame with swept-back thruster mounts. However, after testing the buoyancy in the pool, we pivoted to make our final frame with thrusters mounted further forward. On the electrical and software side, we prototyped many possible video systems. We experimented with USB cameras plugged into a Jetson Nano, USB cameras plugged into a Raspberry Pi, and multiple Raspberry Pi cameras. We tested each prototype using the metrics of latency, video resolution, power consumption, and size before settling on our current system of multiple Raspberry Pi cameras.

# REFLECTIONS

## Challenges

This year, one of our most difficult challenges was our two-board custom PCB system. We spent all of the first semester designing the PCBs but once they were ordered and assembled, we realized there were many issues such as connections did not line up between the two boards and parts did not fit. The fatal flaw was that the connectors between the two boards would cut in and out to the point where we finally decided they would never work inside a moving electronics enclosure.  This was incredibly disheartening as the electrical team had invested a lot of time and effort in the PCBs. However, despite this serious setback, we needed to move past it to produce a successful ROV. We later chose to modify the custom PCB created the year before. This PCB ended up working well and we learned the importance of testing (specifically testing the connectors before we assembled and devoted a large amount of time to our PCBs) and having a backup option.

## Lessons Learned

One lesson that we learned was to always test as we build. In addition to the many problems with the PCB, testing would also have greatly benefited the mechanical team. After the frame was completed, we waited a couple more months for electrical to finish the board before putting the ROV into the pool for a pool test. While we expected to drive around the ROV that day, we instead found that the ROV tilted almost 90 degrees up due to our original design featuring swept-back rails. Mechanical then had to scramble to redesign the ROV within a week, which could have been avoided if we had simply put the ROV in the pool without the electronics many months earlier to test the buoyancy.

## General reflections

As I look back on this year from a technical standpoint, the most important piece of technology developed was our Ethernet-based camera and communications system. This system is faster, more reliable, and has allowed us to implement more computer vision technologies. I believe that this system will be implemented in many future WarriorTides ROVs. From an interpersonal perspective, it has been great seeing new, younger members of the team step up and play large roles in developing Black Flounder, from designing PCBs to planning out mission tasks. As a graduating senior, it is hard to say goodbye, but fabulous to see that WarriorTides will continue to thrive well into the future.

- Sheryl Hsu, CEO

# SAFETY

## Philosophy

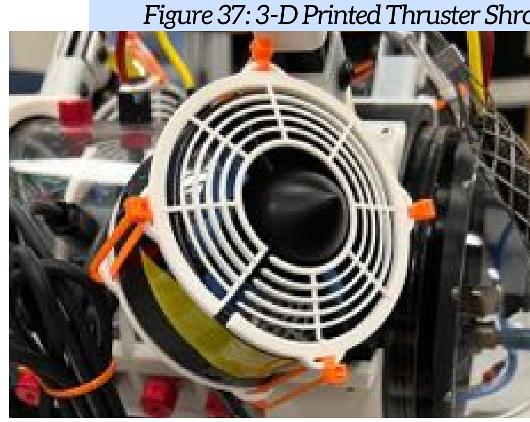
WarriorTides takes the safety and health of our employees into consideration in every aspect of production. It is of utmost importance to guarantee and maintain each employee's safety by calculating and preventing any electrical or mechanical dangers. With that in mind, the ROV was designed to fulfill safety requirements and standards to minimize injury risks during operation.

## Features

- **Eye-catching labels:** noticeable labels to warn about moving parts or hazardous components
- **Upper rails:** Reduce the risk of injury while transporting the vehicle
- **Rounded Edges:** The structure of the ROV is designed to have smooth edges and 3d printed parts are sanded down
- **Thruster shrouds:** The T200 motors are fitted with 3D printed shrouds that meet IP-20 standards
- **Fuses:** 2 24A fuses are installed on the positive power line of the ROV, one next to the connection to the MATE power supply and one directly before the connection to the tether
- **Desiccants:** 2 Blue Robotics Moisture Indicating Silica Gel Desiccant bags are located in the ROV's electronic enclosure. These allow for visibility into the tube as well as reduced chance of short circuits from exposure to water

*Figure 36: WarriorTides engineer wears safety glasses while sanding down a sharp edge.*

*Figure 37: 3-D Printed Thruster Shrouds*



# Safety Construction and Operation Checklist

| | Operational Safety Protocols |
|---|---|
| | Masks will be worn and CDC guidelines will be followed at all times during meetings |
| | Safety glasses are worn when soldering, using drills/dremels/bandsaw, and when thrusters are on |
| | Fume extractor used when soldering |
| | Team members wears closed-toed shoes while working on deck |
| | No running on the deck |
| | No team members in the pool with the ROV |
| | No food/drink near the equipment/ROV |
| | Machinery will only be operated by those with the certification to do so |
| | All shared materials will be wiped down and sanitized in between use |

| | Construction and Operation Checklist |
|---|---|
| | ROV has no exposed/unsealed wiring |
| | ROV has no sharp edges/any sharp edges are marked |
| | Tether has proper strain relief on both sides (ROV-side and topside) |
| | 25 amp inline fuse on positive line |
| | All ROV components fastened to frame |
| | All topside station components/wiring fastened to box |

# CORPORATE RESPONSIBILITY

WarriorTides highly values giving back to the community. Although our intellectual growth and success are important, it is just as important to us that we are able to use our skills to serve our community.

## Mentoring

To nurture an environment of engineering and leadership at our school, we created and continue to mentor Warrior Waves, our Navigator class team. We offer them tools, training, and advice and mentor them individually whenever needed. Under our guidance, they were able to win first place in the Monterey Regional last year and are competing again this year.

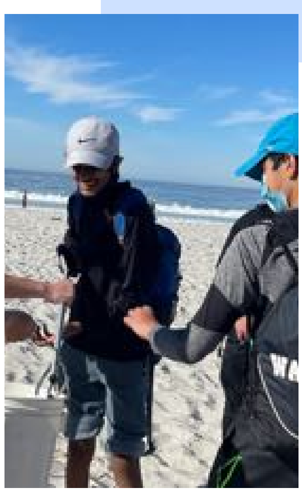
*Figure 38: Answering students* questions

We reached out to middle school science teachers and students at Valley Christian Junior High to teach classes about underwater robotics. We went over the idea of an ROV and what it means, along with real-world applications. We also brought in our robot and allowed them to drive it to give them a hands-on experience in our world!.

*Figure 39 and 40: Beach Cleanup*

Along with this, we hosted a "Drive Day" to allow anyone interested to drive our ROV and learn about the program. We hope we were able to inspire future engineers with these opportunities.


*Figure 41: Drive Day*



## Beach Cleanups

Lastly, we invested in global issues. We understand how important it is to keep our oceans and planet clean, so we took the initiative to participate in beach cleanups. This year, we partnered with Save Our Shores and collected trash at Carmel Beach. This activity helped us grow our community and taught us essential lessons about plastic pollution in our oceans.

WarriorTides hopes to impact our community in whatever way we can positively. We learned a lot through these outreach activities and hope to be able to participate in many more!

# FINANCE

WarriorTides began with a budget of 6,000 dollars this year, provided by Valley Christian High School. This budget was split into categories of Hardware, Electrical, and Miscellaneous. The sheet below shows our projected cost and the actual cost we spent. The only re-used items from last season were our T200 thrusters and tools previously purchased. Valley Christian High School provided 3D printers and filament materials. Upon qualifying for the world championships Valley Christian High School provided an additional 4,500 dollars to fund travel for our mentors and improvements to the ROV.

## BUDGET

| | | | | |
|---|---|---|---|---|
| **School Name:** | Valley Christian High School | | From: | 8/14/2021 |
| **Instructor:** | George Sousa | | To: | 6/21/2022 |
| **Income** | | | | |
| *Income at start of project (if any)* | | | | |
| **Source** | | | | **Amount** |
| Valley Christian Highschool | | | | $ 9,500.00 |
| **Expenses** | | | | |
| **Category** | **Type*** | **Description/Examples** | **Projected Cost** | **Budgeted Amount** |
| Hardware | Purchased | Fastening hardware, extrution, enclosure hardware, acrylic tubes, tools | $ 1,700.00 | $ 1,880.00 |
| | Re-Used | T200 Thrusters | $ 1,512.00 | - |
| | Donated | 3D Printing Filament | $ 1,200.00 | - |
| Electronics | Purchased | Components, sensors, topside materials | $ 3,200.00 | $ 3,500.00 |
| | Purchased | PCB manufacturing | $ 500.00 | $ 500.00 |
| Miscellaneous | Purchased | Stationary, Snacks, marketing materials, merchandise, etc | $ 500.00 | $ 500.00 |
| | Re-used | Tools (Ifixit kit, Drill, etc) | $ 500.00 | $ - |
| | Purchased | Props | $ 200.00 | $ 250.00 |
| | Travel | Accomidation and transporation for chaperones | $ 2,000.00 | $ 2,500.00 |
| | | ** either purchased, donated, or reused* | Total Income: | $ 9,500.00 |
| | | | Total Expenses: | $ 11,312.00 |
| | | | Total Expenses-Re-use/Donations: | $ 2,712.00 |
| | | | Funds Used: | $ 9,130.00 |
| | | | Funds Remaining: | $ 370.00 |

*Figure 42: Running Budget Sheet*

## PROJECT COSTING

*Figure 43: Project Costing*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **School Name:** | | | | Valley Christian High School | | From: | 8/14/2022 |
| **Instructor:** | | | | George Sousa | | To: | 6/21/2022 |
| **Funds** | | | | | | | |
| **Date** | **Type*** | **Category** | **Expense** | **Description** | **Sources/Notes** | **Amount** | **Running Balance** |
| 9/6/2021 | Purchased | Software | Jetson Nano | Jetson Nano | For prototyping camera systems | $ (358.00) | $ (358.00) |
| 9/12/2021 | Purchased | Software | USB Camera | Blue Robotics low-light usb camera | For prototyping camera systems | $ (297.00) | $ (655.00) |
| 9/12/2022 | Purchased | Electrical | Bluerobotics ESCs | Electronic speed controller | For onboard electronics | $ (300.00) | $ (955.00) |
| 9/14/2021 | Purchased | Mechanical | ROV Enclosure | BlueRobotics 6" Enclosure | For housing onboard electronics | $ (432.00) | $ (1,387.00) |
| 9/16/2021 | Purchased | Electrical | Fathom X | Fathom X interface board | For topside and onboard electronics | $ (960.00) | $ (2,347.00) |
| 9/16/2021 | Purchased | Mechanical | Frame | Aluminum railings, fasteners, etc. | All materials used for ROV frame, including accessories | $ (349.00) | $ (2,696.00) |
| 10/6/2021 | Purchased | Mechanical | Extruder | MakerBot Extruder | For MakerBot 3D printer | $ (224.95) | $ (2,920.95) |
| 10/15/2021 | Purchased | Mechanical | Strain/Stress Relief | Sourced from McMasterCarr | To meet safety requirements | $ (150.00) | $ (3,070.95) |
| 11/27/2021 | Purchased | Electrical | Ethernet switch | Blue robotics small footprint Ethernet switch | For onboard electronics enclosure | $ (474.00) | $ (3,544.95) |
| 1/15/2022 | Purchased | Mechanical | Mechanical Consumables | M1-4 screws, nuts, etc. | To secure | $ (364.00) | $ (3,908.95) |
| 1/21/2022 | Purchased | Miscellaneous | Prop Building Materials | PVC pipe, PVC connectors, green fencing, etc. | for practicing the competition tasks at our headquarters | $ (435.72) | $ (4,344.67) |
| 3/7/2022 | Purchased | Electrical | PCB | PCB manufacturing | Send our custom PCBs off for manufacturing through PCBWay | $ (543.34) | $ (3,229.24) |
| 3/16/2022 | Purchased | Software | Shields | Arduino and Raspberry Pi hats | To make them connected to Ethernet | $ (270.91) | $ (3,815.86) |
| 3/9/2022 | Purchased | Mechanical | Fathom Tether | Slim Fathom tether | Bought from Blue Robotics | $ (200.00) | $ (3,439.24) |
| 3/25/2022 | Purchased | Electrical | Raspberry Pi | Raspberry Pi Zeros and 3B+ | Bought on eBay due to shortage | $ (476.23) | $ (3,915.47) |
| 3/26/2022 | Purchased | Electrical | RPI Cameras | Ribbon cable cameras for ROV vision system | Various cameras for testing | $ (242.00) | $ (4,157.47) |
| 3/29/2022 | Purchased | Electrical | PCB Parts | SMD and throughhole components from Digikey and Molex | For custom PCB | $ (334.23) | $ (4,491.70) |
| 4/2/2022 | Purchased | Electrical | Electrical consumables | Wire, solder, flux, headers, pre-crimps | For electrical assembly | $ (482.00) | $ (4,973.70) |
| 4/29/2022 | Purchased | Software | Keyboard | Wireless keyboard | For topside station | $ (133.52) | $ (5,107.22) |
| 5/12/2022 | Purchased | Electrical | Power Supplies | 12V-5V Converters, Variable power supplies for testing | From Blue Robotics | $ (221.00) | $ (4,712.70) |
| 5/14/2022 | Purchased | Mechanical | Waterproofing Testers | Vacuum pumps, Silicon dessicants, | For testing | $ (328.00) | $ (5,040.70) |
| 5/14/2022 | Purchased | Electrical/Mechanical | Power Tools, Soldering Irons | Soldering irons, Hand Drills, etc. | Replacing broken tools | $ (230.00) | $ (5,270.70) |
| 5/15/2022 | Purchased | Electrical/Mechanical | Driver kits, Adjustable Wrenches | Sourced from various local vendors | Replacing lost tools | $ (287.00) | $ (5,557.70) |
| 5/23/2022 | Purchased | Miscellaneous | T-shirts | Custom t-shirts | T-shirts from Customink | $ (422.32) | $ (5,980.02) |
| 5/31/2022 | Purchased | Mechanical | Acrylic | Acrylic sheets for laser cutting | For endcaps and claw mounting | $ (150.00) | $ (6,130.02) |
| 5/31/2022 | Purchased | Mechanical | Polyethylene | Float prototyping and plate frame prototyping | For prototyping | $ (200.00) | $ (6,330.02) |
| 6/1/2022 | Purchased | Miscellaneous | Travel to MATE ROV Worlds | Airfare, hotel room lodging, etc. | Cover chaperone costs | $ (2,130.00) | $ (8,460.02) |
| | | | | | | Total Raised | $ - |
| | | | | | | Total Spent | $ (8,460.02) |
| | | | | | | Funds Used | $ (8,460.02) |
| | | | | | | Funds Remaining | $ - |

# ACKNOWLEDGMENTS

We would like to thank our mentor, Mr. George Sousa, for his stellar support and astute advice and Valley Christian High School for providing us with facilities and funds. We also appreciate his willingness to mentor us even after school ended, well into summer. To Mr. Stephen Huber, whose lab we used and cluttered daily, we sincerely apologize, and we thank you for your patience. Thank you to Mihir Kasmalkar, Howell Ivy, and Cory Deuce, who graciously took the time to do design reviews of our PCBs with us. Thank you, of course, to Blue Robotics for supplying us with numerous parts. Thank you to the MATE ROV team for hosting and planning the competition during a global pandemic. Last but not least, thank you to the outstanding MATE Center for providing us with this opportunity to learn and compete.

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