HYDROZOA
Cabrillo Robotics Club

2022 Technical Documentation

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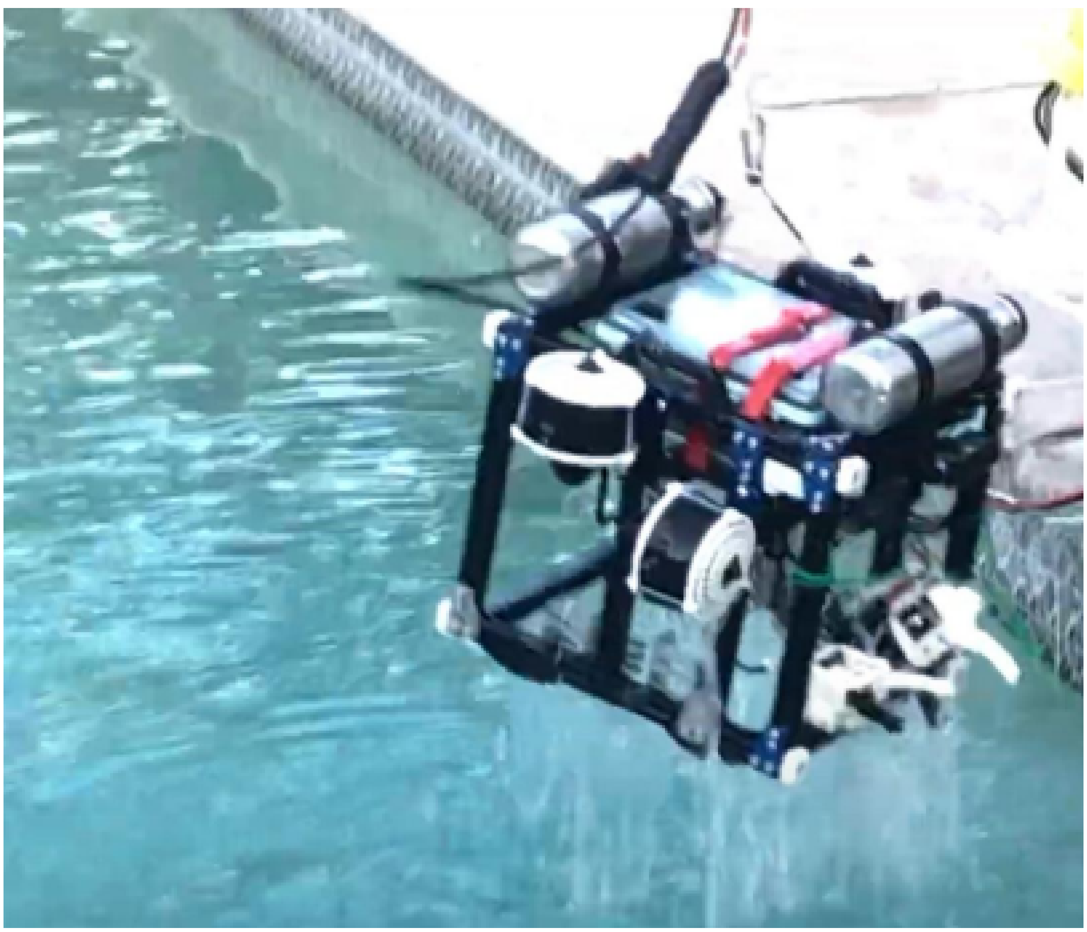

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I. Abstract

Cabrillo College Robotics has designed the Remotely Operated Underwater Vehicle (ROV) Hydrozoa to meet the needs of our ocean community and global clients. A simple yet elegant design leverages robust software to empower a dependable and cost-efficient vehicle optimized to perform tasks in the areas of marine renewable energy, offshore aquaculture and blue carbon and the UN sustainable climate goal for Antarctica. ROV Hydrozoa is capable of performing tasks required in these areas. The seven-member company is newly formed and has built a reliable and expandable platform to address this year's challenge and evolve in the future.

Cabrillo Robotics Club is organized into four teams: Mechanical, Electrical, Software, and Administrative. Cross-disciplinary teams work together to integrate ROV subsystems. Emphasis was given to enhanced project management and safety protocols in the face of the Covid-19 pandemic. This combined with flexible scheduling, careful budget oversight, and remote design review has led to the successful completion of ROV Hydrozoa in the face of many obstacles due to Covid-19 restrictions, wildfire evacuation, and floods.

ROV Hydrozoa was designed to provide an elegant solution to this year's challenge as well as provide a robust platform for expanded innovation in future years. We implemented the high-performance and reliable Robot Operating System (ROS) while keeping the mechanical design simple and reliable.

II. Introduction

Warming, expanding and acidifying oceans, as well as plummeting biodiversity at near mass extinction rates are the challenges scientists and policy makers around the globe face today (1). These leaders and scientists need the data and tools to make informed decisions and execute them on the scale that these problems demand.

Recent advances in technology are empowering a new generation of engineers and scientists to tackle these issues with an unparalleled efficacy and scale. That is where we come in. To tackle these challenges, Cabrillo College Robotics has designed the Remotely Operated Underwater Vehicle (ROV) Hydrozoa.

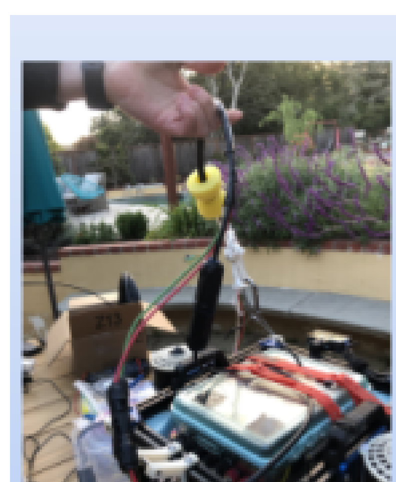
We chose the name Hydrozoa because it is a class of Cnidaria (stinging jellyfish, anemones, and corals.) We took inspiration from the sleek, minimal build of these creators and their highly specialized cnidocyte (stinging) cells that allow them to effectively capture their prey with incredibly simple body structures. Hydrozoa's simple and elegant design leverages a robust software architecture running a dependable and cost-efficient vehicle optimized to construct and maintain marine renewable energy infrastructure, offshore aquaculture systems and blue carbon capture equipment and to help achieve the UN sustainable climate goal for Antarctica.

Our new seven-member company focused on building a reliable and expandable platform to address this year's MATE tasks and to create a platform that can evolve to meet future challenges. Careful project management, prudent budget allocation, and remote design review allowed our team to build an affordable and effective robot in the face of Covid-19 restrictions, wildfire evacuation, and floods.

Fig. 1 - Team photo.

III. Safety

A. Safety Philosophy



Safety was a top priority of Cabrillo College Robotics when working on the Hydrozoa ROV. A safe environment not only prevents injuries but also increases productivity and employee comfort. In advance of work on a project, the safety of all workers and bystanders is assured through a thorough inspection of equipment and the work environment. Safety training must be completed by all team members before using hazardous equipment or chemicals. Mentoring and supervision of new team members ensure a high standard of workplace safety.

B. Safety Standards

When working on the Hydrozoa ROV, Cabrillo College Robotics required that all employees adhere to a standardized set of safety procedures. The team provided and required that all members use personal protective equipment (PPE) such as eye protection, face masks, eyewash stations, shower stations, first aid kits, and fire extinguishers. Covid-19 pandemic guidelines were followed including the wearing of masks at all times and social distancing in work and meeting spaces. Team members were required to wear safety glasses when working with power tools. Cabrillo College Robotics is located on the college campus and follows college safety standards. In the case that an employee worked in an alternate location, the stricter of the two sets of safety standards were applied. (2)

C. Safety Features

ROV Hydrozoa is equipped with a suite of safety features that limit the opportunities for injury and streamline robot operation. The tether is equipped with a master fuse and strain relief webbing (Figure 2). All sharp edges on the frame are covered by 3D printed custom caps (Figure 3). A safety checklist is used in advance of the deployment of ROV Hydrozoa to protect operators, observers, and the robot (See Appendix A).

Hydrozoa ROV is equipped with custom 3D printed shrouds that meet IP20 standards, blocking objects larger than 12mm (Figure 4). The shrouds are mounted using zip ties to allow for quick replacement.

The grippers are equipped with a disposable gear that will strip under unsafe loads providing a mechanical limit safety feature (Figure 5).

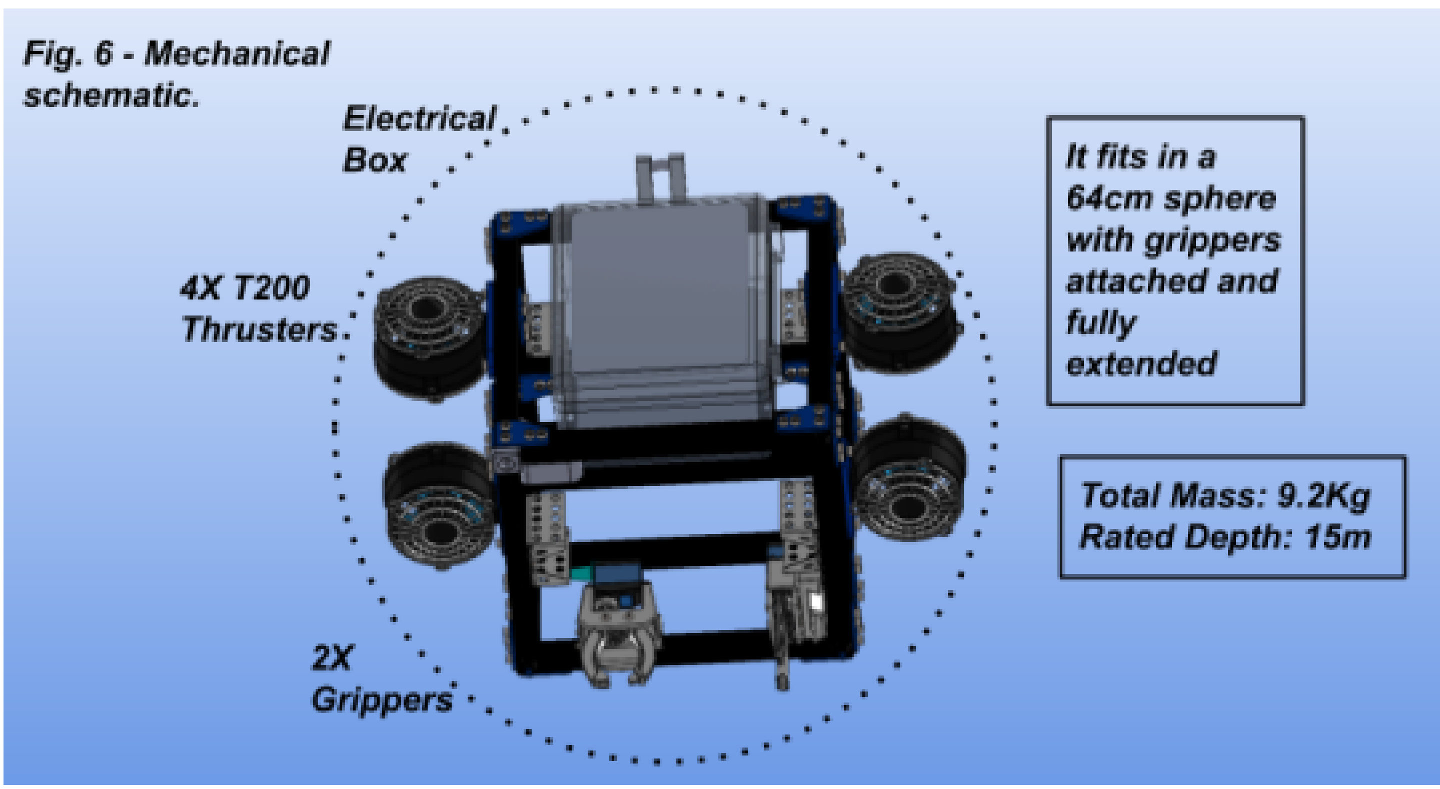
The ROV software provides the pilot a check on the system in advance of the ROV launch into the water. Once all systems are confirmed safe, the pilot instructs tether handlers to deploy the ROV. Once in the water, the software continuously monitors ROV systems. If any system becomes unsafe, the pilot is able to immediately shut down the ROV.

III. Mechanical Design Rationale

A. Mechanical Overview

In the development of ROV Hydrozoa, the Mechanical Engineering team prioritized modularity, simplicity, and flexibility. The process of design involved brainstorming, design in SOLIDWORKS, ANSYS finite element analysis, and rapid prototyping using 3D printing. The design was optimized through rigorous review and improvement of each component and refinement of electrical integration. All electrical housings were first tested using ANSYS hydrostatic pressure simulations and then rigorously tested in a pool. The ROV was designed and tested to withstand depths up to 15 meters. It was constructed with aluminum extrusions joined with custom-made, anodized, aluminum brackets. We harnessed the power of 3D printing to quickly prototype tools and accessories. This allowed tools to be efficiently modified through successive rounds of testing and improvement to meet the demands of many missions. The completed ROV fits within a 64 cm diameter sphere and weighs 9.2 kg, qualifying for membership in the smallest weight and size class. This workflow resulted in a high-value ROV capable of achieving mission tasks with great efficiency and reliability and allows for the option of rapid modification to tackle new mission objectives (Figure 6).

Fig. 6 - Mechanical schematic.



B. Frame

When we set out to design the frame of our robot, we had 4 goals: modularity, low price, consistent buoyancy, and ease of use. We used these goals when choosing materials for the frame. PVC plumbing pipe is relatively strong and affordable but lacks the desired design flexibility and affects buoyancy. Carbon fiber tubing is stronger but has many of the same challenges as PVC and a significantly higher cost. To accomplish our goals we used 20x20 t-slot Aluminum extrusion. The slots allow effortless

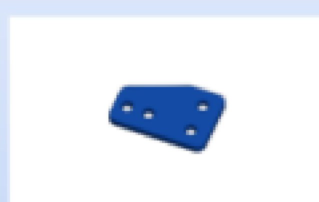


Fig. 7 - Anodized frame corner bracket.

mounting and vehicle configuration and the extrusion is stiff, strong, and relatively cheap. To connect the extrusion, we designed a single common corner bracket that joins all frame pieces together. This commonality reduces the cost of manufacture and simplifies the vehicle's design. All manufactured aluminum parts are made from grade 6061 aluminum and anodized to prevent galvanic corrosion when in contact with stainless steel mounting hardware (Figure 7). Enclosures and grippers were attached so that the center of buoyancy (COB) was placed in line on the x-y plane and was an optimal distance above the center of mass (COM). This resulted in optimized passive stability and control. A ballast system allowed for swift buoyancy adjustments. Four Blue Robotics T200 propulsion thrusters, two vertical and two horizontal, were mounted using custom aluminum machined brackets due to the inadequate strength of 3D printed brackets. For safety, we designed and printed shroud guards. Using flow simulations, we were able to minimize shroud impact on thrusters from a 23% to 15% reduction in efficiency compared to the initial shroud prototype (Figure 8). The initial configuration for camera and gripper placement was improved by using SolidWorks to draw vectors between the camera lens and target view to assure acceptable placement of cameras for ease of view and operation of grippers. To make operators' lives better, we added a set of lifting handles, an easily adjustable ballast system as well as quick-release grippers (Figure 9). To avoid wear and tear, we designed a swiveling strain-relief system for the tether that is easily detachable and has more than forty degrees of freedom in all directions. Replaceable 3-D printed caps were placed to cover all exposed corners. Skids were designed and printed to reduce friction when sliding on surfaces and to prevent scratching (Figure 10). Finally, all onboard electronics were positioned conveniently for rapid and painless access.

C. Electrical Housing

Our System was designed around one single waterproof enclosure (Figure 11). Our engineering team used an off-the-shelf polypropylene Lexan gearbox designed for kayaking (3). Our analysis and testing found that this style of box was pressure proofed well past the designed operating depth and provided a level of reliability and affordability that we could not match with a custom design. The electronics were mounted on aluminum heat sinks located on the top and bottom of the box. After thorough analysis and testing, we deemed that it

Fig. 11 - Electrical Box.

provided
sufficient protection from overheating without being overly complex. Penetrations were made using Blue Robotics penetrators. To prevent the box from being scratched, we machined Delrin spacers that go in between the nut of the penetrator and the wall of the box.

D. Cameras

ROV Hydrozoa was equipped with three cameras to provide the pilot with clear views of grippers and props (Figure 12). Camera enclosures were custom-designed and 3D printed to minimize assembly and potting time. The housing consists of an inner shell into which the camera board was bolted. This was seated in an outer shell and the 4mm gap between shells was potted with epoxy. The front of the case is an acrylic window with 6 machined pockets. These alignment holes provided for easy assembly of the enclosure when cameras were potted. Off of the outer shell we placed a swivel joint which can be adjusted by loosening a bolt. The swivel joint was attached to a 3D printed bracket which was mounted to the frame via one M5 bolt. This allowed two axes of freedom with the use of only one Allen wrench to modify the view poolside. Two Logitech USB cameras provided views of mission tools. A third Logitech USB camera had a straight-down view for computer vision tasks. Combined, the three cameras assured views such that the pilot had optimized visualization of the mission environment and tools.

E. Buoyancy and Ballast

The buoyancy and ballast system was designed to create net-neutral buoyancy and stability to optimize conditions for pilot control. We achieved net-neutral buoyancy through the use of machined, high density, polyurethane surfboard foam for fine adjustment and stainless steel floats made from repurposed water bottles for primary buoyancy. The foam floats were sealed in epoxy and were mounted with bolts in the four top corners of the ROV frame (Figure 13). The stainless steel bottle floats were attached to the frame with custom-made 3D printed brackets. The electrical box was an additional source of buoyancy. Enclosures and tools are attached so that the center of buoyancy (COB) is placed in line on the x-y plane and is an optimal distance above the center of mass (COM). This results in
optimized passive stability and control. A ballast system allowed for swift
buoyancy adjustments. For small adjustments, ballast was added by dropping 1/4” steel pins into custom sheet metal ballast racks. Ballast
racks were placed on all four corners of the ROV frame to trim and level

Fig. 13 - Custom foam fine adjustment float.

the ROV as tools are added or removed (Figure 14). Pins weigh 34 g each.

F. Grippers

ROV Hydrozoa has 2 identical grippers (Figure 15). They were located on the front in horizontal and vertical gripping positions. Each had two overlapping jaws. They can be rapidly repositioned on the frame or removed using a dovetail quick-release mount. The design was optimized to achieve all mission tasks. The jaws are driven by 20 kg servos providing 6 kg of clamping force. All parts were 3-D printed using ABS for high strength and impact resistance. Using 3D printing allowed for the design of jaws specialized for specific mission tasks.

G. Pin Extractor

A tool was developed to remove pins (Figure 16). Two 3D printed clamps mounted midway down the front of the ROV frame were attached to a thin stainless steel cable that stretches between the clamps. This is used to hook and remove pins. We have found this tool to be much more efficient than the use of grippers.

H. Profiling Float

We opted to use a buoyancy engine as a profiling float (Figure 17). Variable buoyancy was created by compressing and expanding a 100 ml syringe. The syringe plunger was actuated back and forth using a custom linear drive system consisting of an MGN 12C linear rail (4) and a T8 lead screw. This was driven by a continuous 20kg/cm servo. The assembly was encased in a 4 inch diameter acrylic tube with a PVC end cap on one end. The other end has a 3cm pressure release plug. This is machined from aluminum and has 2 O-ring seals. When the pressure inside exceeds that outside of the housing, the plug will release. The syringe penetrates the housing via vinyl tubing connected to a
quarter inch barb fitting.

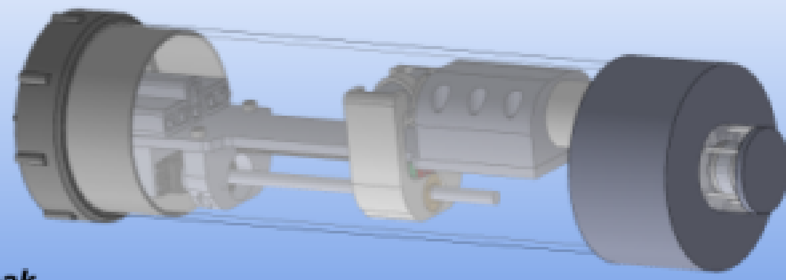
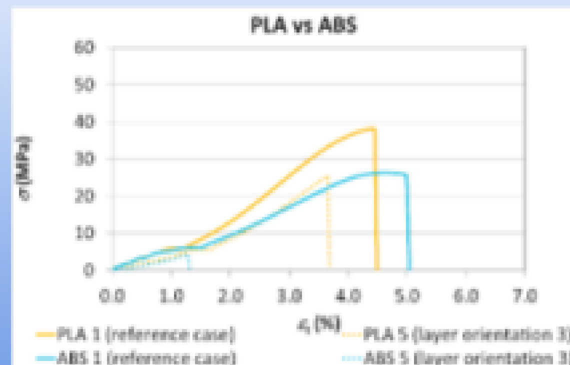


Fig.17 - Profiling float simplified break out view.

I. Material selection and manufacturing

For the manufacture of the ROV, we utilized three key disciplines: machining, water jet cutting, and FDM 3-D printing. Due to budget constraints, 3-D printing was used whenever possible. When a part involved sheet metal and simple 2-D contours we opted to use water jet cutting. As a last resort, we used CNC machining. Material selection was based upon cost-benefit analysis as well as material properties (Figure 18).

Fig. 18 - Stress-strain graph of PLA vs ABS (9).



The frame was made of anodized aluminum alloys of different grades. The custom parts were 6061. For 3-D printing, we opted to use ABS due to its strength, thermal properties, and affordability. PLA provided adequate strength but did not prove thermally stable in hot environments. Polycarbonate was challenging to print and expensive.

J. CAD data and BOM

Organization was key to our team's success during remote and hybrid work necessitated during the Covid-19 pandemic. We opted to use SOLIDWORKS PDM to store CAD data to make it easily accessible from all remote locations. SOLIDWORKS PDM prevened team members from saving files that overwrite others' work. This solved the overwrite problem we encountered when using the Google Drive desktop application. To easily track company parts and status we created a proscribed numbering system utilized in our bill of materials (BOM). The numbering system consisted of a number pulled from our part database and a number that denotes if the part was an assembly, an off-the-shelf component, or a custom part. This allowed us to instantly track down information, CAD files, drawings, and CAM programs.

IV. Electrical Design

A. Overview

The electrical design of Hydrozoa ROV prioritized modularity, accessibility, reliability, and cost-effectiveness (See SID design in Appendix B) (Figure 20). The ROV control initiated via a shore base station. The station consisted of a pilot, a computer, and a monitor Xbox 360 controller. A CAT6 ethernet cable and 48-V power supply were the electrical connections in the tether. The two cables connected to the electrical box. A Cat 6 ethernet cable was used to minimize noise. 48 V was sent to the electrical box via 2 strands of 12 gauge marine-grade wire with an in-line 20A fuse (5).

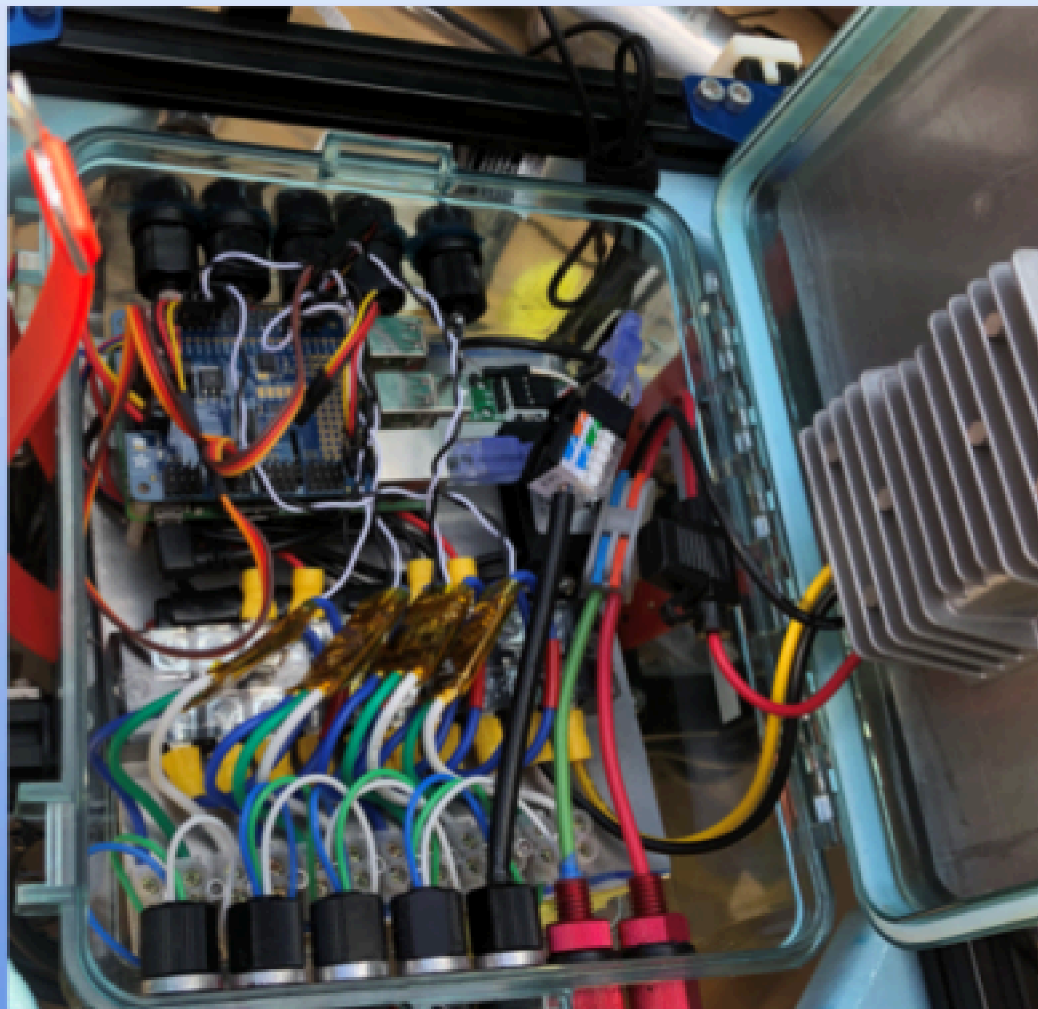


Fig. 20 - Electrical box.

B. Power Distribution

We opted to use 48V power. Power entered the electrical box and was converted from 48 to 12V using a buck converter: 48V to 12V 20A then to 2X 12V to 5V 3A buck converters. This connected to a terminal strip that distributed power to ESCs and 12-5V buck converters. The two 12V IN 5V 3A OUT buck converters powered the Raspberry Pi and the servo motors (Figure 21).

C. Sensors

ROV Hydrozoa was equipped with an IMU, magnetometer as well as multiple cameras. These acted like a gyroscope, accelerometer, and compass (Figure 22). We also had a pressure sensor, but it is not currently implemented.

D. Tether

The tether consisted of two strands of 12 gauge wire and one CAT6 ethernet cable (Figure 23). It was 100 feet long. Using 48V allowed us to use a much thinner power cable. This significantly reduced cost and weight.

E. Raspberry Pi

An Adafruit Pi shield was used to generate PWM signals for the servos (Figure 24). The ESCs connected directly to the Pi GPIO pins. The board was located in a corner of the electrical box held to the aluminum base with brass standoffs to prevent overheating. The Pi was powered via a 5V buck converter and connected to Ethernet.

The Raspberry Pi onboard the robot ran the process to control the vehicle, provide feedback and information to the surface and camera feeds for the pilots. Raspberry Pi was selected to allow for flexibility in programming and design.

F. Servos

Two 20 kg/cm servos drove the ROV manipulators. They were powered from a separate 5V buck converter and each used one PWM pin off of the Raspberry Pi shield.

G. Cameras

Our three USB Logitech digital cameras, which were waterproofed in-house, provided for the vision needs of the ROV (Figure 25). The cameras were 5 megapixels and used an autofocus mechanism. They may be moved to different locations via a quick-release hinge. Three constant secondary video feeds may be distributed around the ROV. They delivered camera feeds by plugging into Raspberry Pi (Figure 26). The output was a video stream that was displayed through ROS on the pilot interface without the need for additional Raspberry Pi processing.

Fig. 25 - Camera USB breakout board.

Fig. 26 - Camera USB breakout board.

V. Software Design

A. Overview

ROV Hydrozoa, in its first year, laid a solid foundation using core principles for ROV software such as modularity and flexibility through standard interfaces (Figure 27). The ROV and Pilot Interface running the robot operating system utilized a standard TCP/IP over an Ethernet network, like what we use in our day-to-day lives for the internet, to utilize the capabilities of Raspberry Pi 3B+ and Python 3. Customized information was presented to the pilot through flexible development of modules with ROS that were integrated with the pilot interface. This provided the infrastructure to allow future releases to be written to make it fully autonomous.

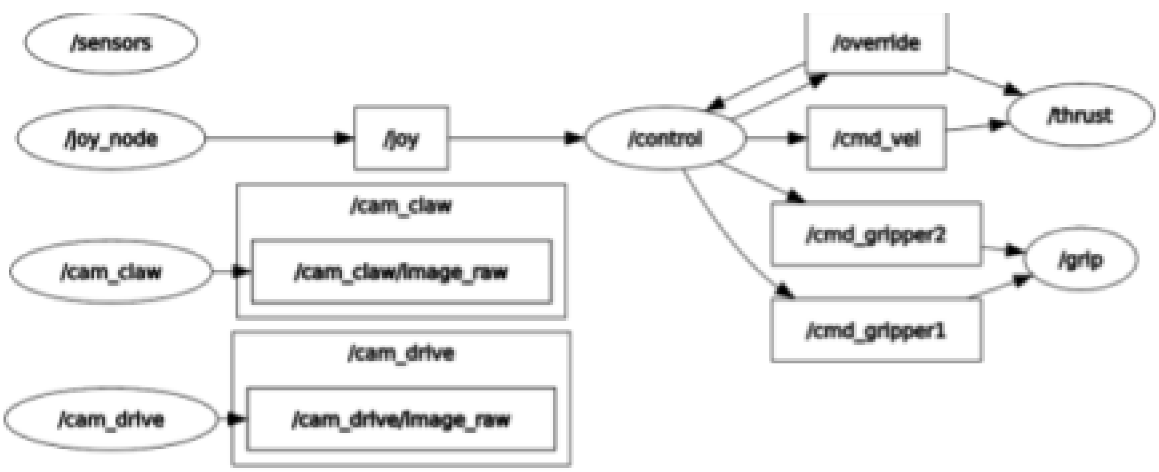


Fig. 27 - Software Flow chart.

B. Pilot Interface

ROV data and control feedback were combined in a Pilot Interface using the ROS C++ rqt_gui which was highly customizable and configurable in real-time. We wrote our own controller interface using the existing ROS joy node to utilize an Xbox 360 controller.

This Pilot Interface runs on any system running Ubuntu 20.04 and can support multiple instances of its running to allow specialists to customize their Interface for their use case (Figure 28).

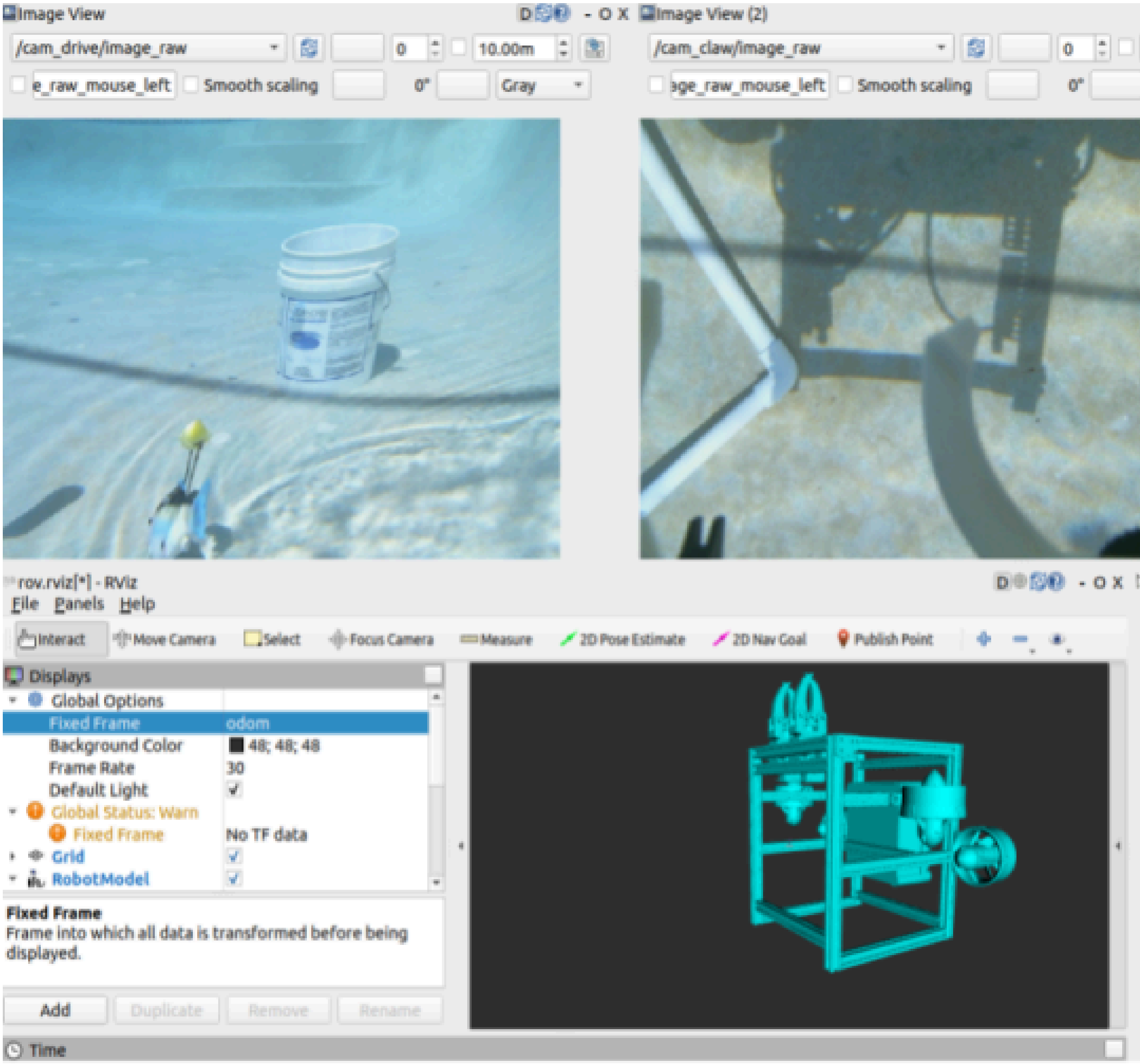


Fig. 28 - Pilot interface.

A modular design was used for components to separate front and backend systems. Cycles of development, debugging and improvement of data structures/implementations were performed.

The Python ROS nodes are executed separately to allow for isolation, robustness, aid debugging, and support code specialization & abstraction. It also supported fast iterative changes. The result was an interface that optimized user needs and provided a clean design that followed a natural flow of features. Preset movement sensitivity profiles within the interface may be selected by pilots to adapt rapidly to specific environments without the need for modification of individual values to change ROV behavior.

C.ROS

The middleware, Robot Operating System (ROS), facilitated communication between processes running on multiple systems. ROS supported modularity and communication between processes and systems. These ROS nodes were testable independently and communicated via ROS topics, the interprocess communication system. We used Third-party libraries such as adafruit files and packages for ROS that utilize solutions existing in the ROS community to solve known problems (6). This allowed the software team to focus on innovation and address challenges specific to ROV Hydrozoa.

D.Propulsion and Gripper Control

While the ROV Hydrozoa's four degrees of freedom for movement and two degrees of freedom for manipulation, low mass, and powerful thrusters were important to the robot's agile maneuverability and smooth operation, the thoughtfully designed control system maximized performance. The thruster node was directed by command velocity ”Twist” messages which contain linear & angular in all three dimensions, this was translated from the input from the pilot. The four thrusters were positioned on the frame to create a thrust envelope that prioritized control authority in yaw and thrust in X and Z directions. This resulted in an ROV that is able to surface/dive and traverse rapidly.

VI. Logistics

A. Company organization

The Cabrillo College Robotics club was in its first year of developing Hydrozoa ROV. The organizational structure was based on prior experiences of the CEO and Engineering Manager who led MATE ROV teams in high school. Three technical teams, Mechanical, Electrical, and Software, handled the technical needs of the ROV. Each team was headed by a lead or co-leads. In addition Project Management, Finance and Marketing teams provided administrative support. All leads reported directly to the CEO. Interdisciplinary project groups worked on the integration of the ROV subsystems. Engineering Integration groups formed subsystem project teams to work on the Frame and Buoyancy, Manipulators, Power enclosure, electronics, and ROS. This approach supported the communication required for complex engineering integration tasks

B. Project management

As a new company, Cabrillo College Robotics, prioritized robust project management to increase productivity and efficiencies for onboarding new members and managing teams. The design cycle had four stages, training, designing, manufacturing, and testing. The training phase onboarded all new members in relevant areas of SolidWorks CAD, ANSYS FEA, HSM Works CAM, CMAKE, Python, and GitHub use for their team. Training processes were documented and will be utilized to train returning members as needed and new members next year.

The CEO and technical leads utilized Discord, Google calendar, and GitHub scheduler to deliver project management. Gantt Charts organized deadlines and were housed in the company GitHub Repo to visualize workflows and production dependencies (Appendix D). Weekly meetings were held to help employees understand task priorities and what tasks depend on task completion. Blockers were reviewed and timelines revised to accommodate workflow revisions. For communication and meetings, we made Discord channels for all teams and subteams. Technical leads made general architecture decisions utilizing SIDs before mission tasks were announced. The design phase continued and made refinements once mission requirements were announced. Sketches and prototypes were posted to Discord channels for team discussion and revision. Weekly the company held an All Hands meeting to discuss progress and high-level planning. Due to Covid-19 restrictions, meetings were held remotely via Discord. Employees collaborated remotely during meetings and additionally met in person in small groups to finalize the design phase. Final prototypes were made and submitted for design review by company advisors. Revisions were made based on design reviews to get ready for the manufacturing phase.

System teams worked together to manufacture ROV components according to the project management plan. Essential components were prioritized and all components were manufactured to meet scheduled deadlines. Upon completion, each component was tested in isolation, then added to the system and tested in the air before being introduced to water. If a component failed it was redesigned to address problems. Once all systems passed testing, the ROV was assembled and tested. Finally, non-essential tools and software features were introduced to complete the manufacturing phase.

The testing phase of the fully assembled ROV included the addition and refinement of tools and software. Buoyancy adjustments were made as tools or other components changed. Piloting software was refined to adjust to pilot and vehicle operation needs while performing mission tasks. Mission tasks were prioritized based on success rate and time of completion to assure a high score for the mission.

C.Budgeting

During our first year competing in MATE, Cabrillo Robotics Club created a budget listing expenses and income (Appendix E). Allocations were made to the Mechanical, Electrical, and Administrative teams and adjusted as needed throughout the year so as not to exceed the total income. Expenses included materials and supplies for robot construction as well as travel expenses to the 2022 MATE competition. Income came from Cabrillo College, Inner College Council (ICC), and the Student Senate. In addition, the Club received sponsorships from companies and discounts on purchases.

VIII. Conclusion

A. Testing and Troubleshooting

In its first year of development of ROV Hydrozoa, the Cabrillo Robotics Club designed, tested, and improved fundamental ROV systems. The software was tested and improved. All electrical connections and circuit boards were continuity and functionality checked and seals were pressure tested in advance of ROV assembly. Cameras, thrusters, and grippers were tested in the air before deployment in water. When a component failed, technical documentation and testing were used to address the malfunction. Once fully functional, the ROV was deployed to execute mission tasks in the pool. To further develop components, they were tested in isolation. In some cases, simulations provided data to help optimize designs.

The Safety Checklist (see Appendix A) was followed before powering the vehicle. Control, piloting, and buoyancy were adjusted based on pool tests. Once optimized, pool tests allowed the practice of mission runs to assess difficulty and time to completion.

B. Challenges

Cabrillo Robotics Club faced many challenges this year related to COVID-19 full remote protocols. Meetings were hosted remotely on Discord. This made it difficult to engage and retain team members. College facilities such as the machine shop and fabrication laboratory were closed until Spring 2022. We adapted by prioritizing work on components that did not require direct access to College facilities. Team members used available home 3D printers and tools. Teams delivered subassemblies to private homes for testing and integration. It is inevitable to have bugs in code when there is a fresh release.Unfortunately with our late start, the testing and debugging timeline was compressed.

An additional challenge was a delay in college funding due to COVID-19 remote restrictions. This led to delays and the cancellations of funding approval meetings,further delaying the purchase of electrical components, already in short supply due to the pandemic. Due to these challenges, we were unable to obtain a backup Raspberry Pi as well as other critical components. This forced us to work around component availability with suboptimal parts.

C. Lessons Learned and Skills Gained

Cabrillo Robotics Club members learned valuable technical skills while working on ROV Hydrozoa. Teams shared knowledge and skills while working to integrate systems. The Mechanical team shared knowledge about SolidWorks, ANSYS, HSMWorks CAM, 3D printing, and machining. They also spent time learning more about theory through taking an online course on finite element analysis offered by Cornell University. The Electrical team shared experience in schematic design, soldering, and proper use of oscilloscopes. The Software team shared knowledge of Git, ROS, Linux, and Python. The administrative team provided best practices for time management, budget management, documentation, outreach, and communication.

Weekly remote meetings on Discord provided opportunities for team members to work on presentation, communication, and writing skills. Teams presented their work and received feedback from team members and advisors. Written documentation is created to list design rationale, testing data, implementation results, and plans for future improvements for all ROV components.

Outreach activities resumed in the Spring of 2022. This allowed team members to share knowledge learned with the general public and at student club recruitment events. We were invited to demonstrate the ROV to two local public schools to encourage students to study STEM (REF 7,8).

D. Future Improvements

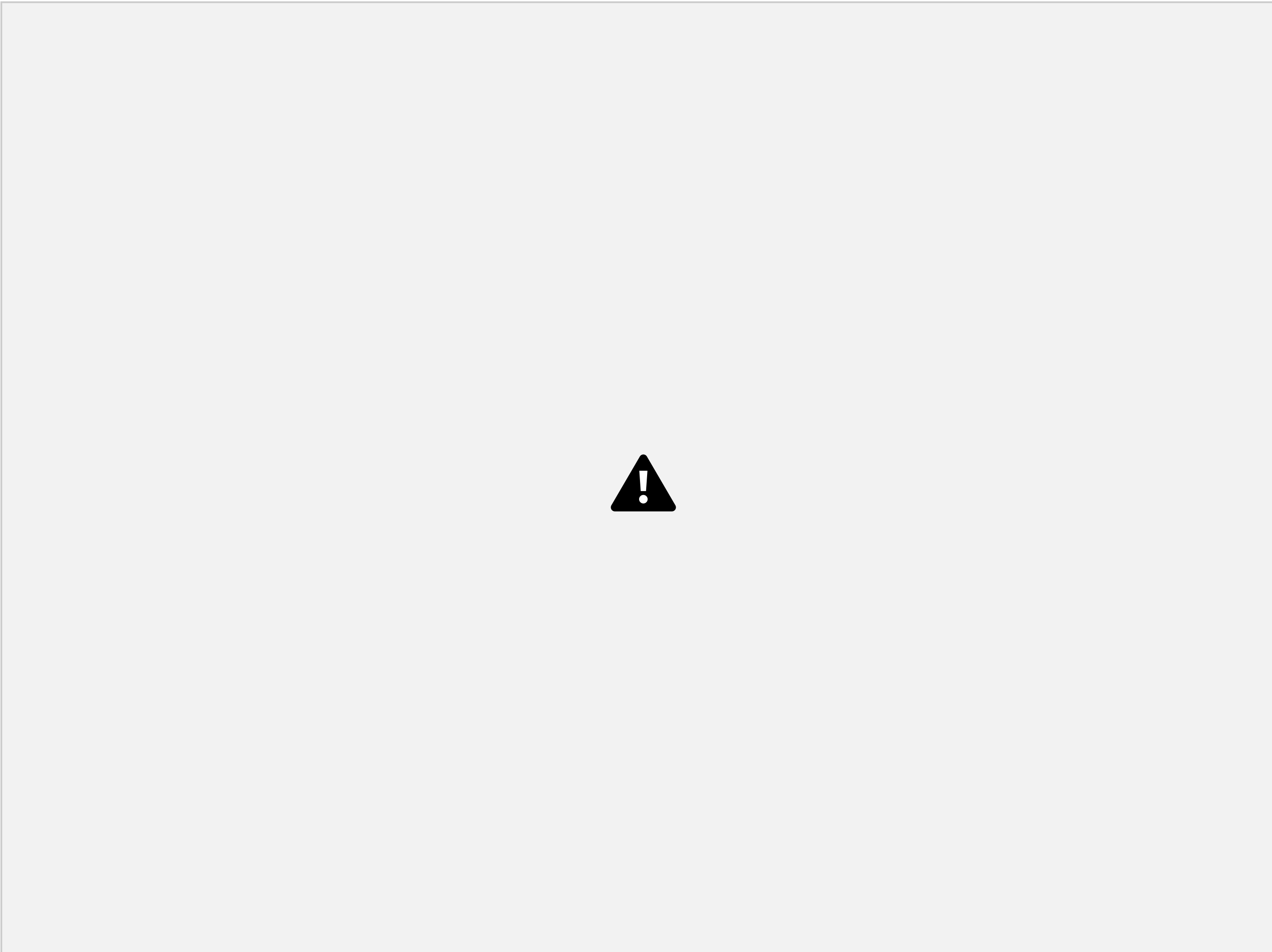
Custom Raspberry Pi Hat: The current Adafruit Raspberry Pi Hat only allowed us to carry out one task at a time. This means that we were only able to drive servo motors, not thrusters, due to the architecture of our code. In the future, we would like to design a custom Hat that will allow us to carry out more than one program at a time.

Pneumatic Grippers: Currently we are using servo motors to drive the grippers. In the future, we would like to swap to pneumatics to allow us to open and shut grippers instantly.

Custom Electrical Box: An off-the-shelf box has served us well this year, however, even better would be a custom-made box that is designed around our electronics with mounting holes and sufficient surfaces for penetrations.

E. Reflections

The last several years have brought unprecedented challenges. From pandemics to fires, floods, and budget cuts, nothing has been as it should be. However, in the face of these challenges, our team has been able to put together a capable robot to meet MATE Challenge specifications in record time on a tight budget.



IX. Appendix

A. Safety Checklist

Pre-Power

Clear the area of any obstructions

Verify power supply is OFF

Connect tether to ROV

Connect Anderson connectors of tether to power supply

Check ROV

Check Electrical Box and connector seals

Check Manipulators and other mission tools

Power Up

Pilot boots up laptop and starts

Pilot calls team to attention

Co-pilot calls out, “Power on,” and Connects

Anderson connectors of tether to power supply

ROV deployment team verifies ROV electronic status lights

ROV enters water under control of Tether management team

Tether team checks for signs of leaks

If leeks occur, go to Leak Check

Otherwise, continue the Power Up sequence

Launch

Pilot calls for launch of the ROV and starts timer

ROV tether team lets go of ROV and shout, “ROV released”

Communication if either problem occurs during the mission

Continue to ROV Retrieval if mission completed

Communication Lost

Pilot checks connections on the surface

Pilot resets ROS

Pilot cycles the power supply

If nothing succeeds, the mission stops

Pilot turns power supply off and calls out, “Power off”

ROV Retravel

Pilot informs tether team that ROV needs retrieval

Tether team pulls the ROV up from water after making contact

Deployment team yells, “ROV retrieved”

Demobilization

Pilot turns power supply off and calls out, “Power off”

Tether team ensure that ROV remains stationary in the water

ROV is neutrally buoyant

Pilot arms ROV and starts thruster test

Continue to Launch procedures if no issues arise

Leak Check

If any bubbles are spotted during a mission, the pilot quickly surfaces the vehicle

Deck crew powers off ROV and calls “power off”

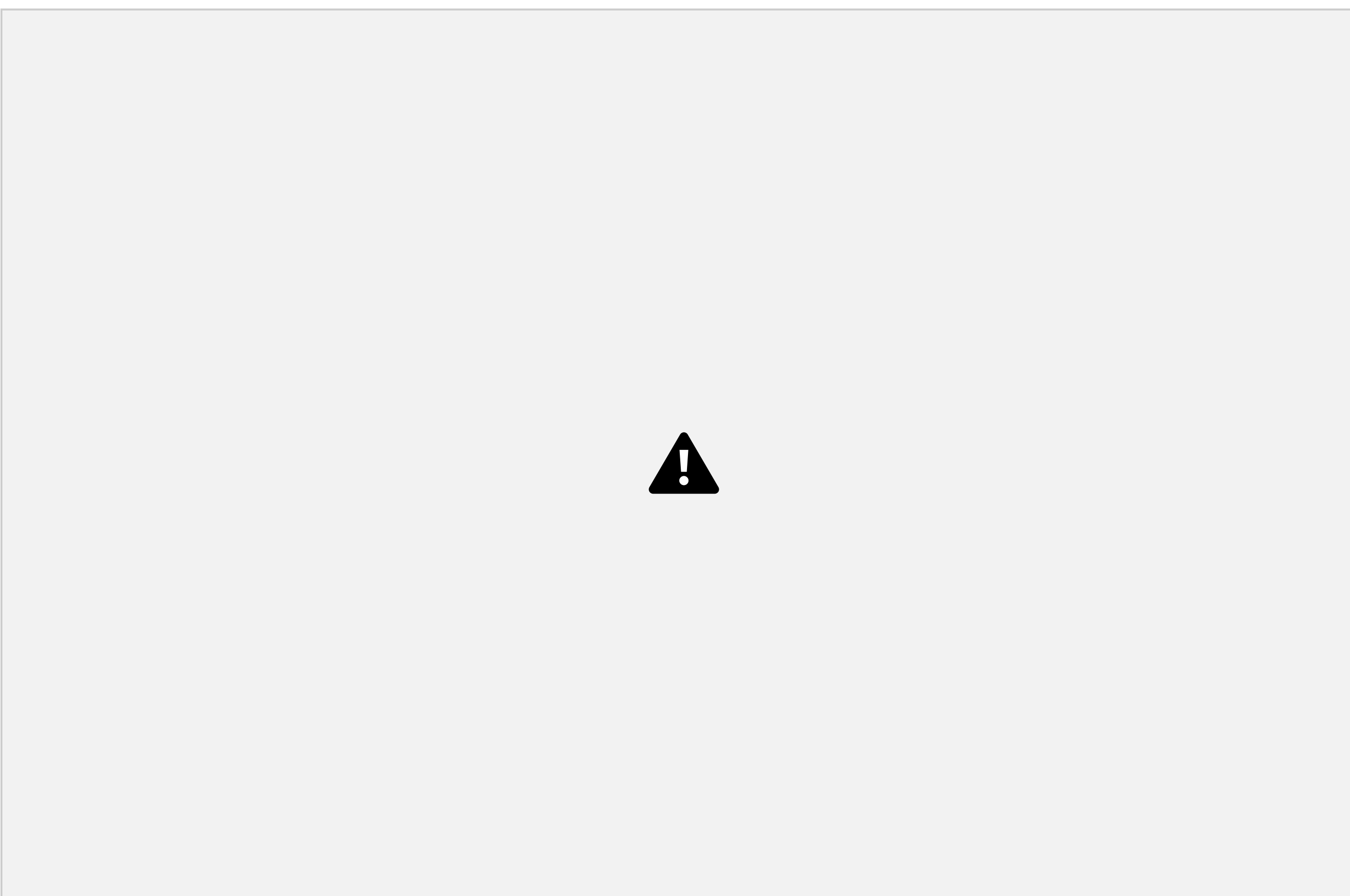
Tether team retrieves ROV

Tether team does inspection for leaks or damage on ROV

Pilot stops Controller and powers off laptop

Anderson connectors of tether are removed from power supply

B. SID



C. Profiling Float SID

D. Simplified Task List

Task Start Date End Date
Recruit Members 11/3/2021 12/7/2021
Start Electrical Design 11/12/2021 2/1/2022
Start Mechanical Design 11/12/2021 2/1/22
Start Software Design 11/15/2021 3/5/2022
Phase Two Electrical Design (Finalize designs) 2/1/2022 2/23/2022
Phase Two Mechanical Design (Finalize designs) 2/1/2022 2/15/2022
Order Electrical Components 2/20/2022 3/1/2022
Manufacturer Parts 2/15/2022 3/10/2022
Assemble ROV Frame 3/1/2022 3/15/2022
Electrical Integration and Testing/Debugging 3/5/2022 3/23/2022
Software Integration and Testing/Debugging 3/23/2022 4/18/2022
Full ROV Integration and Testing/Debugging 4/18/2022 5/1/2022
Register For Competition 3/6/2022 5/16/2022
Pool Test and Video Demo 5/1/2022 5/15/2022

Write Assigned Sections of Teach Report 3/2/2022 5/10/2022Compile and Edit Teach Report 5/10/2022 5/18/2022Finalize Teach Report 5/18/2022 5/25/2022
Write and Edit Spec Sheet 5/7/2022 5/20/2022
Write and Edit Spec Poster 5/27/2022 6/15/2022
Practice Presentation 5/26/2022 6/21/2022
Competition 6/21/2022 6/25/2022

Red Tasks are Mechanical Team Tasks

Blue Tasks are Software Team Tasks

Green Tasks are Electrical Team Tasks

Yellow Tasks are Project Management Team Tasks

Purple tasks are all Team Tasks

E. Budget

Budget Category	Item and Description Type Cost
Electrical	Wires, cables, heatshrink, waterproof connectors etc. Purchase
	Raspberry Pis, IMU, etc. Purc

	T200 Thrusters + ESCs
	Buck Converters/ Power B
	120v ac to 48v 25a power s
	XBox 360 Controls F
Mechanical	Waterproof Box Pu
	Anodizing Purchased $89.00B Purchased $123.44 Aluminum, Polycarbonate Stoc 2020 Aluminum Extrusic
	3D printer filament
	Epoxy Purcha
	Mounting Hardware (bolts, nu
	Tape and PSA Pu
	Prop Parts (PVC, corrugated p etc.) Donate

Total Expenses for ROV Construction	
General	Gas Purchased $65
	Hotels Purchased $4
	Registrations Purchased
	Food Donated $25
Total Expenses for Competing	
Income	Inner Club Console $3,
Total Cash Income for	

2021-2022			
Donations and Discounts	Cash Donations $400.00		
	Part Donations $200.00		
Total Expenses	$3,450.10		
Total Cash Income	$3,603.10		
Net Balance	$153.00		

F. Sponsors and acknowledgements

Cabrillo Robotics Thanks:

Parents, family, and friends for their support

MATE Center for Leading the 2022 Competition

MATE coordinators, judges, and volunteers

Cabrillo College Student Senate and ICC for financial support

The Kirkhart family for their pool use

G. References

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