LANCER LUMINEERS

2023

Technical Documentation

Pasadena City College
Pasadena, CA, USA
Pioneer Division

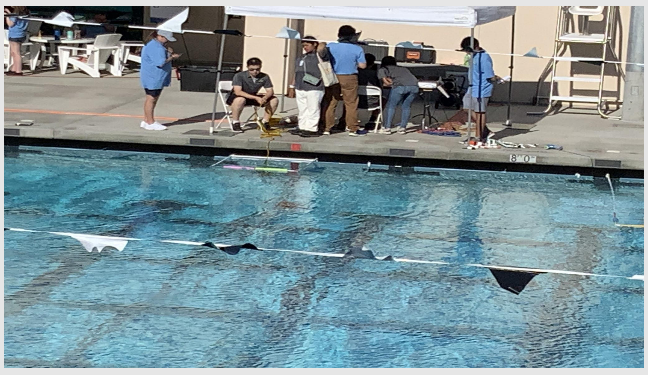
Mentors

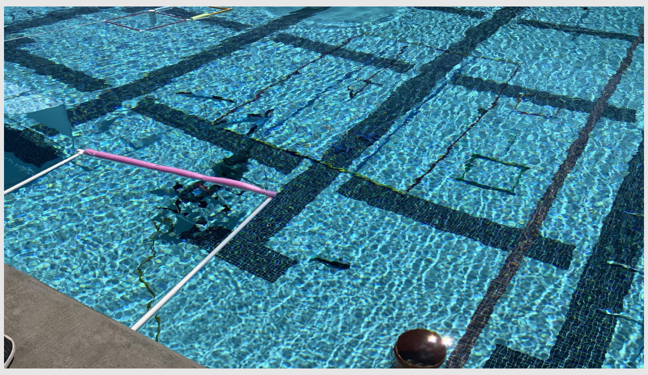
Jared Ashcroft, Yu-Chung Chang-Hou, Thomas Thoen, Doug Foster, Scott Fraser, Dave Smith, Jacob Tucker, Eamon Conklin

Member Name:	Role:	Major:
David Tao	CEO | Safety Advisor	Aerospace Engineering
Rene Nunez	CTO | Electrical Lead	Electrical Engineering
Barozh Smail	COO | Mechanical Lead	Mechanical Engineering
Jan Pastor	Software Lead	Electrical Engineering
Jocelyn Zhu	Marketing Manager	Computer Science
Martin Leung	Budget Officer	Mechanical Engineering
Frank Alas	Mechanical Engineering	Aerospace Engineering
Pete Chayapirad	Mechanical Engineer	Mechanical Engineering
Jasmine Lai	Mechanical Engineer	Mechanical Engineering
Joya Stewart	Mechanical Engineer	Mechanical Engineering
Thet Paing/David Da Na	Software Engineer	Electrical Engineering
Puthyrath/Ben Hy	Software Engineer	Mechanical Engineering
Daniel Weiss	Software Engineer	High School Mentee
Adam Ashcroft	Software Engineer	High School Mentee
Megan Ashcroft	Electrical Engineer	High School Mentee
Brycen Lee	Electrical Engineer	Electrical Engineering
Sabrina Maya	Electrical Engineer	Computer Science

Table of Contents

- Table of Contents……………………………………………………………………..……2
- Abstract..………………………………………………………………………...…………3
- Project Management……………………………………………………………………….4
  - Employee Roles
  - Company Organization and Collaborative Workspace
  - Time/Schedule Pipeline
- Safety……………………………………………………………………………..……..,.7
  - Safety Philosophy
  - Workplace Protocols
- Design Rationale…………………………………………………………………..……..9
- Vehicle Systems………………………………………………………………..………10
  - Frame
  - Electrical
  - Software
  - Control/Electrical
  - Propulsion
  - Buoyancy and Ballast
  - Testing and Troubleshooting
- Payload and Tools ………………………………………………………………………16
  - Claw
  - LED Lights
- Build vs. Buy vs. Used………………………………………………………….……..16
- System Interconnections Diagrams (SIDs)……………………………………………17
- Testing and Troubleshooting……………………………………………………………19
  - Prototyping Phase
  - Testing Phase
  - Troubleshooting and Improvements
- Budget and Cost Accounting…...………………………………………….………..22
- Media Outreach…………………………………………………………….………23
  - STEM Events
  - Social Media
- Acknowledgements…………..…………………………………………………………..24
- References………………………………………………………...…………………...25





Abstract

Formally known as the "Pasadena Care Bears," the Pasadena City College Mate ROV team this year sets its sails in constructing an all new underwater ROV. Placing 3rd place in the Mate ROV World Championship, the team has overcome previous pitfalls and rebranded itself as the "Lancer Lumineers." The ROV was designed to tackle oceanic pollution, monitor the effects of climate change, and the maintenance of a healthy aquatic ecosystem. Learning from past mistakes and forging ahead, the team built and modified an ROV kit and named it, "Hydra".

This Pioneer class ROV, has several new and improved features compared to the previous ROV model. These notable features include a high density polyethylene frame, mechanical claw, a dual camera system, and an updated controller. With these improvements, Hydra is better equipped to accomplish the tasks outlined by the RFP (Request for Proposals). These tasks include the ability to assist in the maintenance and installation of MREs (Marine Renewable Energies), help with restoration of the marine ecosystem, and promote the revitalization of damaged coral reefs.

Fig. 1 PCC's first ROV, "Pipedream"

Fig. 2 3rd Place Award for MateROV2022 World Championship

Teamwork: Project Management

Chief Executive Officer/President (CEO): David Tao
The role of the CEO assumes a crucial role in defining the project's objectives, scope, and deliverables. This position entails verifying comprehensive project plans through the utilization of tools like Gantt charts, timelines, and resource allocation. Moreover, the CEO acts as a vital link between mentors, coaches, and the faculty at PCC. They are responsible for delegating tasks, ensuring smooth project execution, and maintaining productive relationships throughout the process.

Chief Technical Officer (CTO): Rene Nunez
The CTO assists in researching new methodologies for improving ROV performance and ensuring each subteam follows the guidelines set by MATE ROV. This along with collaborating with all subteams to document construction of ROV in stages and identifying technologies and tools to be used in development of ROV

Chief Operating Officer (COO): Barozh Smail
The COO reports team progress to the CEO and tracks skill development of individual team members while suggesting team enhancements.

Marketing Manager: Jocelyn Zhu
Marketing Manager develops marketing strategies to achieve organizational objectives while implementing and managing digital marketing strategies to enhance media outreach.

Budget Officer: Martin Leung
The Budget Officer oversees financial operations of the company and identifies opportunities for cost reductions while presenting financial reports to the CEO.

Job Safety Officer: David Tao
The JSO maintains a safe and healthy work environment while conducting regular inspections of ROV and makes sure to investigate accidents and implement policies as needed.

Employee Roles

The team structure is organized into four distinct categories: mechanical, electrical, software, and marketing. Each division is assigned a designated lead responsible for guiding supporting members within each category. These leads collaborated closely with the Chief Executive Officer (CEO) to devise a comprehensive plan and timeline for the development of the ROV.

Mechanical Engineers
Are in charge of designing and constructing the mechanical portions of the ROV. Items such as the frame and waterproof canister housing fall under this jurisdiction. Other duties comprise of waterproofing of cameras and servo motors, mounting servos, cameras, electronics canister, mechanical grippers, and enclosures onto the ROV frame. Nonphysical responsibilities include modeling and researching specific components for the Hydra.

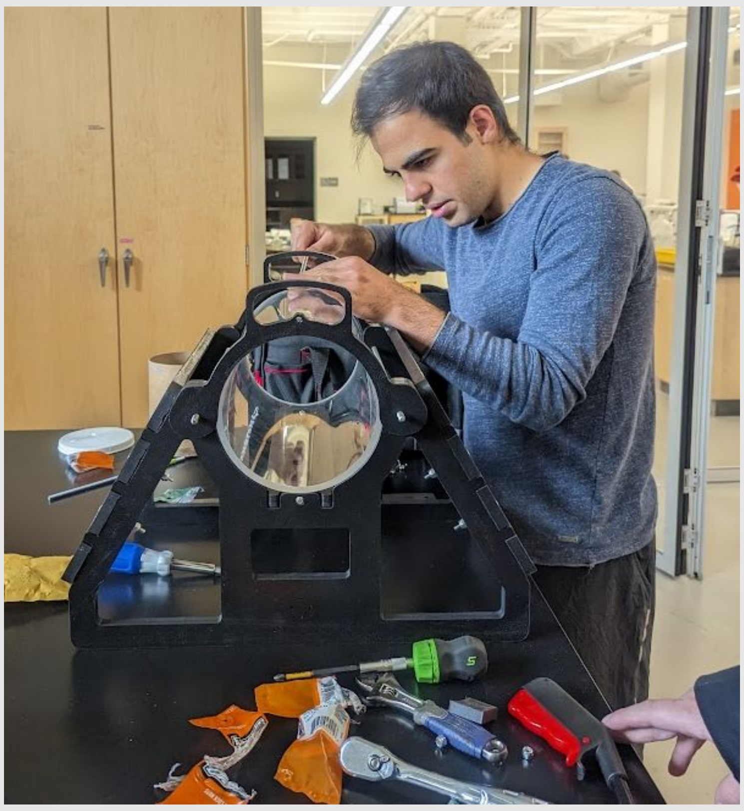


Fig 3. Mechanical engineer making measurements on HDPE frame

Electrical Engineers
Design and develop portions the electrical equipment of the ROV. Tasks include soldering electrical components onto Controller Boards and Supply Boards then ensuring proper connections and functionality. Constructing the 48 VDC Power Supply and tether for the ROV which provides reliable power and communication. Other important work includes wiring the electrical components and circuit boards together, establishing the necessary connections for seamless operation.

Fig 4. Electrical engineer soldering components onto supply board

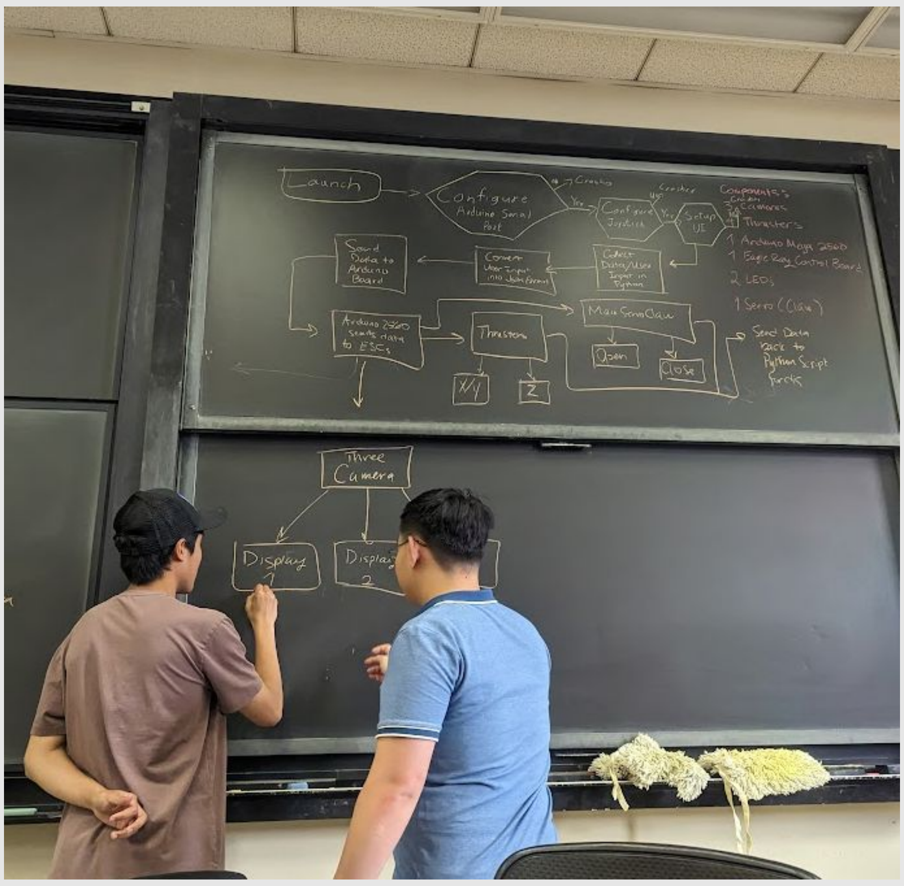


Fig 5. Software engineers creating a flow-chart to visualize ideas and structure code

Software Engineers
Write and develop code and applications that allow for all components of the Hydra to work seamlessly together. This cadre collaborates closely with the electrical engineering subteam. They primarily operate on platforms such as Arduino and Python. The subteam strives to design and code a user-friendly GUI menu as well as program the servo motors, cameras, and thrusters. Algorithms and deep learning AI models were employed to allow for object detection, object measurement and 3D modeling.

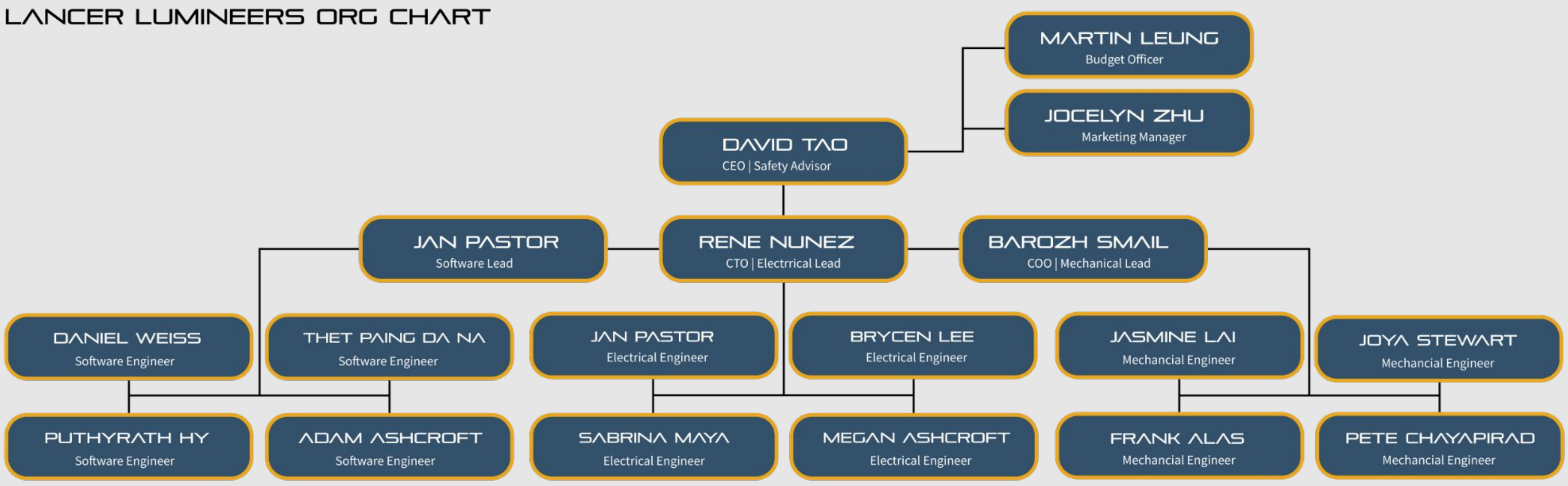


Fig 6. Lancer Lumineers Organizational Chart

Company Organization and Collaborative Workspace

The team meets every Saturday from 12 pm to 4pm to work on the Hydra. In between, additional meetings are occasionally held to address urgent matters. Primary objectives for meetings typically include tackling progress review, provide a place for idea exchange, and make collective decisions. Lancer Lumineers' discord server is the primary platform for communication outside of meeting times. Discord enables the team to virtually exchange ideas and document the ROV's progress. Team leads are responsible for recording the tasks that were completed or unfinished at the conclusion of a meeting.

Time/Schedule Pipeline

A Gantt chart is generally used as a visual tool to effectively monitor and manage weekly milestones and operations (Pg 7, Fig. 8). The chart serves multiple specific purposes, such as establishing a comprehensive timeline for the project and ensuring that critical deadlines are met. It functions by providing a detailed overview of the project's tasks, dependencies, and scheduled durations. Milestones and key deliverables are prominently marked on the chart, adding a visual reference to monitor progress. This enables the team to identify any potential delays. Project managers then use the chart to determine whether to take corrective actions, such as reallocating resources or adjusting timelines to ensure the project stays on track.

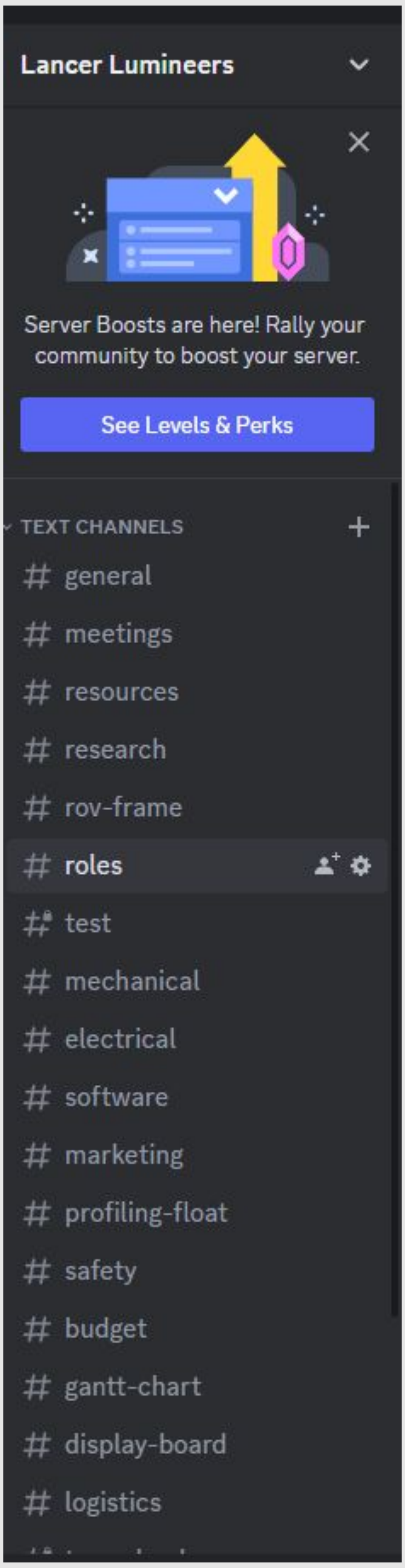


Fig 7. Team Discord server with specified channels for organization

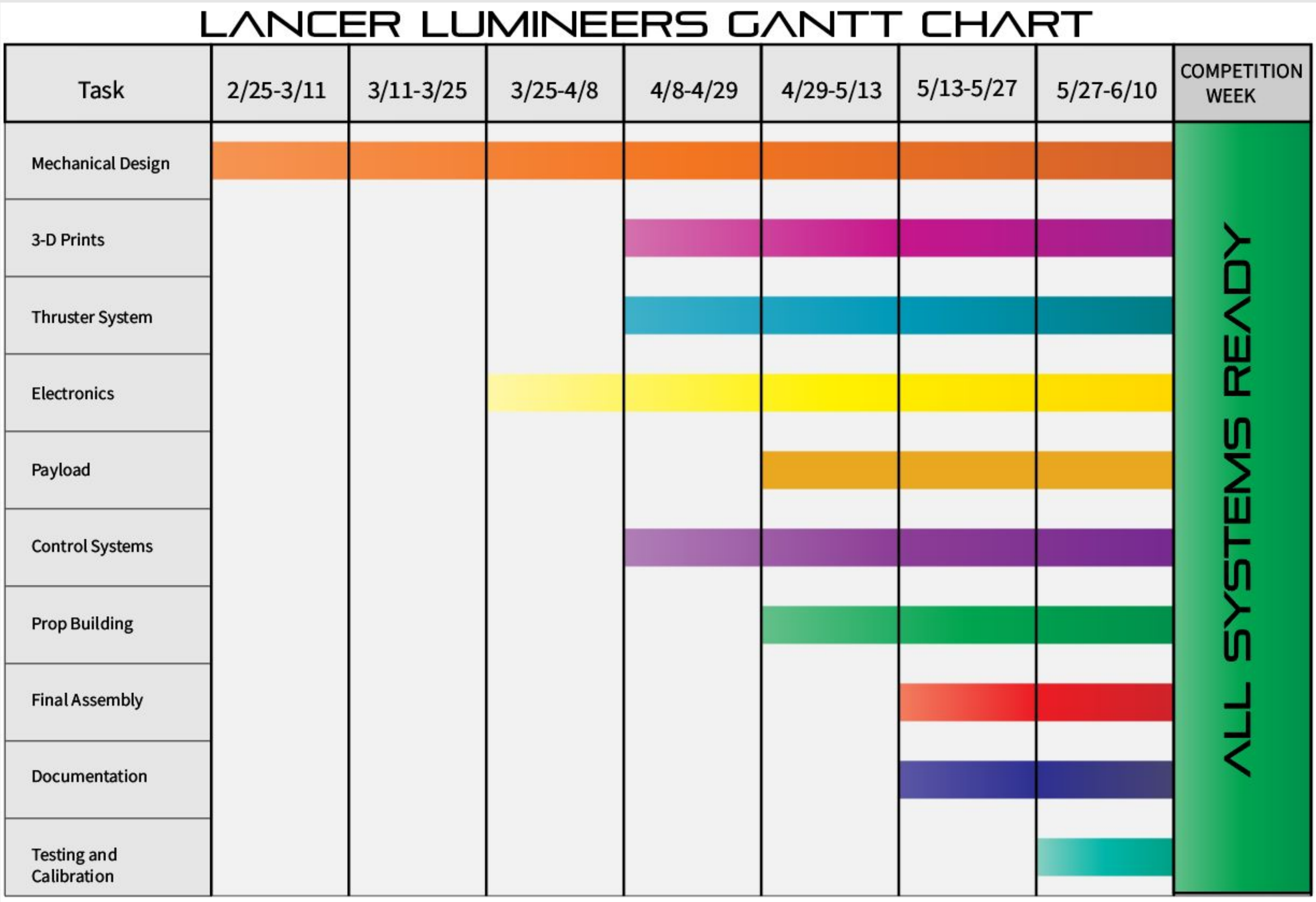


Fig. 8 Team Gantt chart used to check progress and deadlines

Safety

Safety Philosophy

Lancer Lumineers is deeply committed to upholding and surpassing the safety guidelines established by MATE. Guidelines that encompass a comprehensive framework that considers various aspects of safety, including but not limited to personal protective equipment (PPE) usage, hazard identification and mitigation, emergency preparedness, and effective communication protocols. The team uses Job Safety Analysis (JSA) forms for employees to create and review before performing risky operations.

Workplace Protocols

Lancer Lumineers strictly adheres to a comprehensive safety checklist derived from various safety handbooks for the building and handling of Hydra to ensure safety in the workplace. The team is dedicated first and foremost to the safety and wellbeing of its employees, mentors, and mentees.

The checklist covers various aspects:

Workplace Safety: The team maintains clear and unobstructed areas, minimizing tripping hazards and any obstacles that may impede operations.

Electrical Work Precautions: Prior to engaging in any electrical work, the team confirms that all power switches and circuit breakers on the power supply are switched off.

Tether Security: Before entering the water, the team ensures that the tether, which connects the ROV to the control unit, is properly secured and equipped with a strain relief mechanism, guaranteeing its stability during operation.

Waterproofing Measures: Verifying that all electronic housings are tightly sealed to prevent water ingress via tests such as the vacuum test, safeguarding the internal components from damage or malfunction.

Component Inspection: A visual inspection is conducted on all electronic components to identify any signs of damaged wires or loose connections, enabling timely repairs or replacements to maintain optimal functionality and safety.

Fastener Validation: The team confirms that all fasteners, such as screws and bolts, are securely tightened to prevent unintended detachment, ensuring structural integrity during operation.

Thruster Assessment: Thorough checks are performed to ensure that the ROV's thrusters are free from any obstructions, guaranteeing their unrestricted movement and efficient propulsion.

Vacuum Testing: The team conducts a vacuum test on the electronics canister using the prescribed procedure. The test ensures that the vacuum level remains constant within a specified timeframe. Additionally, the team verifies that the vacuum check port is securely capped to maintain the integrity of the system.

Fig. 9 Members wear PPE to prevent injuries

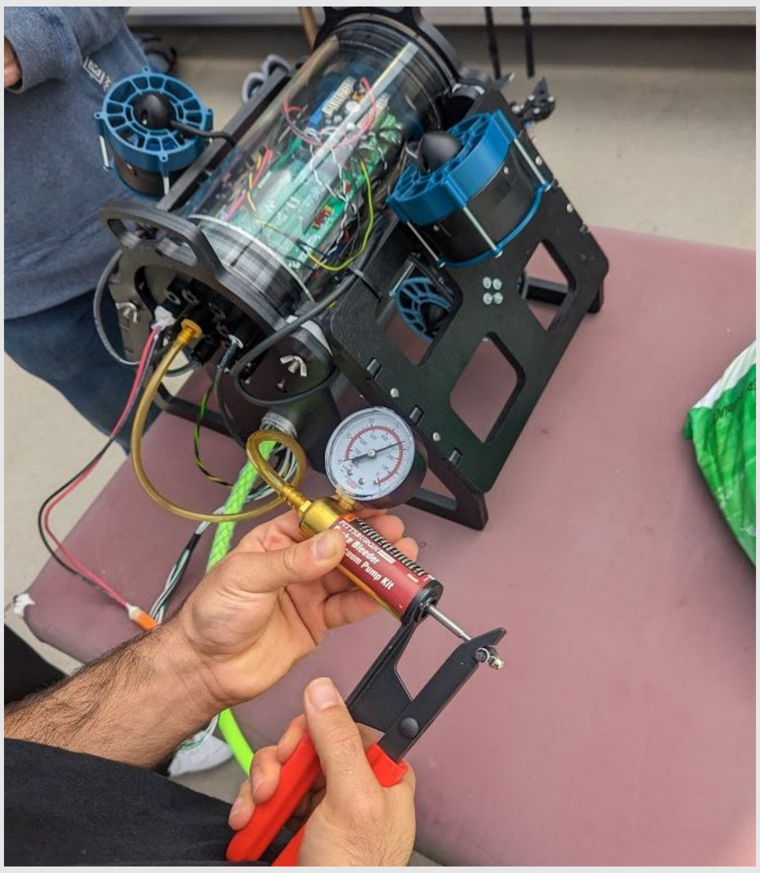


Fig. 10 Vacuum test verification before ROV is submerged in water

Design Rationale

Planning Process

In 2022, the team constructed an ROV using the MATE ROV Barracuda kit. Notable features include a foundational PVC pipe structure, four thrusters encased in a custom-cut mesh wire screen for proper fit and protection, and a shovel-like tool designed to retrieve objects from the pool floor (Image on Pg. 3). Recognizing the limitations of these features, the team set out to build the second generation ROV, Hydra, from a Eagle Ray inspired kit. Upgrades were implemented based on potential areas of improvements from the previous generation's ROV and requirements for this year's MATE ROV competition. From there the team identified key goals and specific challenges needed to execute during the competition to construct ideas for innovating Hydra.

Fig. 11 Lancer Lumineers visit LBCC to get inspired by ROV designs

Design Process

Lancer Lumineers built Hydra from scratch using a kit inspired by the Eagle Ray design. The kit was supplemented with parts procured from various companies and parts designed by the team. Designed parts were fabricated at Pasadena City College's Fabrication and Machine Shop (Fablab). The team received generous support from Professor Jacob Tucker, who provided aluminum mounting plates, Professor Eamon Conklin, who inspected and printed the 3D components; and Professor Thomas Thoen, who provided access to the electronics lab and spare parts and specialized equipment.

The team made the frame out of High Density Polyethylene (HDPE), a material that shares the same density as water. This allows the ROV's frame to achieve near neutral buoyancy without significant weight modifications. The ROV's retrieval capabilities were enhanced with the innovation of a 5-volt claw capable of securely holding objects weighing up to 25kg. To assist in maneuverability, the Hydra ROV incorporates four T200 thrusters obtained from Blue Robotics. Two of these thrusters are positioned on the outer frame to control vertical thrust, while the other two are located within the skeleton of the frame to enable horizontal and/or translational movement.

Vehicle Systems

Frame

In the process of selecting a suitable material for the frame of Hydra, an investigation was conducted focusing on the key aspects of durability, machinability, and stability. Following careful consideration of these requirements, High Density Polyethylene (HDPE) was chosen for characteristics, including corrosion resistance, easy maintenance, simple detachment of all components on the frame. Moreover, HDPE exhibits a density comparable to that of water, rendering it neutrally buoyant. The frame was constructed using Computer Numerical Control (CNC) technology, ensuring precise fabrication. Solid portions within the partially hollow frame introduced added rigidity and stability within the structure. As a naturally light material HDPE provides for efficiencies in weight meaning the structure need less supports and in general less weight to sink for the ballast system. Less weight also means easy storage and transportation. For disassembly, the bolts holding the frame together are made of common sizes of screws meaning the Hydra can be disassembled using common equipment. Sharper points on the structure can cause damage to people and equipment, so in the interest of increased safety in not only the workplace but also of the delicate marine ecosystem the frame of the ROV only has rounded edges.

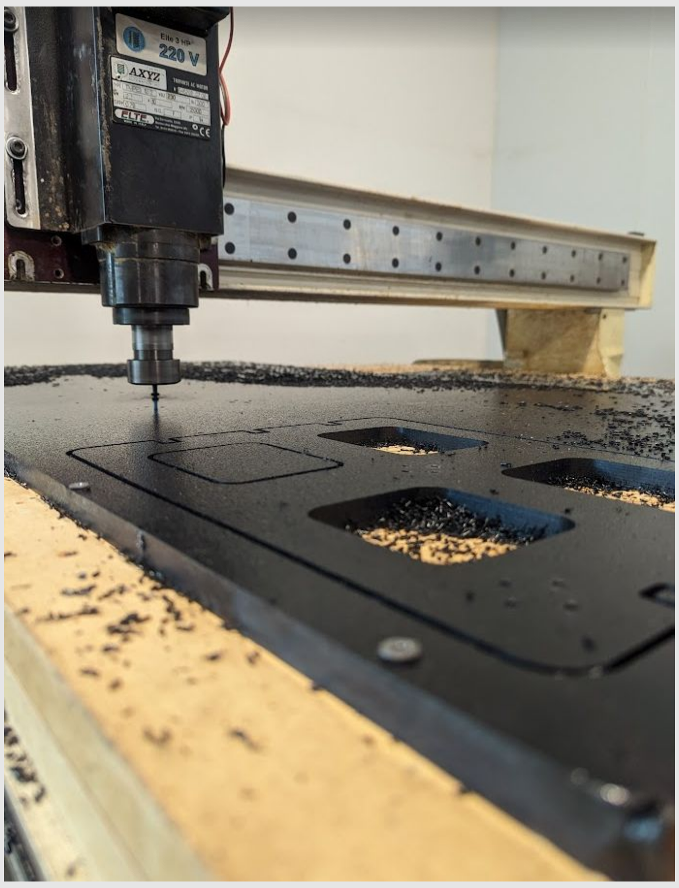


Fig. 12 High Density Polyethylene frame made with CNC machine for a precise cut

Fig. 13 HDPE frame assembled

Canister

At the center of the frame houses the cylindrical piston seal pressure can made of clear acrylic which houses the electrical components. This canister is used to withstand external pressure while ensuring consistently lower air pressure in the interior to protect the contained items. O rings were specifically chosen as a static seal due to the low cost and easy replaceability. This type of seal allows for proper waterproofing of everything while the penetrators going through one end of the canister lets electric cables be brought in from the outside. The flat metal card cage attached to an end cap for stability and housing all the components in the canister. This portion of the canister can be pulled out resulting in easy disassembly and servicing.

Electrical

The electrical systems used in the ROV consist of several electronic components designed and provided by MATE as well as employees of Lancer Lumineers. These components include the Eagle Ray Control Board, the ESCs (Electronic Speed Controllers), supply boards, DC converters, and passive electronic devices. These electronics are housed in a secure and waterproof cylindrical enclosure for the ROV to protect from water damage. The topside electronics remaining outside of the pool include a laptop, Xbox controller, and the battery enclosure. These components interfaces, controls the functions of, and provides power to the Hydra. Connecting both the upper and lower electrical systems is a ten meter long tether system that supplies power and data to the ROV.

Fig. 14 Acrylic canister housing the electrical components

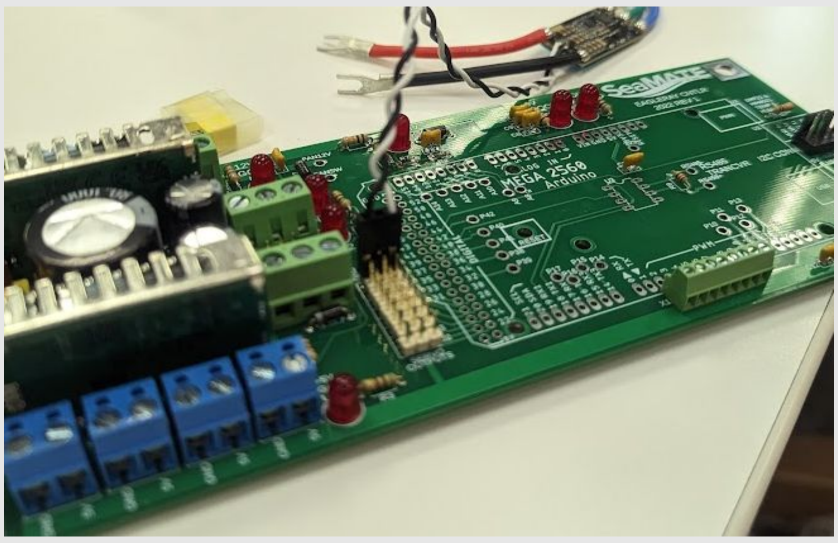


Fig. 15 Image of the control board

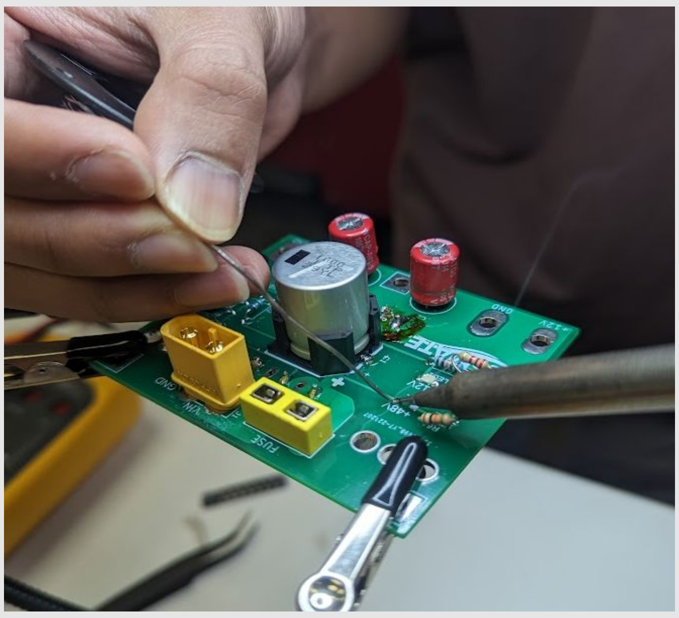


Fig. 16 Surface mount resistors getting soldered onto supply board

Software System

Arduino and Python Programming

For 2023, MATE provided code in both LabView and Python/Arduino for thruster control. The software engineers opted for the latter due to their familiarity with Python and previous experience with Arduino projects.

Software Architecture

Software engineers conducted the brainstorming process by illustrating rough sketches of the software hierarchy that would ultimately control the Hydra. This made it easier for the engineers to discuss and ask questions about specific portions of the code. A high-level view of the step-wise process can be seen in the figure to the right. This helped the software team to refactor the initial code provided by MATE with innovative features and bug fixes.

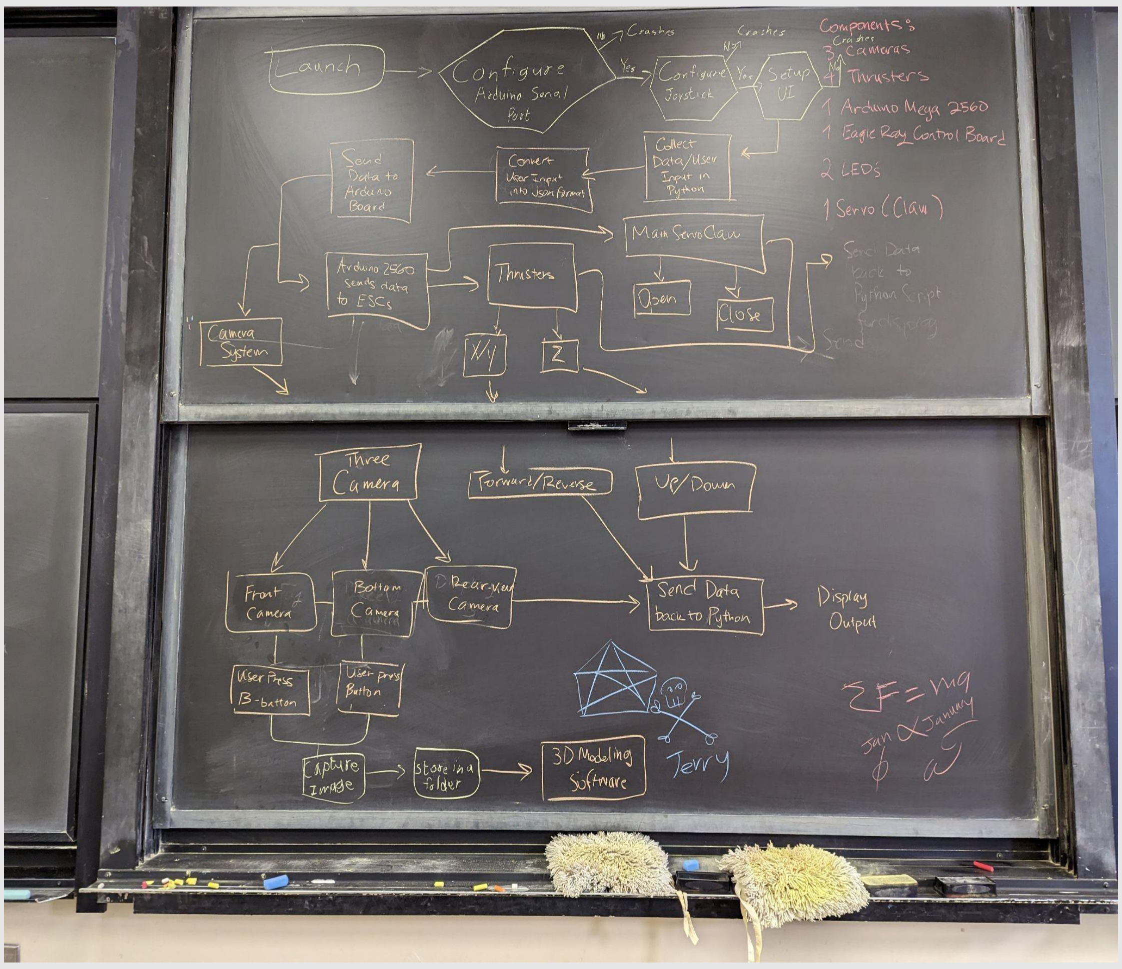


Fig. 17 Rough Draft of Software Flowchart and miscellaneous programming ideas.

Fig. 18 Controlling the ROV with an Xbox Controller using the analog joystick

The initial code provided by MATE was found lacking crucial features such as claw functionality, GUI ease-of-use, and camera vision systems. In response to this, the software engineers decided a comprehensive overhaul of the code would be required. In the early stages of Hydra's development, pool-side test runs were conducted to test the ROV controls without the aforementioned features. The test run confirmed that the provided code was well optimized in handling the ROV controls underwater (Fig. 17). The software team then implemented additional features into the existing code structure to prepare the ROV, Hydra, for competition.

Software System

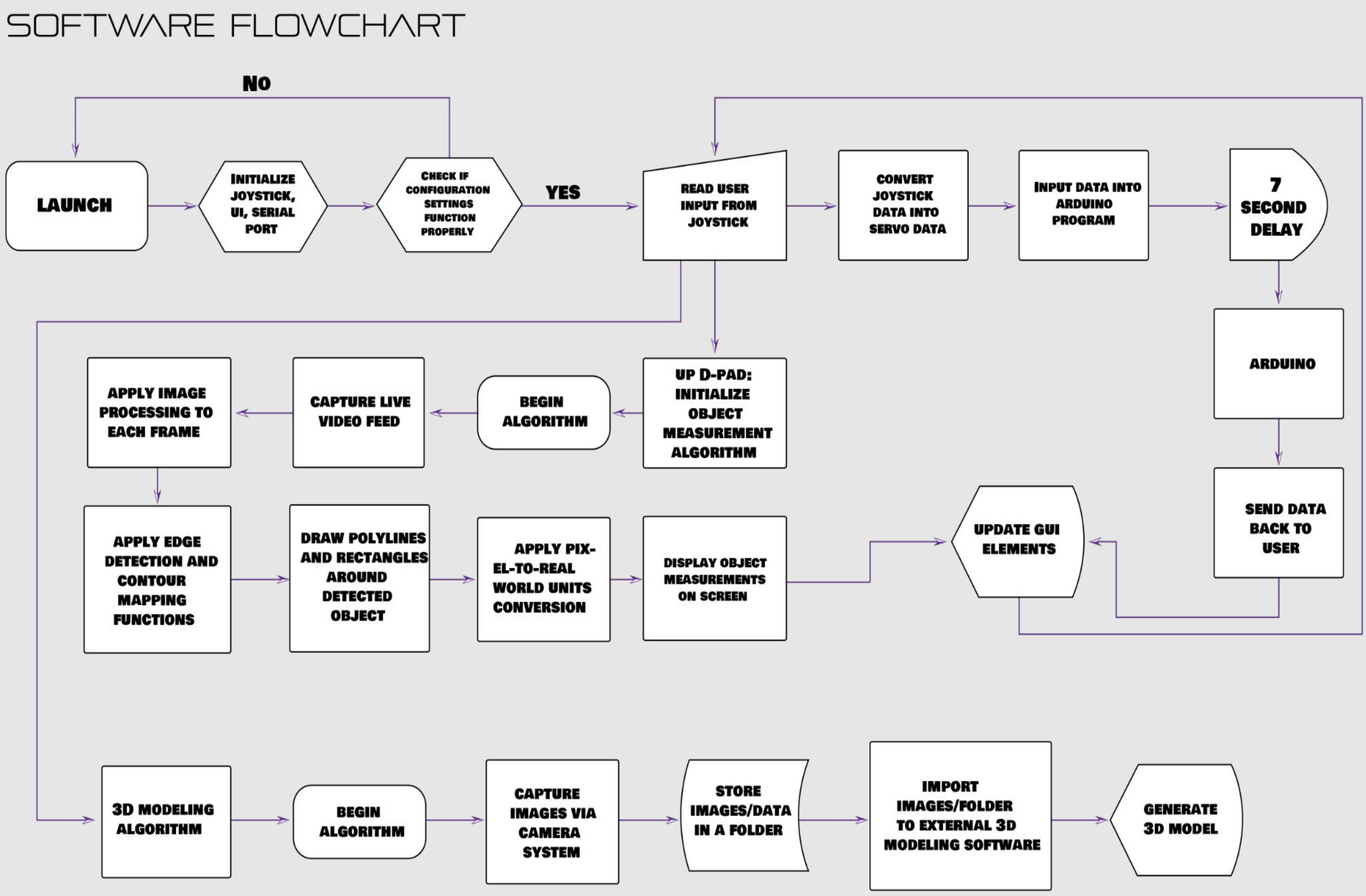


Fig. 19 An overview of the interconnecting software systems for the Hydra

The simplicity of the software flowchart above undermines its complexity. The Hydra's software system contains not only the basic operating functions needed for the ROV to be controlled smoothly by its operator, but it comes with a sleuth of additional software features that further expand its range of capabilities. Most notable of these features is an object detection and object measurement algorithm as well as a 3D modeling script specifically coded to tackle Task 2 for the 2023 MATE competition.

Propulsion System

Hydra's propulsion system features four off-the-shelf T200 thrusters from Blue Robotics. Operating at 12 volts, these thrusters utilize a brushless motor design with encapsulated windings for enhanced water protection and durability. The thruster body, made of robust polycarbonate plastic, provides structural strength, impact resistance, and wear resistance. With its waterproof design, the thruster eliminates the need for shaft seals and enables pressure tolerance for underwater conditions at various depths. The powerful thrust capacity allows Hydra to navigate, maneuver, and perform tasks efficiently. Thus, it was an obvious choice for Lancer Lumineers to buy these thrusters recommended by MATE ROV. In order to comply with safety the mechanical engineers designed a guard to prevent any accidental appendage injury.

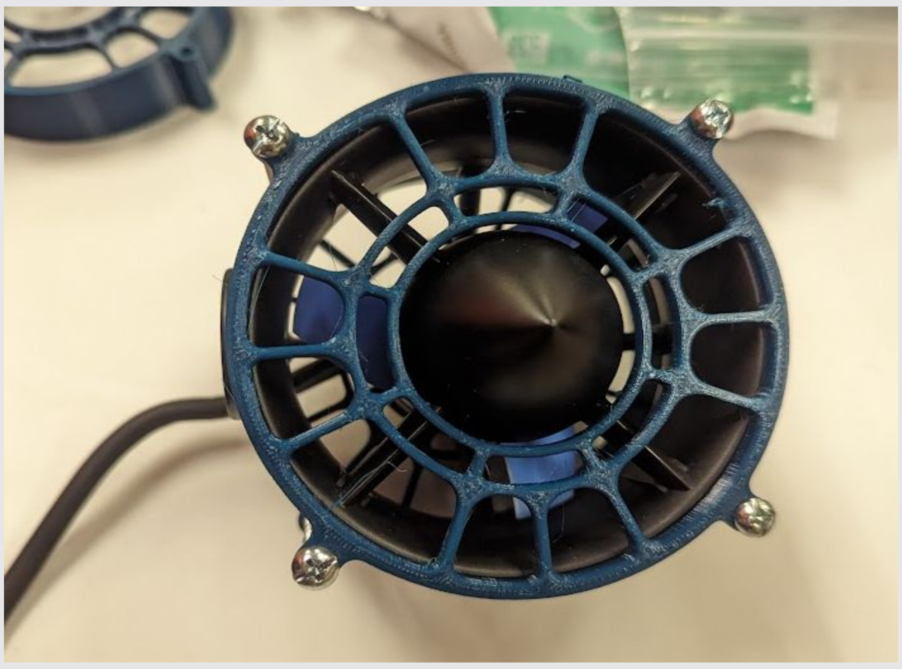


Fig. 20 Front-view of the T200 thruster with the custom 3D printer shroud

Fig. 21. Original T-200 Thruster purchased from Blue Robotics

Brushless vs. Brush Motors

Opting for a brushless motor design offers several advantages over a brushed motor. Firstly, brushless motors are known for their higher efficiency, converting electrical energy into mechanical energy more effectively, resulting in reduced power losses and increased overall system efficiency. Additionally, brushless motors have a longer lifespan since they lack brushes that wear out over time, making them more durable and reliable in the long run. Furthermore, the motors provide higher power density, allowing for more power output in a compact size. While brushless motors do come with a higher upfront cost and require more complex control systems, these drawbacks are often outweighed by the benefits they offer in terms of efficiency, longevity, and power output, making them a preferred choice for applications that prioritize performance and reliability.

Technical Analysis of Propulsion System

Constraints are a blessing in disguise. Lancer Lumineers quickly realized that the provided Eagle Ray Control Kit can only supply a nominal 12 V to the ESCs that come with the purchased T-200 Blue Robotics Thrusters. Therefore this puts an upper threshold for the amount of thrust that can be generated given the operating voltage. Although the team could have maximized the potential use of these thrusters, there was no demonstrable need to do so. Instead the team consulted the technical specifications and performance charts provided by Blue Robotics to gain a better understanding of the operating limits for these thrusters.

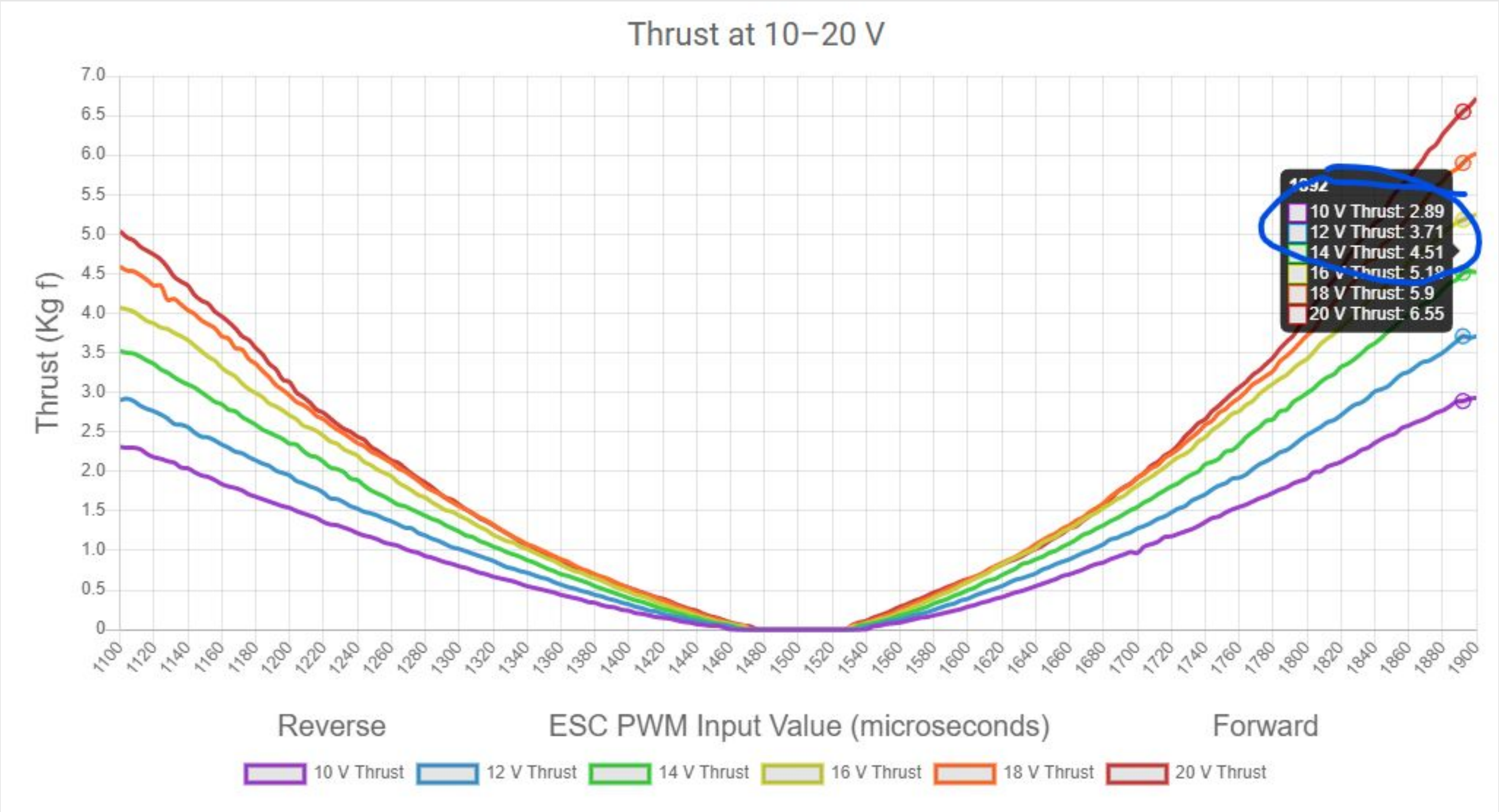


Figure 22: Table from Blue Robotics of T200 Thrust vs. ESC PWM Input Value at 10-20V

The figure above describes the total amount of thrust generated by a single thruster specifically at 12V. At maximum throttle, a single T-200 thruster is capable of generating around 3.71 kg f (kilogram force) where 1 kg f is roughly equivalent to 2.20 lb-f (pound-force). With four thrusters, total thrust generated is 14.84 kg f or about 32.64 lb-f. The total weight of the ROV is 10.5 kg or 23.15 lbs (in air), therefore actual lifting force of the Hydra is around 9.565 lb or 42.547 Newtons. The mechanical engineers found this to be adequate for tackling mission objectives outlined in the MATE 2023 Pioneer manual.

Buoyancy and Ballast

Lancer Lumineers chose a static ballast system consisting of PVC pipes filled with sand. Meaning that the weight and floatation is preset with the vehicle being slightly positive when there is no change in thrust. The roles of diving and surfacing will be placed with the thrusters. With the canister itself providing floatation, the only part of the ballast system that required alteration was the weight system. Through testing in a pool, it was discovered the amount of weight required to maintain a neutral buoyancy in the water was approximately 1.5 kg. Both steel and the PVC pipe with sand was considered, with the PVC system being chosen due to steel being much more expensive and corrosive.

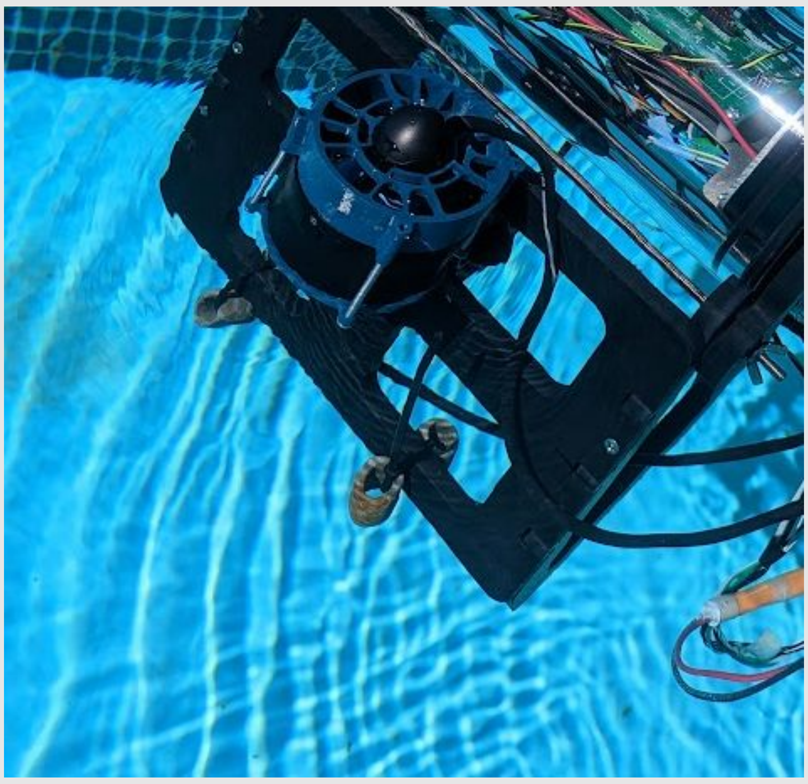


Fig. 23 Testing the ROV with temporary fishing weights to achieve neutral buoyancy

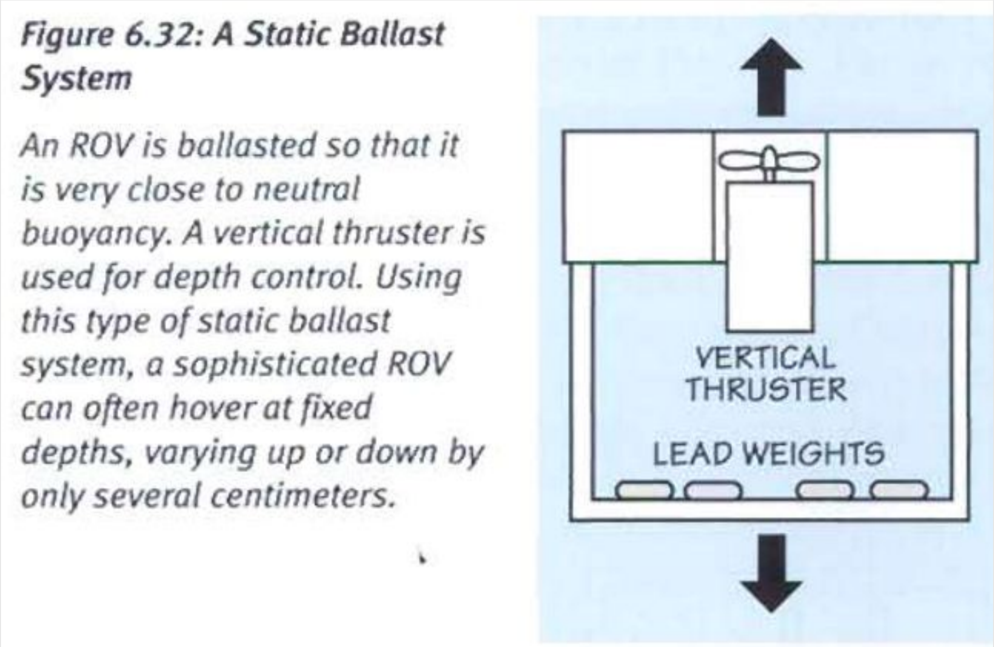


Fig. 24 Static Ballast System Figure

Thruster Placement

According to *Underwater Robotics: Science, Design, and Fabrication,* the optimal placement of four thrusters on an ROV is near the center of the frame. In this configuration, two thrusters are positioned facing forward but near the bottom sides of the ROV chassis. This placement helps in achieving efficient forward and backward movement while maintaining stability. Additionally, the vertical thrusters are placed closer to the upper sides of the ROV, nearer to its center of mass. This arrangement aids in effective vertical maneuverability, allowing the ROV to ascend and descend smoothly. By placing the thrusters in this manner, with consideration for the center of mass, the ROV can maintain balance, stability, and maneuverability in different directions.

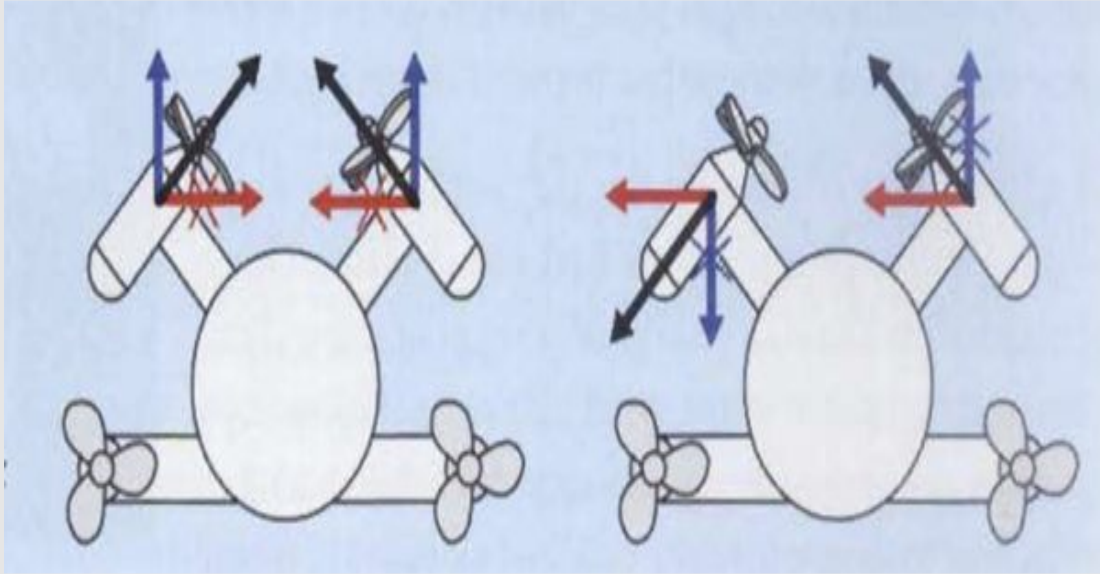


Fig. 25 Diagram of Vectored Thrust

Payload and Tools

The most important payloads found on the Hydra are the mechanical claw, the camera and LED lights. The mechanical claw design was created using files of pre-existing claw designs and altered to become mechanical via a servo motor attached to the claws. Resulting in better grip and control of the claw in the case the task required demanded finer movements and delicate handling. The camera and lights are among the most important payload/ tools on the Hydra. These tools allow for the team to see what is going on near the ROV, allowing for more precise movement than if the team were to maneuver the vehicle using only the view from one angle above the ROV.

Build vs. Buy vs. Used

The Lancer Lumineers committed to optimizing the cost efficiency of ROV expenses for this year's competition. To plan for the expenditure, the team sought advice from the mentors regarding budget and cost efficiency of ROV components. The decision to omit the second generation ROV from competing in case the situation of failed functionality was also taken into consideration. To address this issue, the team maintained the original structure of the first generation rover and decided not to repurpose its equipment as an alternative option. Despite this precautionary measure, the Lancer Lumineers focused on constructing a more efficient and improved second generation ROV.

Fig. 26 pair of 5V LED used for ROV

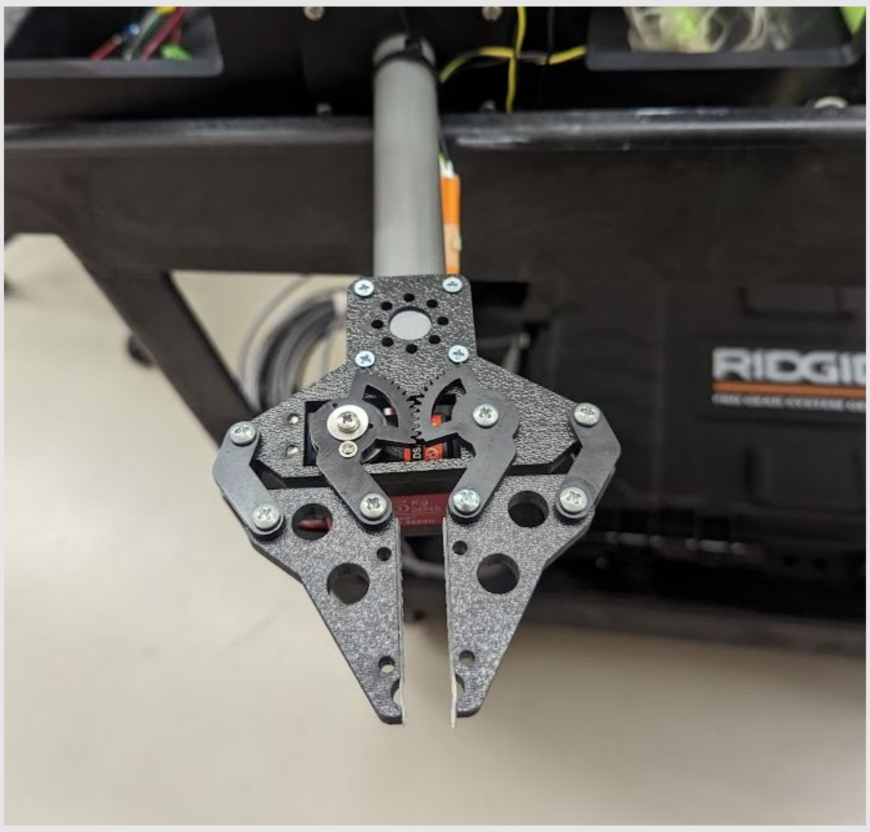


Fig. 27 Mechanical claw with 5V servo motor

System Interconnection Diagrams (SID)

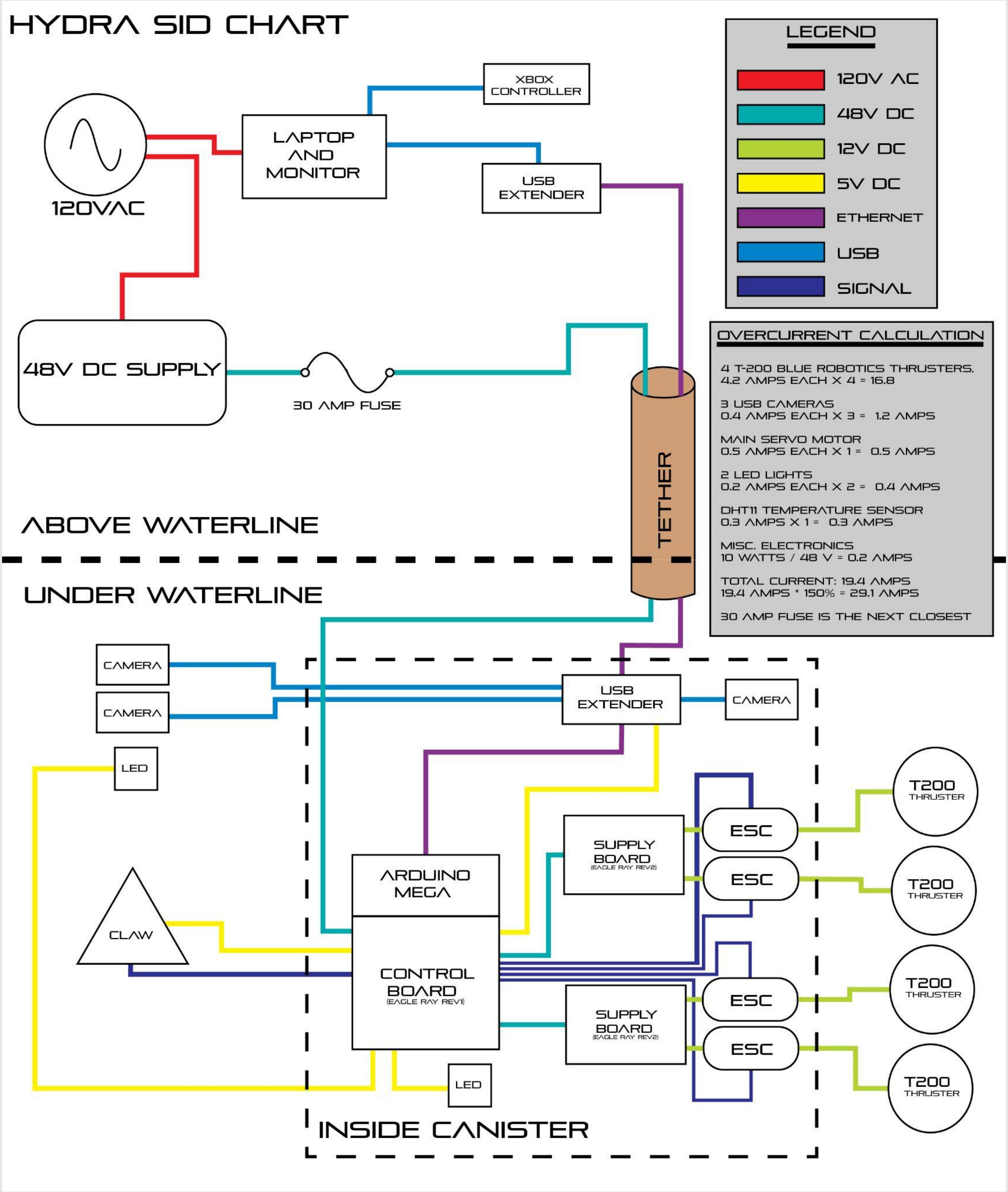


Fig. 28 SID Chart

Troubleshooting

Prototyping Phase

Before wide-scale application, it was essential that prototypes were developed and thoroughly tested for feasibility, functionality, and performance. The engineers understood that discrete and step-wise improvements to the Hydra can streamline the ROV's development.

Fig. 29 Software and Mechanical engineers prototype gripper functionality.

The left figure is one such example of engineers from different sub-teams collaborating on the claw functionality via physical calibration and testing newly implemented gripper code. The Eagle Ray Control board can be seen powered by a PSU Bench-tester and connected components such as the joystick controller and the main servo claw.
Design. Improve. Iterate.

The figure on the right shows the first version of a waterproofed servo for the mechanical gripper in the earliest stages of the Hydra's development.The claw was submerged in a 400 ml glass beaker half-filled with water. It was later discovered that this claw was not actually fully waterproof despite being marketed otherwise. This flaw was caught during later tests. It serves as a reminder that sometimes the prototyping techniques employed may not readily catch errors that are not immediately apparent.

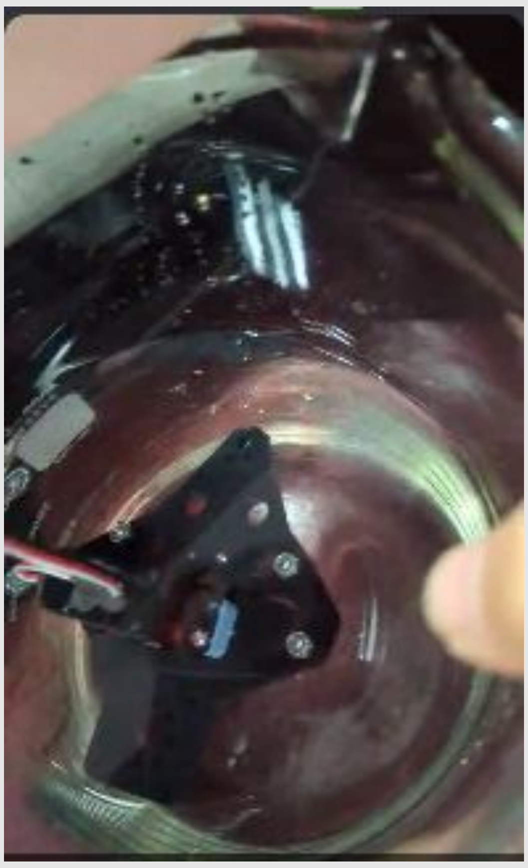


Fig. 30 Water-proof test for first servo-claw.

Fig. 31 Early prototype of thruster guards

The figure on the left is an early prototype of the thruster guards. The engineers believed it to be sufficiently safe for handling and for preventing injury during operation of the thrusters. Later tests have exposed a serious design flaw to the thruster guards. The wide gaps in the design allowed for debris and prop material to enter the thrusters and cause the propellers to stall.

Testing Phase

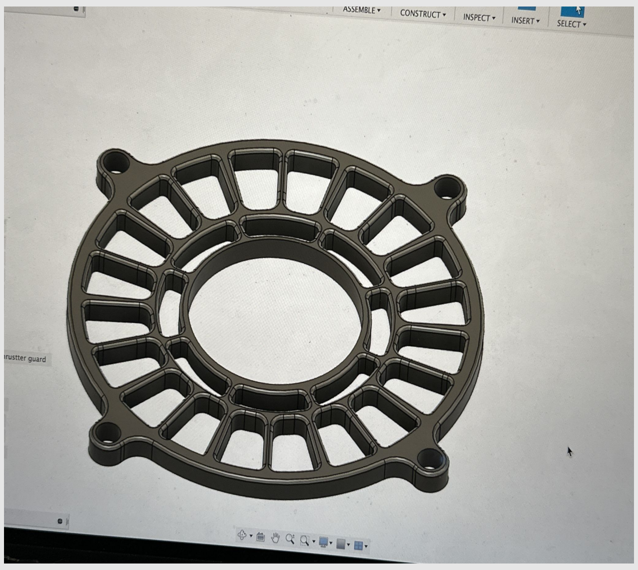
From theory to application, tests are a necessary aspect of engineering. With tests, earlier design prototypes either excelled for their intended purpose or contained serious design flaws that demanded revision. Lancer Lumineers conducted thorough tests on individual components prior to complete assembly to minimize risk of damaging systems and reduce reiteration time.

The figure on the right shows a completed Eagle Ray Control Board with all the necessary passive components, DC-to-DC converters, and Arduino Mega 2560 (bottom of PCB). Several on board LEDs turned on once the board received 24V from a PSU bench tester. A multimeter was used to validate connections and test for any short-circuits in the system. Fortunately, the Electrical Sub-team were consummate in their soldering skills to assemble the kit without any initial problems.

Fig. 32 Electrical test after. All systems green.

Fig. 33 Thruster guards failure. Redesign required.

In the left figure, immediately after attempting Task 1, Hydra's propellers were stalled when string was suctioned through the thruster guards during ROV operation. The pilot could no longer move the ROV forward and backward. Mechanical engineers quickly returned to prototyping a new thruster guard to prevent this issue from occuring again.



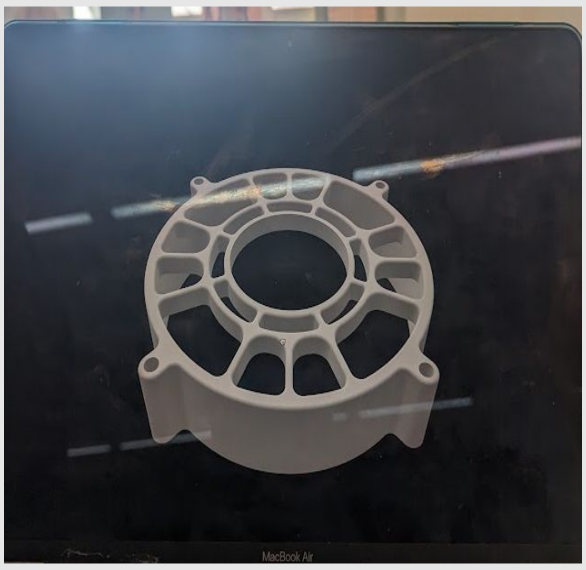


Fig. 34 New thruster guards (Left) vs. Old design (Right).

Design. Improve. Iterate.

The figures on the left show the Mechanical engineers designing iterative improvements upon an existing design to be 3D printed. The new thruster guards now have gaps that are 12 mm wide.

Troubleshooting and Improvements

For most challenges, the team:

- Sought inspiration from previous MATE ROV team tech documents.
- Engaged esteemed professors knowledgeable in the relevant fields.
- Employed a collaborative and democratic approach using a team-wide vote.
- Divide and conquer approach. Larger tasks were broken down into manageable chunks that were completed in a timely manner.

Solution to Water Resistant Servo Motor:

An example of a larger scale issue was realizing the "water-proof" servo motor was not actually waterproof. To fix this, the team JB-welded the top and bottom of the motor. To maintain the balance between the internal and external pressure underwater the team injected olive oil into the motor via a method found on YouTube. This method proves to be effective after extensive testing.

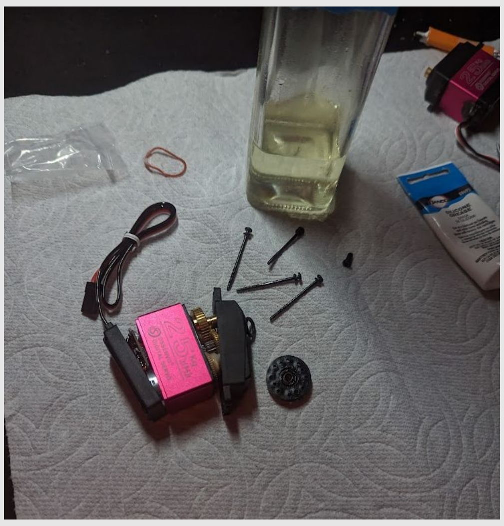


Figure 35: Use of JB-weld and olive oil

Figure 36: Waterproofed Servo Motor

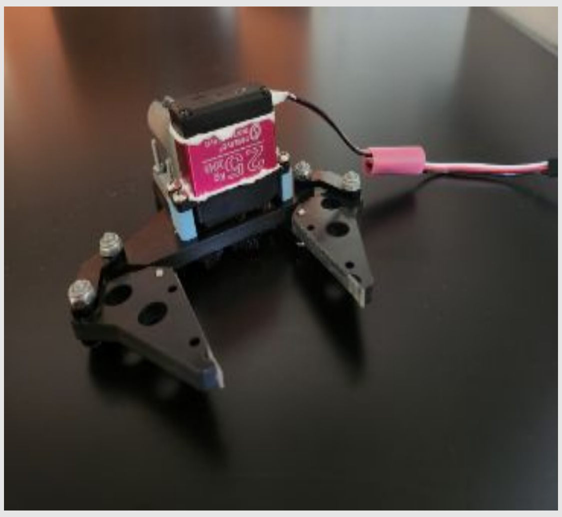


Figure 37: Waterproofed Servo Motor with claw assembly

Solution to Vacuum Test:

The final verification test of Hydra ROV required checking the seals of the ROV to ensure that it was waterproof and conducting a pressure test. Initial procedure included pressurizing the canister to 3 psi and due to the pressure slowly decreasing in the system, there was an air leakage. In an attempt to locate the leak, soapy water was sprayed on the seals to check for bubbles. Subsequently it was placed in the pool to check for the origin of the air leak. Only after this test was it discovered that the culprit was the loosely insulated ethernet-cable (top-side tether). To resolve this, epoxy was placed to properly seal the tether.

Figure 38. Air escaping from main canister through the top-side end of the ethernet cable.

Budget and Cost Accounting

Below is the Lancer Lumineers budget for this year's competition. A sizable $70,000 budget was provided through grants from the Micro Nano Tech and MATE ROV National Science Foundation, and Pasadena City College McKenzie Scott programs to purchase the necessary equipment, supplies, and cover for travel expenses.

Income				
Source				**Amount**
NSF: MATE ROV				$20,000
NSF: MNT-EC				$10,000
PCC: McKenzie Scott				$40,000
Expenses				
Category	**Type**	**Description/Examples**	**Projected Costs**	**Budgeted Value**
Chasis	Purchased	HDPE, 6" enclosure, end caps, aluminum sheet	$450	$422.37
Electronics	Purchased	Thrusters, Servos, Tether, Board Components, Controller, Camera, Power Supply, Fuses	$2,320	$2,226.92
Payload	Purchased	Manipulators, LEDs	$60	$60
Equipment/Tools	Purchased	Vacuum Pump, Potting Kit, Crimper, Grease, Epoxy	$225	$381.15
Travel	Purchased	Hotel, Flight, Food	$10,000	$16,951.14
Prop Building	Re-Used/Donated	PVY Pipes	$100	$0
General	Purchased	Marketing, Packaging Material	$200	$200
			Total Income	$70,000
			Total Expenses	$20,241.58
			Total Fundraising Needed	$0

Fig. 39 Budget Sheet

Qty	**Blue Robotics Items**	
4	Blue Robotics T200 Thruster w/ Penetrator	$ 600.00
4	Blue Robotics Basic ESC Speed Controller	$ 144.00
1	Blue Robotics 6 inch Enclosure with clear acrylic end cap	$ 327.00
8	Blank Penetrators (M10 thread)	$ 8.00
2	Potted Cable Penetrator, M10 thread for 8mm cable	$ 6.00
1	Blue Robotics Potting Kit	$ 10.00
1	Blue Robotics Hex Key Set	$ 6.00
1	Outland Tether	$ 150.00
	Amazon	
1	Tool: RJ-45 crimper with	$ 17.99
1	Silicone grease tube	$ 4.28
1	Envirotex Lite (potting Cable Seal Fixture)	$ 18.81
1	1/2-inch HDPE sheet, 4 ft x 2 ft	$ 72.38
1	Threaded rods with wing nuts	$ 15.99
1	Wing nuts for threaded rod	$ 11.88
	Mouser	
1	Anderson Powerpole Connector	$ 3.00
4	Anderson PP Lug	$ 12.00
1	Littelfuse Holder	$ 80.00
3	Littelfuse	$ 7.00
1	Tool: Hand vacuum pump - From Tool Discounter	$ 79.18
1	Marine grade epoxy - From Home Depot	$ 8.28
1	Bottomside strain relief - Kellums - From Zoro	$ 37.68
1	Arduino Mega 2560 Rev3 — Arduino Online Shop	$ 62.00
1	USB Hub for Camera	$ 59.99
1	USB Camera	$ 64.99

Qty	DigiKey	
4	CF14JT10K0 Stackpole Electronics Inc | Resistors	$0.40
5	CF14JT1K50 Stackpole Electronics Inc | Resistors	$0.50
4	CF14JT510R Stackpole Electronics Inc | Resistors	$0.40
1	ERA-8APB1332V Panasonic Electronic Components | Resistors	$1.02
1	RNCF1206BKC698R Stackpole Electronics Inc | Resistors	$0.49
1	CFM14JT120R Stackpole Electronics Inc | Resistors	$0.10
10	TLHR6401 Vishay Semiconductor Opto Division | Optoelectronics	$3.21
4	SR2010-TP Micro Commercial Co | Discrete Semiconductor Products	$1.76
1	80MXG1000MEFCSN20X25 Rubycon | Capacitors	$3.71
2	16PK2200MEFC10X20 Rubycon | Capacitors	$1.44
10	SR201E104MAA KYOCERA AVX | Capacitors	$2.18
1	C320C103K1R5TA KEMET | Capacitors	$0.24
1	1718563004 Molex | Connectors, Interconnects	$1.74
10	BG301-03-A-0540-L-B GCT | Connectors, Interconnects	$4.73
1	OSTVN08A150 On Shore Technology Inc. | Connectors, Interconnects	$2.38
5	TC0323620000G Amphenol Anytek | Connectors, Interconnects	$3.65
4	EBA-02-D-BU-01 Adam Tech | Connectors, Interconnects	$2.72
1	3568-20 Keystone Electronics | Circuit Protection	$1.19
1	L7809ABD2T-TR STMicroelectronics | Integrated Circuits (ICs)	$1.15
3	IRF7809AVTRPBF Infineon Technologies | Discrete Semiconductor Products	$4.74
2	RNF14FTD1K13 Stackpole Electronics Inc | Resistors	$0.20
2	RNMF14FTC51K0 Stackpole Electronics Inc | Resistors	$0.20
4	RNF14FTD20K0 Stackpole Electronics Inc | Resistors	$0.40
2	RNF14FTD100K Stackpole Electronics Inc | Resistors	$0.20
2	EEE-TP1J102V Panasonic Electronic Components | Capacitors	$9.26
4	860020375017 Würth Elektronik | Capacitors	$1.72
2	CL32B105KBHNNNE Samsung Electro-Mechanics | Capacitors	$0.46
2	3568-20 Keystone Electronics | Circuit Protection	$2.38
2	ZVN4206AVSTZ Diodes Incorporated | Discrete Semiconductor Products	$1.50
4	302-HDS/03 WECO Electrical Connectors Inc. | Connectors, Interconnects	$5.52

Qty	Power Supply	
1	Switching Power Supplies 2016W 48V 42A	$515.00
1	Heavy Duty Power Connectors SBS50 PANEL MOUNT BRKT (2/SET)	$ 15.30
1	Heavy Duty Power Connectors SBS50 2P HOUSING ONLY, BLUE	$ 6.57
4	Heavy Duty Power Connectors SBS50 #10-12 AWG LOW DETENT CONTACT	$ 9.48
1	Circuit Breakers 30A TOGGLE ACTUATOR	$ 35.89
1	LED Panel Mount Indicators Green 9.1mm Metal Panel Mnt Ind	$ 17.67
1	LED Panel Mount Indicators PMI 22mm LED 120V Wire Red MS	$ 13.15
1	AC Power Cords 10' GRAY/GRAY PLUG 3 X 12 AWG HOSP	$ 27.74
1	AC Power Entry Modules 1P 20A w/ circ break Embossed I/O mark	$ 41.72
1	22 in. Pro Organizer, Black	$ 39.98
1	Charge-Discharge Monitor, DROK 0-90V 100A DC Ammeter Voltmeter	$ 32.99
	Other items	
65 cm	10-gauge power wire from Powerwerx	$ 24.09
3 ft	Angle Aluminum	$22.99
	Screws	
30 cm	12/3 Electrical Wire	$ 39.49
8	Terminal Rings	$ 8.99
8	Female Spade Connectors Yellow	$ 10.99
1	Wire Battery Cable Lug Terminal Crimper Crimping Tool with 9 Dies	$ 45.90
1	Insulated Wire Terminals Connectors Ratcheting Crimper Tool for 22-10AWG	$ 16.62
1	IRWIN VISE-GRIP Wire Stripper, Self-Adjusting, 8-Inch (2078300)	$ 24.98
	Non-Digikey Board Components	
1	NID100-12 - MEAN WELL - TRC Electronics	$ 15.71
1	NID100-5 MEAN WELL | Mouser	$ 18.45
2	I7A4W033A033V-0C1-R TDK-Lambda Americas Inc | Power Supplies	$180.70

Fig. 40 MATE ROV Equipment and Supplies Budget

Media Outreach

STEM Events

The team actively engaged with the community by participating in multiple STEM events, where they demonstrated the construction of the ROV and promoted the team's goals. On March 14, 2023, seven team members participated in the Pi-Day event at Pasadena City College. This event, aimed at promoting math learning, featured representatives from Caltech, JPL, and other notable institutions. The team also took part in a STEM event called STEM SAVVY on March 25th at Pasadena City College. This event focused on inspiring middle school girls to pursue careers in STEM. The team participated in the events by creating posters to actively promote the ROV and Environmental, Social, and Governance (ESG) issues. They promoted environmental awareness by highlighting ROV project's purpose: to assist in fixing underwater systems for marine renewable energy.

Fig. 41 Showcasing ROV project and ESG issues to other students

Fig. 42 Team poster display used for STEM events

Social Media

Promoting public engagement and interest, the team took the initiative to create an Instagram page to effectively showcase their achievements to a wider audience. By leveraging the popular Instagram platform, the team was able to establish connections and stay updated with other ROV teams participating in the MATE ROV competition. This not only enhanced their public presence but also facilitated networking opportunities and the potential for increased support from the community. The Instagram page served as a powerful tool for the team to engage with a larger audience, share their progress, and foster a sense of community within the ROV community at large.

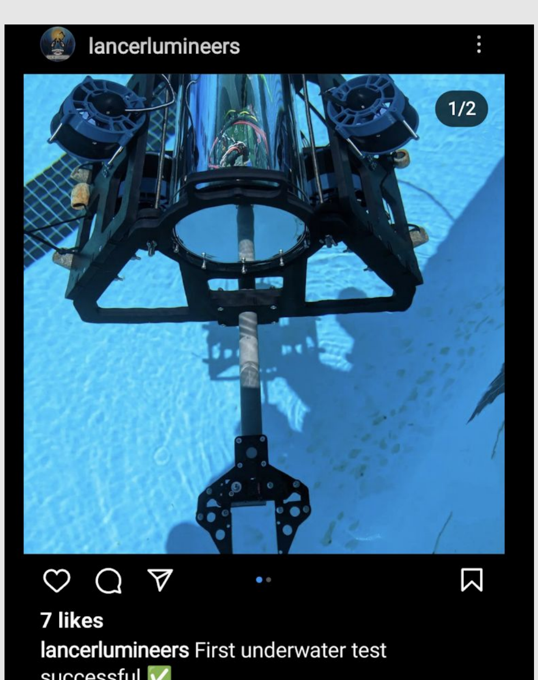


Fig. 43 Instagram post of Hydra in water

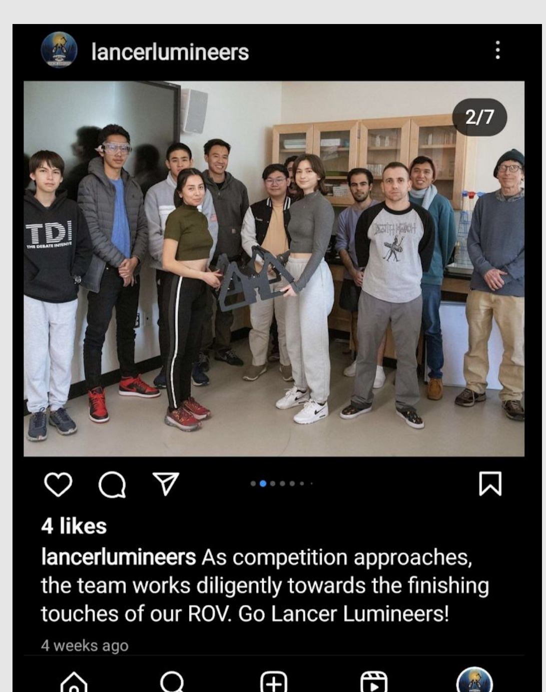


Fig. 44 Instagram post of team members

Acknowledgements

The team would like to acknowledge the contributions of the mentors and sponsors who have made the progress of this project possible. The Lancer Lumineers would like to thank Micro Nano Technology Education Center NSF Award # 2000281, the Community College MATE ROV NSF Award #2031249, and the McKenzie Scott Foundation for their sponsorship towards the cost of Lancer Lumineer team activities. The team also expresses much gratitude towards mentors Doug Foster, Professor Thomas Thoen, Professor Dave Smith, Dr. Yu-Chung Chang-Hou, Professor Eamon Conklin, Professor Jacob Tucker, Professor Scott Fraser, and Professor Jared Ashcroft for their guidance and contributions.

The team thanks Doug Foster for the advice he provided the team from his previous experience in the MATE ROV competition and contribution towards building the rover during weekly meetings. The Hydra Team extends its gratitude towards the professors of Pasadena City College: Professor Thomas Thoen, who helped inspect electrical components and established the cost efficiency of purchasing equipment within the designated budget; Professor Dave Smith, who coordinated software development of the ROV and provided advice on improvements and revision; Dr. Yu-Chung Chang-Hou, who supervised weekly team meetings and helped with media outreach for social events; Professor Eamon Conklin, who aided the 3D printing process of essential components of the ROV; and Professor Jacob Tucker, who provided the team access to his machine shop and aided the construction of the rover's aluminum mount and mounting plate. The team also thanks Professor Scott Fraser from Long Beach City College for helping CNC the HDPE frame and designing Eagle Ray kit for competition participants. Lastly, the Lancer Lumineers is deeply grateful to team coordinator Professor Jared Ashcroft organizing the team and overseeing communication between MATE ROV and the ROV team in preparation for competition.

Fig. 45 Goodie bags to show appreciation to all of the mentors

References

1. “Mate Rov Competition Website.” *MATE ROV Competition Website*, materovcompetition.org/.
2. “Store.” *Blue Robotics*, 23 Jan. 2020, bluerobotics.com/store/.
3. “The 17 Goals | Sustainable Development.” *United Nations*, sdgs.un.org/goals. Accessed 8 May 2023.
4. Bai, Y., Hu, R., Bi, Y., Liu, C., Zeng, Z., & Lian, L. (2022). Design and Depth Control of a Buoyancy-Driven Profiling Float. *Sensors*, *22*(7), 2505. https://doi.org/10.3390/s22072505
5. Blue Robotics. (2020, January 23). *Blue Robotics Store for Marine Robotics Components and Systems*. https://bluerobotics.com/store/
6. Blue Robotics. (2022, July 19). *Blue Robotics Tutorial: Vacuum Testing the Enclosures on a BlueROV2* [Video]. YouTube. https://www.youtube.com/watch?v=3_aok75rA5U
7. Fenlon, W. (2023). How to use any Xbox controller on PC. *Pcgamer*. https://www.pcgamer.com/xbox-one-controller-on-pc/
8. *MATE ROV Competition Website*. (n.d.). https://materovcompetition.org/
9. *Mechanical principles part 03*. (n.d.). YouTube. https://youtube.com/watch?v=YM2O3TufUlY&feature=share
10. Moore, S. W., Bohm, H., & Jensen, V. (2010). *Underwater Robotics: Science, Design & Fabrication*.
11. RCSubGuy. (2019, September 23). *How to make a TRUE waterproof servo!* [Video]. YouTube. https://www.youtube.com/watch?v=iSKlw3ZUEwU
12. *Safety Management - Hazard Identification and Assessment | Occupational Safety and Health Administration*. (n.d.). https://www.osha.gov/safety-management/hazard-Identification
13. *Shops and Trades | Office of Environment, Health & Safety*. (n.d.). https://ehs.berkeley.edu/shops-and-trades