Lancer Lumineers Technical Documentation

MATE ROV 2024

Pasadena City College | Pasadena, CA, USA | Explorer Division

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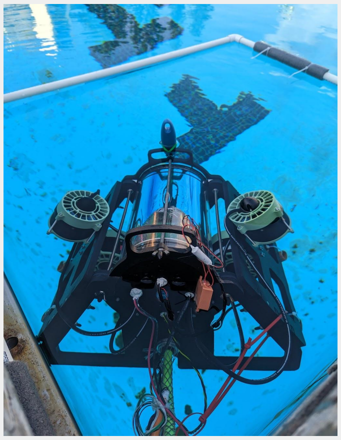
Abstract

Formerly known as the “Pasadena Care Bears,” the Pasadena City College MATE ROV team has undergone a significant engineering journey since its formation in 2021. In 2023, the team rebranded itself as the “Lancer Lumineers” and built a new ROV, earning second place in the Pioneer division (Fig. 3). The new ROV, “Hydra” (Fig. 2), was designed to tackle oceanic pollution, monitor the effects of climate change, and maintain a healthy aquatic ecosystem. Learning from past mistakes and forging ahead, the team will now be competing in the Explorer division with a modified version of Hydra and their new vertical profile float, Zeus.

Notable features of Hydra include a high-density polyethylene frame, rotating mechanical claw, dual camera system, Xbox controller, and practical user interface. With these features, Hydra is equipped to accomplish the tasks outlined by the RFP (Request for Proposals). These tasks include the ability to deploy and service SMART cables, as well as analyze and treat damaged coral reefs. Hydra is well-prepared to support the restoration of marine ecosystems through the navigation of Tennessee lake sturgeon spawning grounds.

(Fig. 1) PCC’s first ROV, “Pipedream” (2022)



(Fig. 2) PCC’s 2nd ROV, “Hydra” (2023)

(Fig. 3) 2nd Place at Mate ROV 2023 World Championship

Project Management

Chief Executive Officer/President (CEO): Thet Paing Da Na

The role of CEO assumes a crucial responsibility in defining the project's objectives, scope, and deliverables. This position involves validating comprehensive project plans using tools such as Gantt charts, timelines, and resource allocation. Furthermore, the CEO serves as a vital liaison between mentors, coaches, and school faculty members. They are accountable for task delegation, ensuring seamless project execution, and fostering productive relationships throughout the process.

Chief Technical Officer (CTO): Rene Nunez

The CTO plays a key role in developing new methodologies for improving ROV performance and ensuring that the rest of the team adheres to the operational guidelines established by MATE ROV. Additionally, they collaborate with all team members and identify methods and tools that might be beneficial within different parts of the project.

Chief Operating Officer (COO): Jocelyn Zhu

The COO reports project development to the CEO by keeping track of individual team members' progress. They are able to oversee the entire project while keeping track of important dates and deadlines.

Marketing Manager: Joya Stewart

The marketing manager develops strategies to enhance social outreach within the community. They are also responsible for documenting team progress in an organized manner for public presentation.

Budget Officer: Martin Leung

The Budget Officer oversees financial operations of the company and identifies opportunities for cost reductions. They are able to communicate team needs effectively to financial supporters and provide regular reports to the CEO.

Job Safety Officer: Jasmine Lai

The JSO enures the team maintains a safe and healthy work environment. They conduct regular inspections of the ROV before and after its deployment in water. If necessary, they investigate safety hazards and implement policies as needed.

Employee Roles

The team is organized into three distinct role categories: mechanical, electrical, and software. Each division has a democratically elected lead who guides the members within their category. These leads work closely with the CEO to devise a comprehensive project plan and timeline for ROV development.

Mechanical Engineers

The team's mechanical engineers are responsible for designing and constructing the mechanical portions of the ROV. Designing and machining items such as the high-density polyethylene (HDPE) frame (Fig. 4) and mechanical claw fall under this jurisdiction. Other tasks executed by the mechanical team include waterproofing machinery, mounting mechanical constituents of the ROV, and using computer aided design (CAD) for the development of components that require team fabrication.

(Fig. 4) Mechanical engineer making measurements of HDPE frame

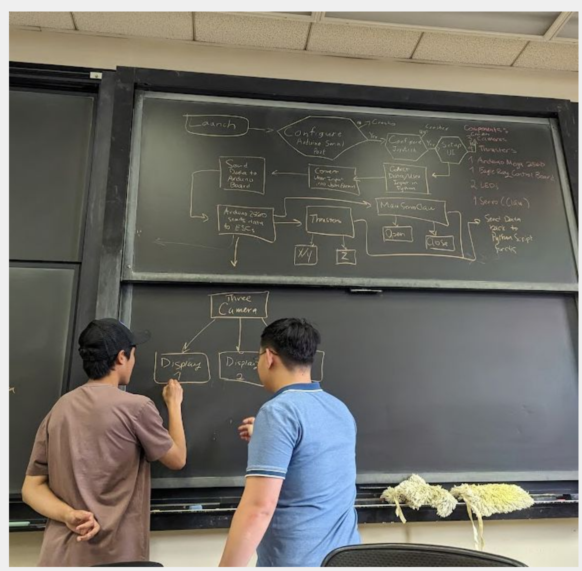
Electrical Engineers

The electrical engineers manage the design and development of the ROV's electrical components. Responsibilities of the electrical team include soldering electrical components (Fig. 5) onto control boards, ensuring connection functionality, and calculating voltage distribution. They are responsible for putting together and troubleshooting the 48V DC power supply and tether, essential components that provide reliable power and communication for Hydra. Additional duties include wiring electrical components and establishing necessary connections for seamless operation.

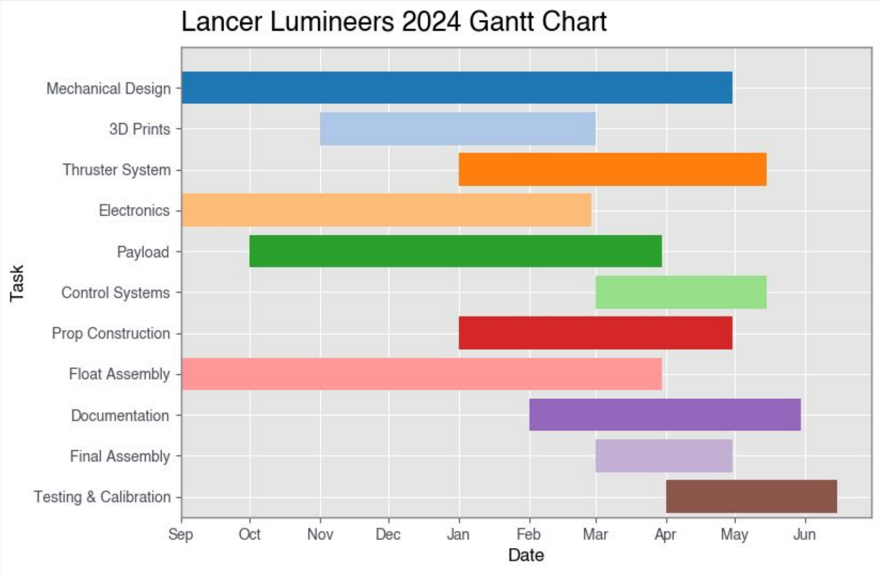
(Fig. 5) Electrical engineer soldering components onto supply board

Software Engineers

The software engineering department programs applications that allow electrical components to work seamlessly together. Software engineers collaborate closely with the electrical engineering team (Fig. 6) to ensure smooth integration between electrical and software components. Code implemented by the software team operates on Arduino and Python programs. This subteam developed the software for Hydra's servo motors, camera system, thrusters, and and developed a user-friendly GUI menu.



(Fig. 6) Software engineers creating a flow-chart to visualize ideas and structure code



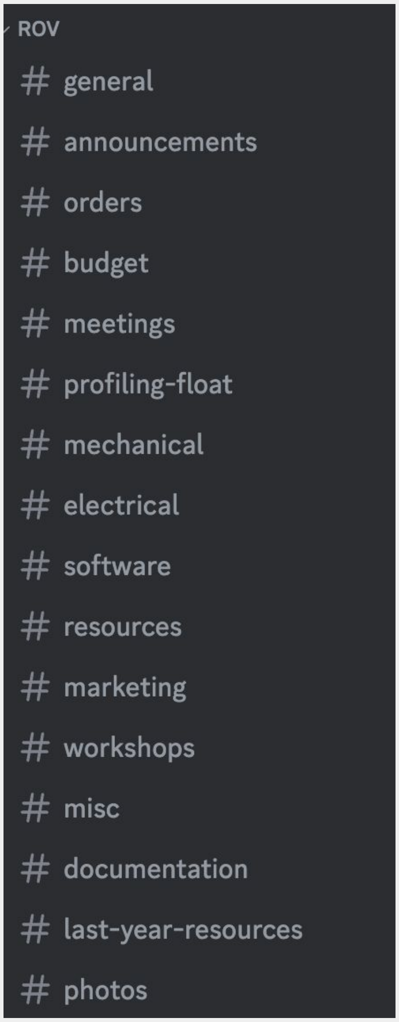
(Fig. 7) Team Gantt chart used to check progress and deadlines

Company Organization and Collaborative Workspace

The team meets every Friday from 9AM to 1PM to work on Hydra and the float, Zeus. However, when extra work is required, additional meetings are held throughout the week. Primary objectives for meetings typically include progress review, team troubleshooting, and machining specific items. Lancer Lumineers' Discord server (Fig. 8) 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 end 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 (Fig. 7). The chart serves multiple purposes, such as establishing a comprehensive timeline for projects 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 tasks or adjusting timelines to ensure the project stays on track.



(Fig. 8) Team Discord server with specified channels for organization

Safety

Safety Rationale

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

Safety Checklist

1. Workplace Safety: The team maintains clear and unobstructed areas, minimizing tripping hazards and any obstacles that may impede operations.
2. 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.
3. 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.
4. Waterproofing Measures: Verifying that all electronic housings are tightly sealed to prevent water from seeping into ROV canister by using vacuum tests, safeguarding the internal components from damage or malfunction. Use of O-rings and liquid tight fittings to create seals between mating surfaces to maintain watertight integrity.
5. Component Inspection: A visual inspection is conducted on all electronic components to identify any signs of damaged wires or loose connections. This enables timely repairs or replacements to maintain optimal functionality and safety.
6. Fastener Validation: The team confirms that all fasteners, such as screws and bolts, are securely tightened to ensure structural integrity during operation.
7. Thruster Assessment: Thorough checks are performed to ensure that the ROV's thrusters are free from any obstructions, guaranteeing their unrestricted movement.
8. Vacuum Testing: The team conducts a vacuum test on the electronics canister using a 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.

Design Rationale

Planning Process

In 2021, the team constructed their first 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 a pool floor. Recognizing certain mobility limitations of the first-generation ROV, the team set out to build the second-generation ROV, “Hydra,” from an Eagle Ray inspired kit. Upgrades were implemented based on potential areas of improvement. These included improved mobility, a dextrous mechanical claw, and enhanced camera view system.

(Fig. 9) Lancer Lumineers visit Long Beach City College to get inspired by ROV designs

Design Process

Lancer Lumineers built Hydra using a kit inspired by the Eagle Ray design. The team designed and machined their own custom additions at Pasadena City College’s fabrication lab and machine shop. 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, spare parts, and specialized equipment.

The team constructed the frame using ½” sheets of high-density polyethylene (HDPE), a material with the same density as water. This choice allows the ROV frame to achieve near-neutral buoyancy without requiring significant weight modifications. To enhance the ROV’s object manipulation capabilities, the team designed a 5-volt servo-controlled claw capable of securely holding objects weighing up to 25 kg. For improved maneuverability, Hydra 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 forward and reverse motion. The team carefully considered factors such as longevity, weight, and price when selecting all components.

Vehicle Systems

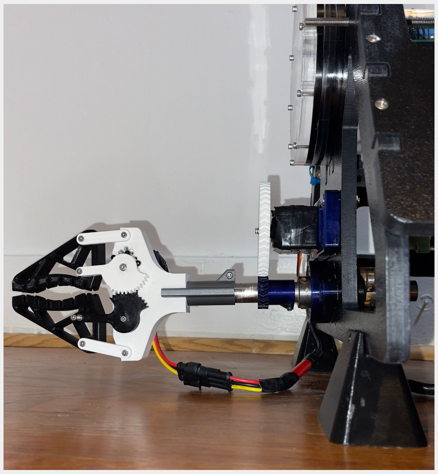
Frame

In the process of selecting a suitable material for the frame of Hydra, the team considered aspects such as durability, machinability, stability, and overall cost per material sheet. High Density Polyethylene (HDPE) was chosen for its characteristics, including corrosion resistance and ease of machining. Moreover, since HDPE has the same density as water, it would be easier to achieve neutral buoyancy with Hydra. The frame was constructed using computer numerical control (CNC) technology to ensure precise fabrication (Fig. 10). Structural elements within the partially hollow frame provide added rigidity and stability.

HDPE's light weight means the ROV will require less mass to sink when developing the ballast system and promotes easy storage and transportation. This reduced weight translates to less power needed to move the ROV, which in turn reduces its environmental footprint. For disassembly, the bolts holding the frame together were standardized, allowing the Hydra to be disassembled using accessible equipment. The frame was designed with rounded edges to eliminate safety hazards. Additionally, risers were later added to the frame to prevent the ROV's claw from scraping the floor as it rotates.

(Fig. 10) High Density Polyethylene frame made with CNC machine for a precise cut

(Fig. 11) Side view of the claw and risers



(Fig. 12) HDPE frame assembled

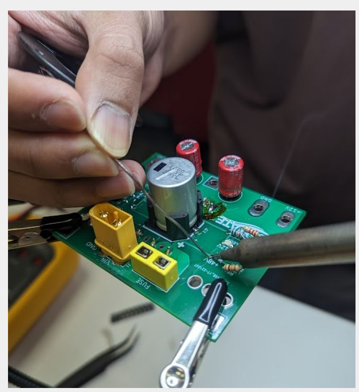
Canister

The canister, constructed from clear acrylic, encases the electrical components of the ROV (Fig. 13). O-rings were selected as the static seal for the canister due to their reliable waterproofing and cost efficiency, as they are inexpensive and easily replaceable. Penetrators on the end cap enable the use of external electric cables. Additionally, a flat metal card cage is affixed to an end cap for stability, acting as the mounting platform for the electrical boards and serving as an electrical heat sink (Fig. 15). This segment of the canister can be withdrawn, facilitating a more time-efficient disassembly and servicing process.

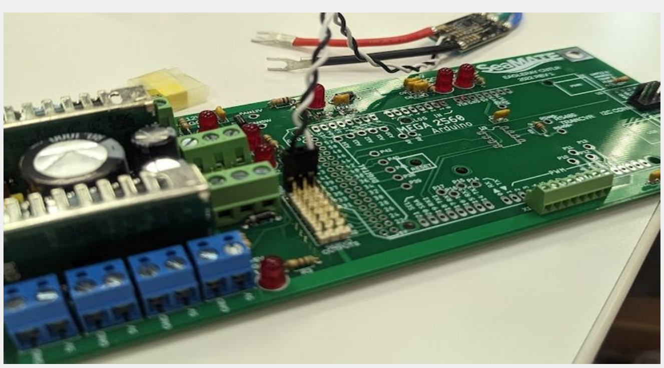
Electrical and Electronic Systems

Power to the ROV is supplied by a power source that converts 120V AC to 48V DC. The 48V DC is then transmitted via the tether to DC-to-DC converters on the main board of the ROV. These converters switch the 48V DC to 12V DC and 5V DC. The electronic systems utilized in the ROV comprise numerous components designed and provided by MATE, as well as employees of Lancer Lumineers. These components encompass the Eagle Ray Control Board (Fig. 14), ESCs (Electronic Speed Controllers), supply boards, DC converters, and passive electronic devices. These electronics are housed within the ROV's canister. The topside electronics, which remain outside of the pool, include a laptop, Xbox controller, and the power supply. These components control the functions and supply power to the Hydra through the 10-meter tether.

(Fig. 13) Acrylic canister housing the electrical components



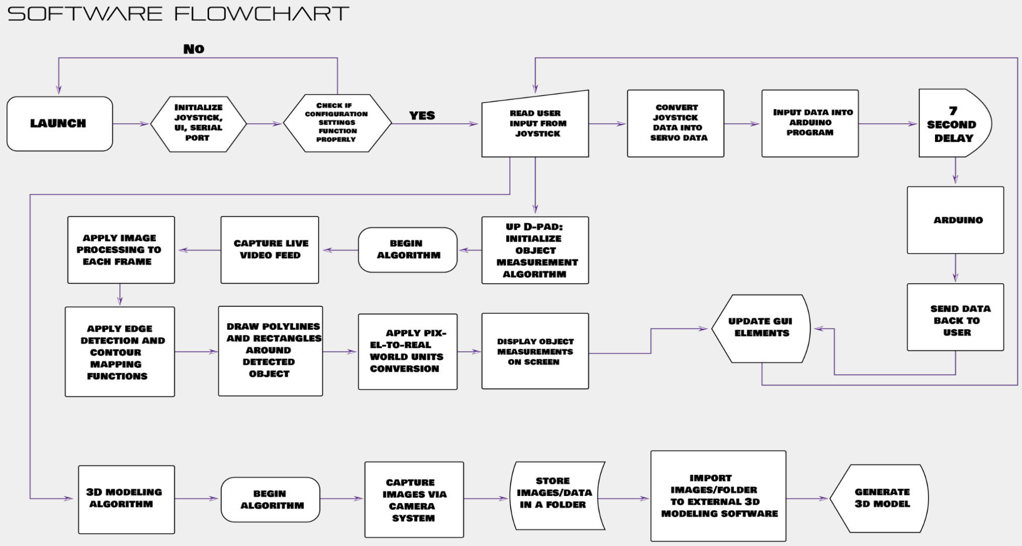
(Fig. 15) Surface mount resistors getting soldered onto supply board



(Fig. 14) Image of the Eagle Ray control board

Software System

Arduino and Python Programming



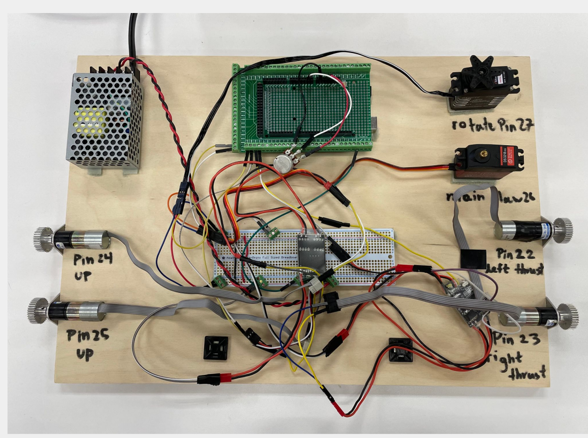
(Fig. 16) Software Flowchart

The initial code provided by MATE ROV was found to lack crucial features such as claw functionality, an easy-to-use GUI, and camera systems. The software engineers analyzed the initial code and improved it for more efficient ROV control. In the early stages of ROV development, pool-side test runs were conducted to test ROV controls. The tests confirmed that the code revisions were well-optimized in managing ROV controls underwater (Fig. 17). Additionally, the software team implemented extra features to prepare Hydra for specific tasks that require high quality claw performance. Programming features such as horizontal thruster movement were also used to improve the ROV's directional capabilities for mission tasks such as 3D modeling.

(Fig. 17) Controlling the ROV with an Xbox Controller using the analog joystick

Troubleshooting Procedure

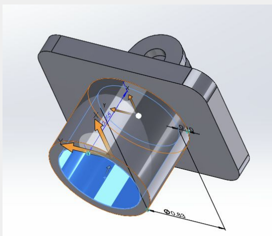
The software team developed a replica board (Fig. 18) to conduct propulsion system testing independently from Hyra. The prototype consists of an Arduino Mega Board, four motors, two servos, and a 5V power supply. Innovating a replica of the ROV thruster system also allowed the team to test and troubleshoot new software on the thruster systems without wasting Hydra's valuable pool testing time. These tests are conducted by connecting the board to a power supply and running programming components that controlled the propulsion system.



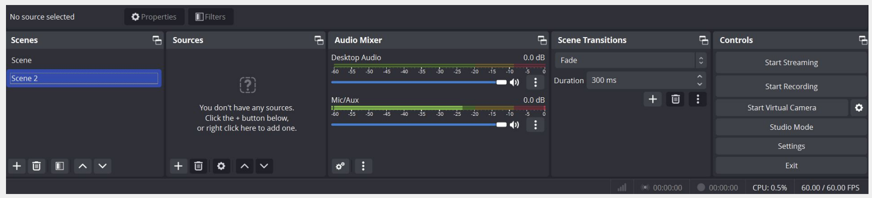
(Fig. 18) Prototype board of ROV thruster setup

Camera System

Hydra has bottom and rear view cameras, each held onto the frame with custom 3D-printed mounts. A free software, Open Broadcaster Software (OBS) Studio, is used to run them due to its user adaptability and cost effectiveness. The cameras are directly connected to the pilot's laptop through an Ethernet adapter hub. This system helps the pilot control Hydra by providing a comprehensive image on an easy-to-use interface.



(Fig.19) CAD design of camera mount



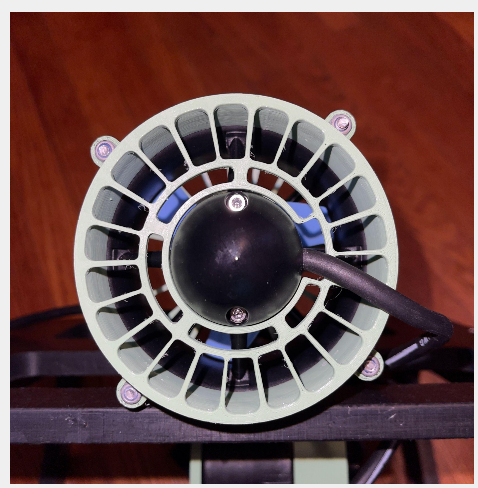
(Fig.20) OBS Studio user interface

Propulsion System

Hydra's propulsion system features four 12V T200 thrusters (Fig. 21) from Blue Robotics. These thrusters have a brushless motor design with encapsulated windings, providing water protection and durability. Brushless motors are known for their higher efficiency and longer lifespan, making them more cost-efficient in the long run. The thruster body, made of robust polycarbonate plastic, offers structural strength, impact resistance, and wear resistance. With its waterproof design, the thruster eliminates the need for shaft seals and improves pressure tolerance at various depths. The powerful thrust capacity allows Hydra to navigate, maneuver, and perform tasks efficiently. To comply with established safety protocols, the mechanical engineers designed and 3D-printed thruster guards (Fig. 22). Noticing that the hole spacing was too large in the first version of the guards, they were later revised to have smaller holes (Fig. 23).

(Fig. 21) T-200 Thruster purchased from Blue Robotics

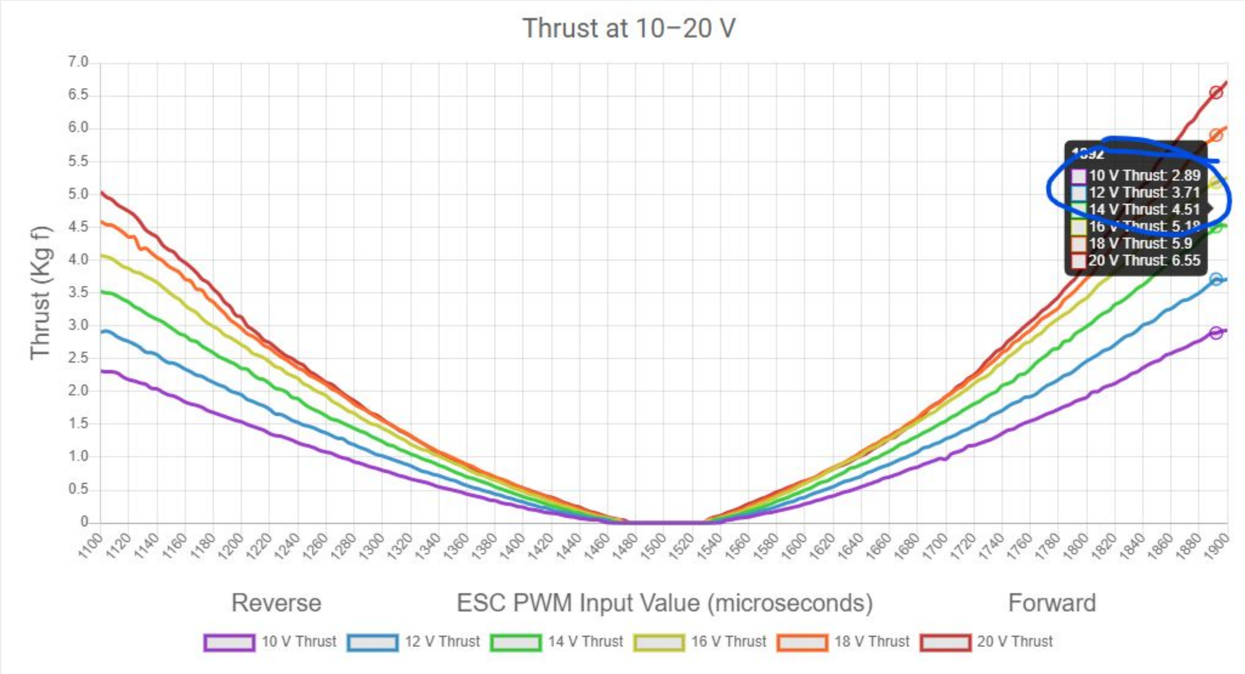
(Fig. 22) T200 thruster with custom 3D printer shroud



(Fig. 23) Top-view of the improved thruster guards, with minimized hole space

Technical Analysis of Propulsion System

Lancer Lumineers realized that the provided Eagle Ray Control Kit can only supply a nominal 12V to the electronic speed controllers (ESCs) included with the purchased T-200 Blue Robotics thrusters. This limitation sets 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 of these thrusters.

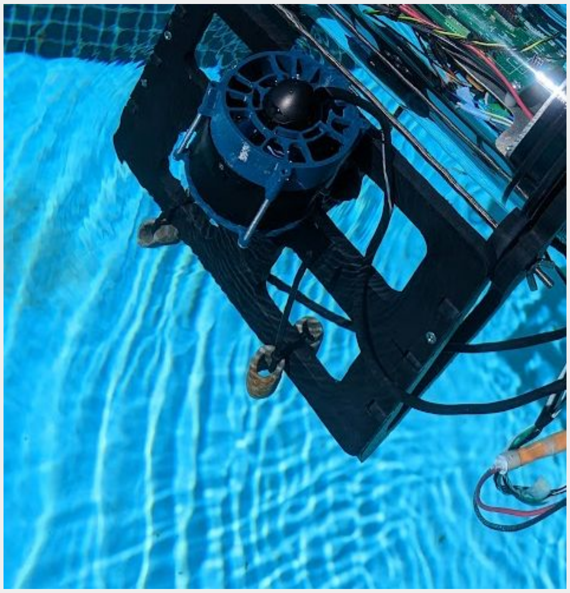


(Fig. 24) Table from Blue Robotics of T200 Thrust vs. ESC PWM Input Value at 10-20V

(Fig. 24) A single T-200 thruster at 12V is capable of generating around 3.71 kgf (kilogram-force) at maximum throttle, where 1 kgf is roughly equal to 2.20 lbf (pound-force), or 31.5 newtons. However, due to the 30-degree angle of each of the two vertical thrusters from the ROV body, the total theoretical force produced is 63.0 newtons. Accounting for the effect of water on this thrust and subtracting twenty percent, a more accurate theoretical value of 50.4 newtons is obtained. The mechanical engineers determined this to be adequate thrust for accomplishing mission objectives, such as transporting a vertical profiling float and deploying SMART cables.

Buoyancy and Ballast

As Hydra is slightly positively buoyant, Lancer Lumineers opted for a static ballast system, comprising a pack of steel weights and a 3D printed container (Fig. 27). Through pool testing, it was determined that approximately 1.6 kg of weight was necessary to maintain neutral buoyancy in the water. According to Underwater Robotics (10), 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 positioning facilitates efficient forward and backward movement while maintaining stability. Additionally, the vertical thrusters are situated closer to the upper sides of the ROV, near its center of mass. This arrangement enhances vertical maneuverability, enabling smooth ascents and descents.



(Fig. 25) Testing the ROV with temporary fishing weights to achieve neutral buoyancy

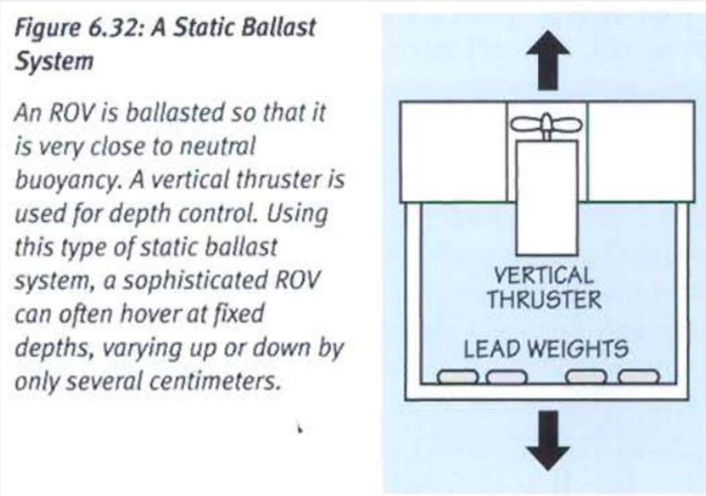
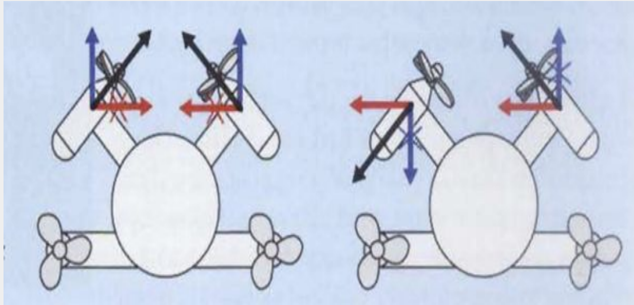


Figure 6.32: A Static Ballast System

An ROV is ballasted so that it is very close to neutral buoyancy. A vertical thruster is used for depth control. Using this type of static ballast system, a sophisticated ROV can often hover at fixed depths, varying up or down by only several centimeters.

(Fig. 26) Static Ballast System Figure

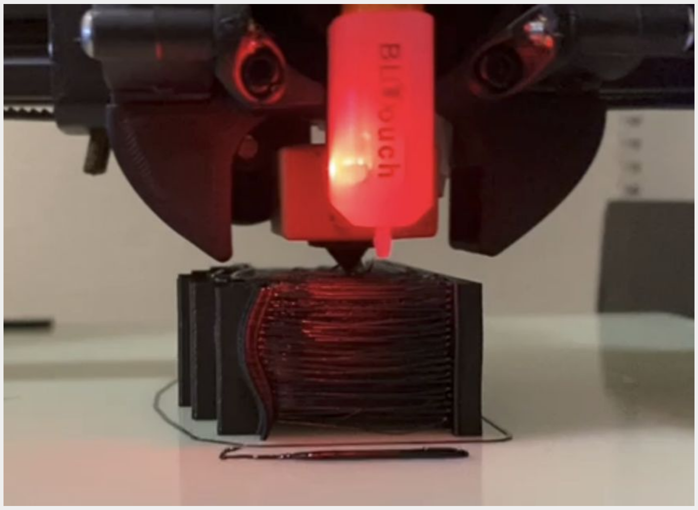


(Fig. 28) Diagram of Vectored Thrust

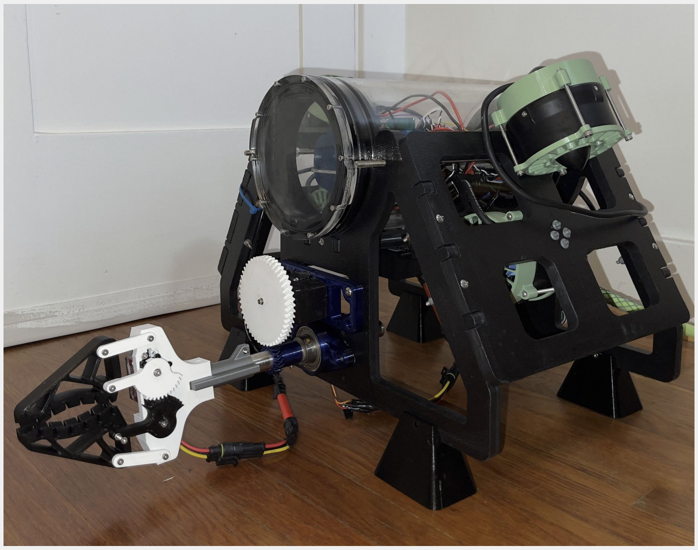
(Fig. 27) Holes at the bottom of the ballast container to create a water drain

Payload and Tools

As stated by Underwater Robotics (10), “Payload” refers to “the set of tools, instruments, collecting devices, or other equipment carried by an underwater vehicle in support of the mission.” Hydra’s payloads consist of a mechanical claw and a dual camera system. The team’s ROV camera system is comprised of 1080 pixel USB and 4k USB cameras. This camera system allows the team to clearly view Hydra’s surroundings, making it easier to maneuver the vehicle from above water. A front and rear view camera system provides a comprehensive image on the user’s mission station, which is necessary for successfully navigating mission tasks. A claw gear system (Fig. 30) was implemented to enable the rotational movement of Hydra’s previously static claw arm. The team optimized existing claw designs for better grip and control, enabling more dexterous motion. The claw was specifically designed to be compatible with the types of objects it will be holding (e.g., SMART cable rounds, vertical profiling float). It features a unique bristle texture (Fig. 29), allowing more of its surface area to be in contact with the objects it grabs, adding additional grip to the inside. Both the gear and claw were 3D printed to be budget-friendly.



(Fig. 29) 3D Printed bristle claw prototype

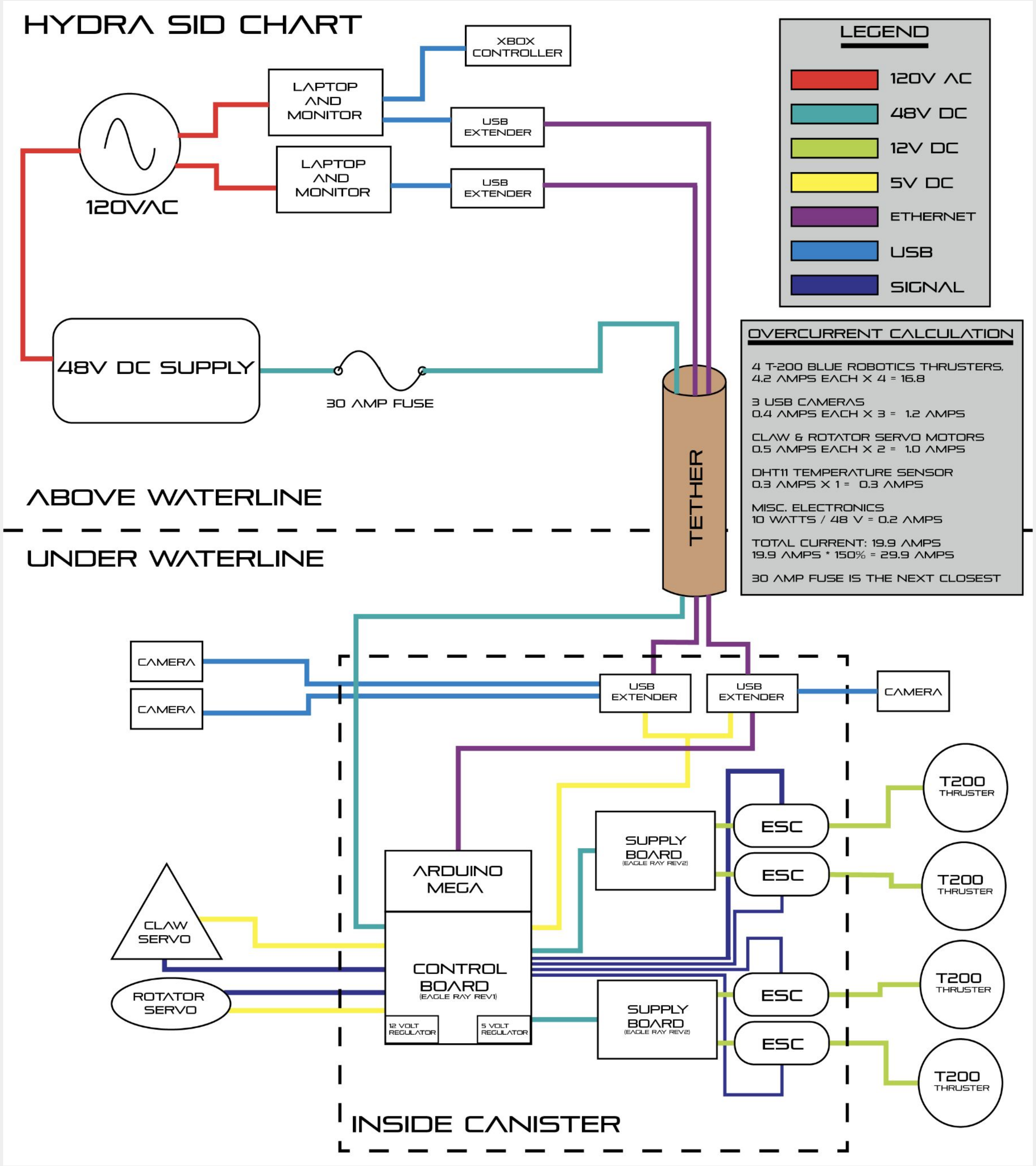


(Fig. 30) 3D Printed gears and claw frame

Build vs. Buy vs. Used

The Lancer Lumineers committed to optimizing the cost efficiency of ROV expenses. To eliminate additional component expenses, the team utilized the Pasadena City College Fabrication Lab (PCC Fablab) to 3D print and computer numerical control (CNC) cut many of Hydra’s components. Most of the ROV’s parts were reused from last year’s design and also machined in the PCC FabLab. The FabLab generously donated many of their leftover materials to the team, including laser-cut wood for prototyping, and a few power tools. The budget officer meticulously tracked the origin of each of Hydra’s components, whether machined, bought, or donated, in the budget spreadsheet.

System Interconnection Diagrams



(Fig. 31) ROV SID

Testing and Troubleshooting

Prototyping Phase

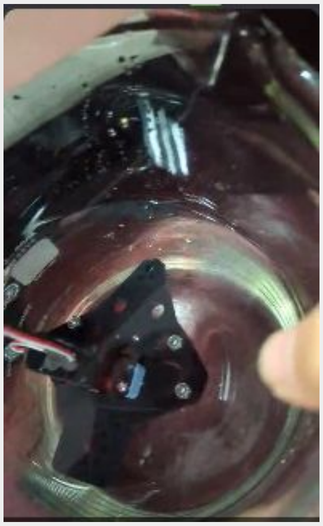
Prototypes were developed and tested for feasibility, functionality, and performance. These discrete and step-wise improvements streamlined the ROV's development.

Sub-teams collaborated to enhance claw functionality and experiment with new gripper code (Fig. 32). The Eagle Ray Control board can be observed powered by a PSU Bench-tester and connected to components such as the joystick controller and the main servo claw.

(Fig. 32) Software and Mechanical engineers prototype gripper functionality.

In the early stages of Hydra's development, a prototype of a waterproofed servo for the mechanical gripper was implemented (Fig. 33). The claw was submerged in a 400 ml glass beaker half-filled with water. It was discovered that this claw was not fully waterproof despite being marketed as such. This serves as a reminder that prototyping techniques may not always detect errors that are not immediately apparent.

The first prototype of the thruster guards (Fig. 34) were initially believed to be sufficient for preventing injuries during operation of the thrusters. However, later tests revealed a serious design flaw where wide gaps in the design allowed debris and prop material to enter the thrusters, causing the propellers to stall.



(Fig. 33) Water-proof test for first servo-claw

(Fig. 34) Early prototype of thruster guards

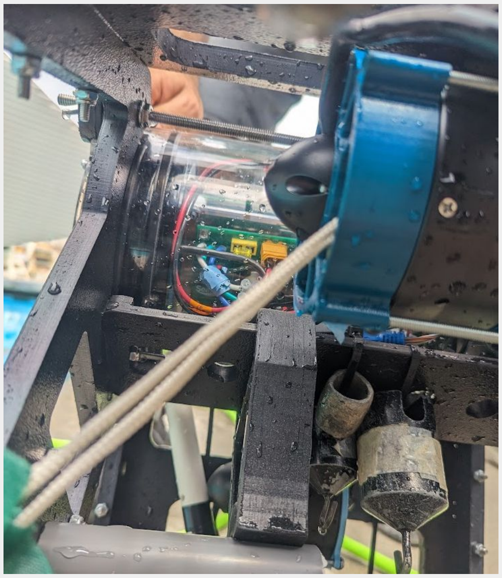
Testing Phase

From theory to application, tests are a necessary aspect of engineering. With the use of testing, prototypes are used to find out what designs excel for their intended purpose, or contained serious flaws that demand revision. The Lancer Lumineers conducted thorough tests on individual components prior to complete assembly to minimize risk of damaging systems and reduce reiteration time.

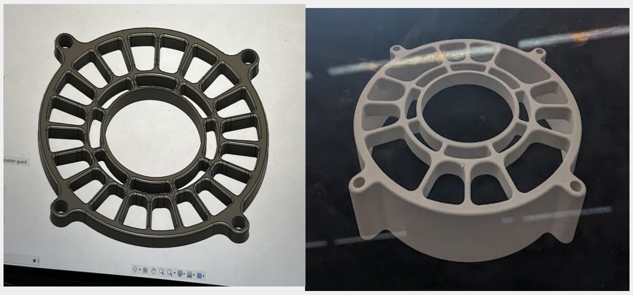
A completed Eagle Ray Control Board, featuring all the necessary passive components, DC-to-DC converters and an Arduino Mega 2560, was one of the components tested (Fig. 35). Upon receiving 24V from a PSU bench tester, several onboard LEDs illuminated. The Electrical Sub-team used a multimeter to validate connections and check for any short circuits in the system. Subsequently, they were able to solder and assemble the kit without encountering any conflicts.

An early version of Hydra's propellers stalled during pool testing, and it was found that string was suctioned through the thruster guards, rendering the ROV immobile. The mechanical team prototyped a new thruster guard to prevent repeating this issue (Fig. 37).

(Fig. 35) Electrical test



(Fig. 36) Thruster guards failure.



(Fig. 37) New thruster guards (Left) vs. old design (Right).

Troubleshooting and Improvements

For most challenges, the team:

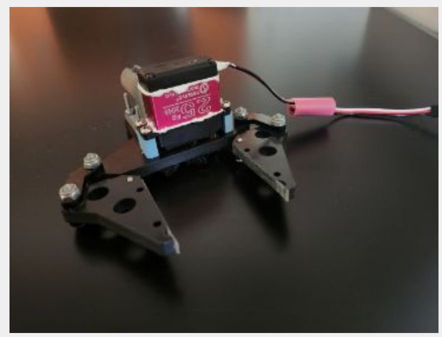
- Sought inspiration from existing MATE ROV tech documents
- Engaged knowledgeable professors
- Employed a collaborative and democratic approach using a team-wide vote
- Divided and conquered, larger tasks were broken down into manageable chunks

Solution to Water Resistant Servo Motor

A significant issue the team faced was assuming the “waterproof” servo motors were water resistant to high underwater pressure. Water ended up flooding one of Hydra’s servos, preventing the claw from performing its necessary tasks. The team used JB Weld to seal the top and bottom of the motor (Fig. 38) to maintain balance between the internal and external pressure underwater. Olive oil was then injected into the motor using a method found on YouTube. This method proved to be effective after extensive testing.

(Fig. 38) Use of JB-weld and olive oil

(Fig. 39) Waterproofed Servo Motor



(Fig. 40) Waterproofed Servo Motor with claw assembly

Solution to Vacuum Test

The final verification test of the Hydra required seal checks and pressure testing for waterproofing. The initial procedure called for the canister to be pressurized to 3 psi. However, due to a slow pressure drop in the system, the team concluded that there was an air leak. To locate the leak, soapy water was sprayed on the seals; the formation of bubbles would indicate where the air was being pushed out. Subsequently, the ROV was placed in the pool to check for the origin of the air leak (Fig. 41). After this test, it was discovered that the culprit was a loosely insulated ethernet cable (top-side tether). To resolve this, epoxy was applied to properly seal the tether.

(Fig. 41) Air escaping from main canister through the top-side end of the ethernet cable.

Accounting

The Lancer Lumineers understood that constructing an advanced ROV like Hydra would be a costly endeavor. To make the most of the funding offered, they employed various budgeting strategies. These included machining their own products whenever possible, utilizing 3D prints for prototypes and final components, and opting for free software whenever viable. An overview of the funding sources, ROV expenses, and travel cost estimates are provided in the sheets below. Since the bulk of the ROV was constructed from 2022-2023, expenses for that time frame, as well as 2023-2024 are provided:

Grant Money

Income	
Source	**Amount**
NSF: MATE ROV	$20,000
NSF: MNT-EC	$10,000
PCC: McKenzie Scott	$40,000

(Fig. 42)

2022 - 2023 Expenditures

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

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. 43)

2023 - 2024 Expenditures

ROV Component	Quantity	Price	Ext. Price	Type
3-pin connector	1	$14.99	$14.99	Purchased
Steel Shaft	1	$16.99	$16.99	Purchased
Steel Weights	1	$26.99	$26.99	Purchased
Pillow Block Bearing	1	$13.99	$13.99	Purchased
Servo	2	$24.99	$49.98	Purchased
20 Gauge 3 Conductor Electrical Wire	1	$9.98	$9.98	Purchased
3D Printed parts	1	$25.00	-	Donated
			Total Cost	$157.92

Travel	Quantity	Days	Amount	Subtotal	Type
Hotel Rooms	8	5	$175.00	$7,000.00	Predicted
Flights	20	Round-Trip	$700.00	$14,000.00	Predicted
Rental Car	1	5	$600.00	$600.00	Predicted
Food	20	5	$40.00	$4,000.00	Predicted
Uber			$200.00	$200.00	Predicted
				Total	$25,800.00

Overall	Budget	Expenses
ROV	$1,000.00	$132.92
Float	$2,000.00	$553.16
Travel	$25,000.00	$25,800.00
General	$300.00	$300.40
	Total Budget	$28,300.00
	Total Expenses	$26,786.48

(Fig. 44)

Media Outreach

STEM Events

The Lancer Lumineers actively engaged with the community by giving presentations at multiple STEM events. The team demonstrated the construction of the ROV and promoted their environmental preservation goals. They additionally created posters to actively promote the ROV and Environmental, Social, and Governance (ESG) issues and gave formal lectures to large groups of college students, showcasing the ROV's purpose and how it was built.

- (03/14/24) Team members participated in the Pi-Day event at Pasadena City College. This event featured representatives from Caltech, JPL, and other notable institutions, aiming to promote math learning. A few team members led Arduino workshops and gave formal lectures about the ROV to around 50 individuals (Fig. 47).
- (04/12/24) The CEO, mechanical lead, and other team members hosted an annual water festival, in celebration of the new year for Southeast Asian countries. This served as a bonding activity within the community, and a networking event for the team.
- (04/27/24) The team presented at PCC STEM Saturday, where they demonstrated practical applications of mathematical knowledge, coding skills, and underwater robotics to middle and high school students. They also gave a talk about the Lancer Lumineers' ecosystem preservation goals. (Fig. 46).

(Fig. 45) The CEO presenting at STEM Saturday

(Fig. 46) Arduino Workshop led by Linn Khant Thuya, a member of the software team

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 initiative 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.

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PASADENA CITY COLLEGE FOUNDATION

MNT-EC
Micro Nano Technology Education Center

MATE ROV COMPETITION

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