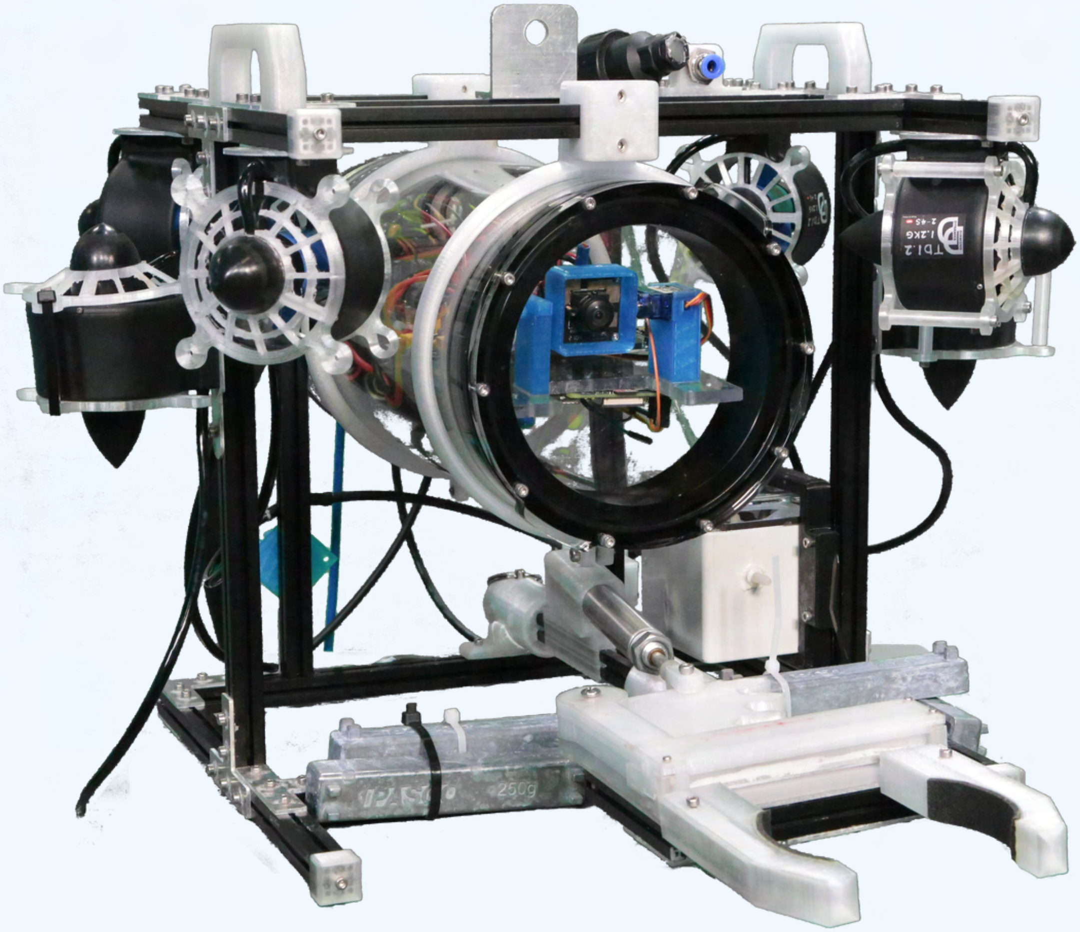
GENESEAS

St. Francis Catholic High School
Sacramento, CA USA



COMPETITION MEMBERS:

Allie Dinh** '23	CFO
Sydney Goodall** '23	Software Lead
Morgan Jones** '23	CEO
Sofia Stuck** '23	Electrical Lead
Norah Zhou** '23	Mechanical
Isa Gutierrez** '24	Tools Lead
Lauren Grindstaff** '24	Mechanical Lead
Siena Marois** '24	Software Lead
Audrey Mayo** '24	CMO
Azul Kuppermann* '25	Tools
Kin Tirumala** '25	Software

CREW:

Emily Asperger** '23 Mae Alvarez* '24; Franziska Kungys* '24; Grace Chavez* '25; Dar Eugenio* '25; Yixin Huang* '25; Izzy Ramos** '25; Alyssa Renomeron** '25; Gabby Rosario** '25; Laila Shamshad* '26; Yogja Singla* '26

COACHES:

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*** New Members**
**** Returning MATE Comp Participants**

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I. ABSTRACT

Geneseas is an underwater robotics company with expertise in designing and manufacturing innovative Remotely Operated Vehicles (ROVs) developed to perform mission tasks in global marine ecosystems. Based in Sacramento, California, the company comprises 22 highly skilled female engineers who are driven to develop technology addressing complex problems, motivated by the potential and promise of engineering solutions.

Geneseas' newest and most technically advanced product is *Medusa,* their fourth-generation ROV. *Medusa* is engineered through detailed planning, prototyping, analysis, and testing, resulting in a custom-built ROV designed to perform highly targeted mission tasks with precision. This year's latest advancements improve mobility and mission efficiency through the addition of a Raspberry Pi processor, six thrusters, and a buoyancy engine with wifi signaling capabilities.

Fully equipped with an array of specially designed tools, *Medusa* is a highly reliable and efficient submersible robot. Designed to meet diverse mission requirements, *Medusa* offers extensive capabilities with a high level of customization and precision, making it an excellent tool for advancing the achievement of the UN Sustainable Development Goals.

This technical document details *Medusa's* design and development process. *Medusa's* meticulously engineered features make it capable of assisting the global community by servicing marine renewable energies, conserving diverse species, and collecting data to monitor ocean health, understand ocean processes, and predict the consequences of climate change.

Figure 1. Geneseas Team Members
Photo by Melissa Triebwasser

II. PROJECT MANAGEMENT

A. Company Profile

Geneseas is a five-year-old company located in Sacramento, California, that engineers submersible robots designed to address issues related to climate change and its impact on global marine ecosystems.

The company's all-female workforce of 22 engineers is organized into five departments (Figure 2): mechanical, electrical, tool development, movement software, and image recognition software. Each department is led by a senior member of the team, who teaches employees about their respective systems. The *Geneseas* CEO performs the dual roles of managing team progress and serving as the Head of Hardware Systems, providing oversight to the mechanical, electrical, and tools departments. The CFO manages team expenses and serves as the Head of Software, responsible for overseeing the image recognition and movement departments. The CEO, CFO, and department heads work together to perform design reviews, conduct testing, and promote cross-team collaboration to produce robust and reliable components.

Geneseas experienced a 25% growth in team size this year. All new employees underwent a semester of training in which they were introduced to the ROV's five subsystems and learned skills such as coding, CAD, and soldering. Following this, they were assimilated into the rest of the team and assisted with mission tools development while learning from their department heads. Genesea's peer-to-peer training system provides employees a solid foundation of knowledge and experience, paving the way for long-term growth and success.

Geneseas' company structure and training process helps support the design, production, and rapid iteration of innovative new ROVs designed to effectively perform mission tasks in global marine ecosystems while ensuring company stability and prosperity.

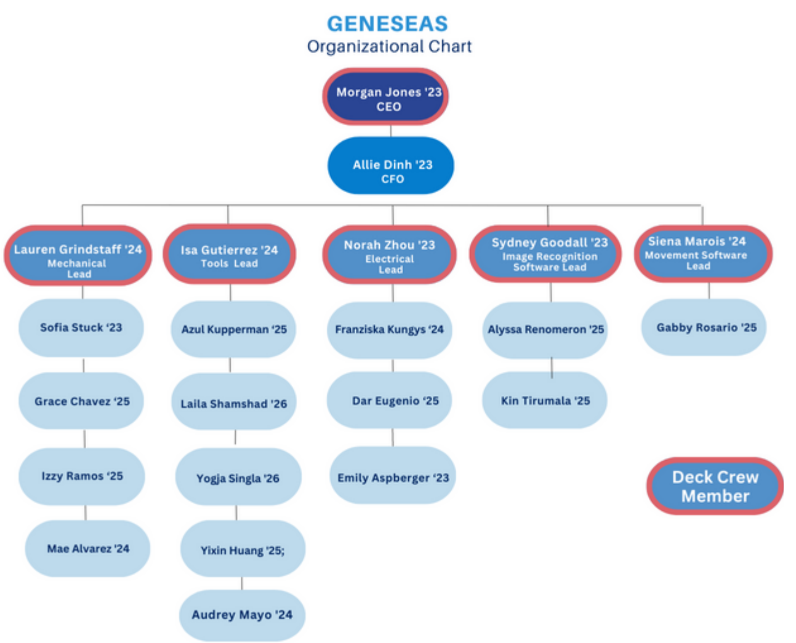
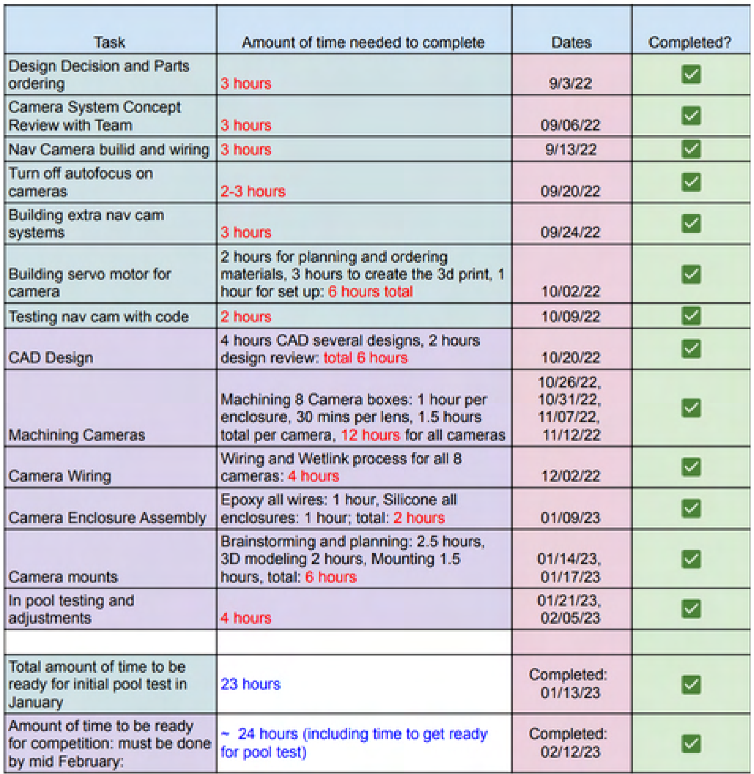


Figure 2. Geneseas Company Organization Diagram by Morgan Jones

B. Scheduled Project Management

This year, *Geneseas* implemented a comprehensive project management approach to effectively manage department assignments and achieve key milestones, helping keep the project organized, on time, and on budget.



Task	Amount of time needed to complete	Dates	Completed?
Design Decision and Parts ordering	3 hours	9/3/22	☑
Camera System Concept Review with Team	3 hours	09/06/22	☑
Nav Camera builld and wiring	3 hours	9/13/22	☑
Turn off autofocus on cameras	2-3 hours	09/20/22	☑
Building extra nav cam systems	3 hours	09/24/22	☑
Building servo motor for camera	2 hours for planning and ordering materials, 3 hours to create the 3d print, 1 hour for set up: 6 hours total	10/02/22	☑
Testing nav cam with code	2 hours	10/09/22	☑
CAD Design	4 hours CAD several designs, 2 hours design review: total 6 hours	10/20/22	☑
Machining Cameras	Machining 8 Camera boxes: 1 hour per enclosure, 30 mins per lens, 1.5 hours total per camera, 12 hours for all cameras	10/26/22, 10/31/22, 11/07/22, 11/12/22	☑
Camera Wiring	Wiring and Wetlink process for all 8 cameras: 4 hours	12/02/22	☑
Camera Enclosure Assembly	Epoxy all wires: 1 hour, Silicone all enclosures: 1 hour; total: 2 hours	01/09/23	☑
Camera mounts	Brainstorming and planning: 2.5 hours, 3D modeling 2 hours, Mounting 1.5 hours, total: 6 hours	01/14/23, 01/17/23	☑
In pool testing and adjustments	4 hours	01/21/23, 02/05/23	☑
Total amount of time to be ready for initial pool test in January	23 hours	Completed: 01/13/23	☑
Amount of time to be ready for competition: must be done by mid February:	~ 24 hours (including time to get ready for pool test)	Completed: 02/12/23	☑

Figure 3. Geneseas PMT: Individual Department Timeline by Morgan Jones

Starting in September, the team met every Monday and Saturday and scheduled additional meetings to achieve critical project deadlines. The *Geneseas* Leadership Board, which consists of the CEO, CFO, and five department heads, meets for an hour every Thursday to track progress, conduct design reviews, and refine plans for the Saturday meetings.

Using *Geneseas'* Project Management Tool (PMT), department heads created and updated project schedules at the beginning of the year. The PMT includes individual department project timelines (Figure 3), meeting objectives, overall project deadlines (Figure 4), and links to other organizational tools. The team utilized the PMT to assign and manage tasks, set timelines, allocate resources, monitor progress, identify potential roadblocks, and adjust the project plan. It ensured timely completion, enabling the initial in-pool test in January and preliminary tools testing in mid-February. The PMT expedited *Medusa's* production and taught *Geneseas* team members the importance of effective time management.

Throughout the year, *Geneseas* utilizes a pool log (Figure 5) to document the amount of time spent testing the ROV and tools in the pool. This pool log tracks the hours spent practicing as well as the amount of time spent on specific tasks. The data is used to improve tools and adjust the ROV's movement code to enhance mission efficiency.

Geneseas' team members maximized lab time and improved communication by utilizing schedules and stand-up meetings to set goals and analyze progress. Additionally, the use of the PMT, pool logs, and weekly leadership meetings facilitated the achievement of key design objectives and provided a structure for day-to-day operations.This management strategy improved the ROV production process by addressing previous operational issues stemming from disorganization and insufficient pool practice.

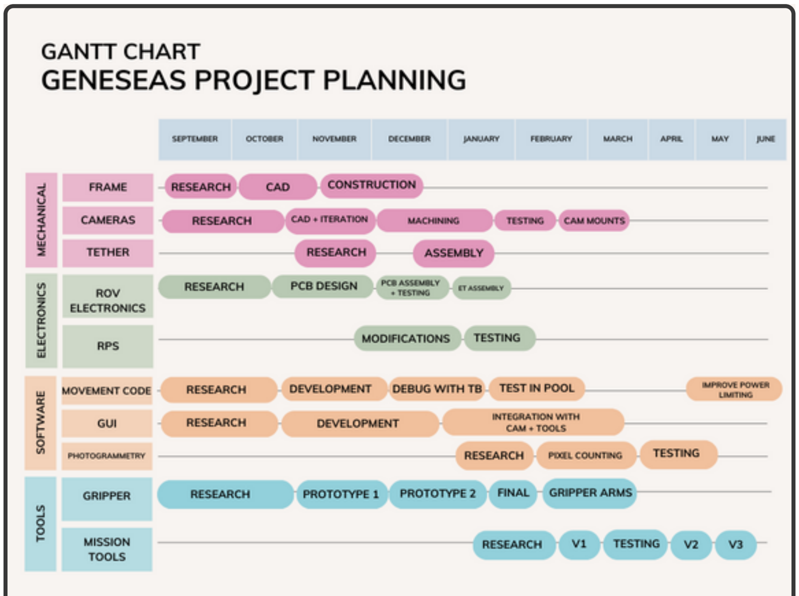
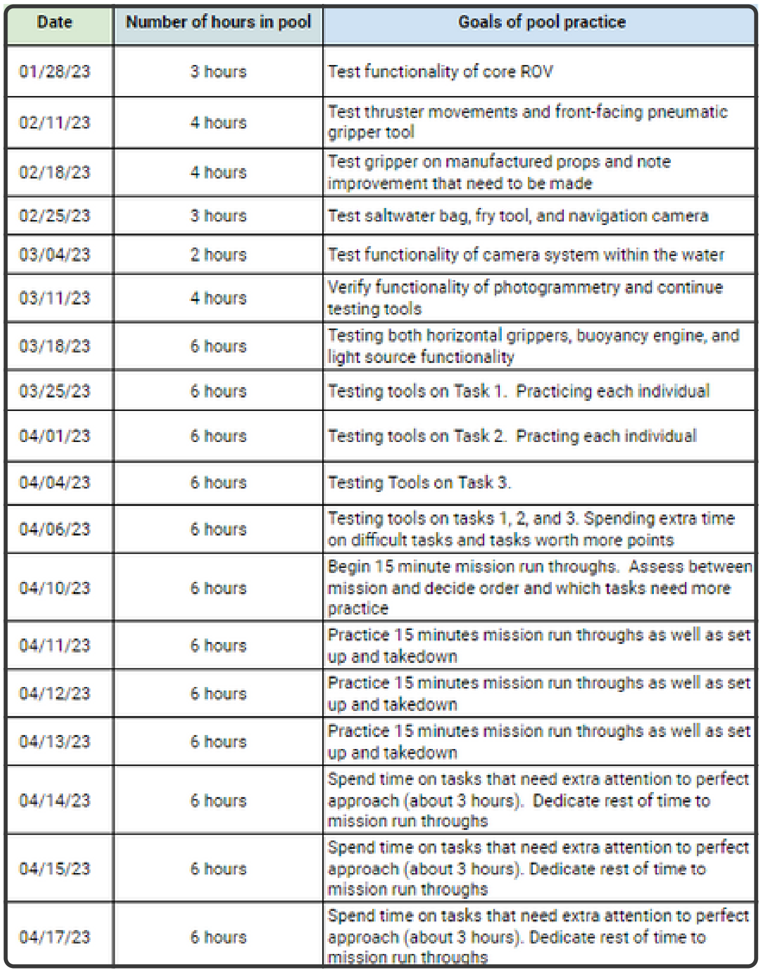


Figure 4. *Genseas* PMT: Gantt Chart - *Geneseas* Project Planning by Morgan Jones



Date	Number of hours in pool	Goals of pool practice
01/28/23	3 hours	Test functionality of core ROV
02/11/23	4 hours	Test thruster movements and front-facing pneumatic gripper tool
02/18/23	4 hours	Test gripper on manufactured props and note improvement that need to be made
02/25/23	3 hours	Test saltwater bag, fry tool, and navigation camera
03/04/23	2 hours	Test functionality of camera system within the water
03/11/23	4 hours	Verify functionality of photogrammetry and continue testing tools
03/18/23	6 hours	Testing both horizontal grippers, buoyancy engine, and light source functionality
03/25/23	6 hours	Testing tools on Task 1. Practicing each individual
04/01/23	6 hours	Testing tools on Task 2. Practing each individual
04/04/23	6 hours	Testing Tools on Task 3.
04/06/23	6 hours	Testing tools on tasks 1, 2, and 3. Spending extra time on difficult tasks and tasks worth more points
04/10/23	6 hours	Begin 15 minute mission run throughs. Assess between mission and decide order and which tasks need more practice
04/11/23	6 hours	Practice 15 minutes mission run throughs as well as set up and takedown
04/12/23	6 hours	Practice 15 minutes mission run throughs as well as set up and takedown
04/13/23	6 hours	Practice 15 minutes mission run throughs as well as set up and takedown
04/14/23	6 hours	Spend time on tasks that need extra attention to perfect approach (about 3 hours). Dedicate rest of time to mission run throughs
04/15/23	6 hours	Spend time on tasks that need extra attention to perfect approach (about 3 hours). Dedicate rest of time to mission run throughs
04/17/23	6 hours	Spend time on tasks that need extra attention to perfect approach (about 3 hours). Dedicate rest of time to mission run throughs

Figure 5. *Geneseas* Pool Log
by Morgan Jones

III. DESIGN RATIONALE

A. Key Design Objectives

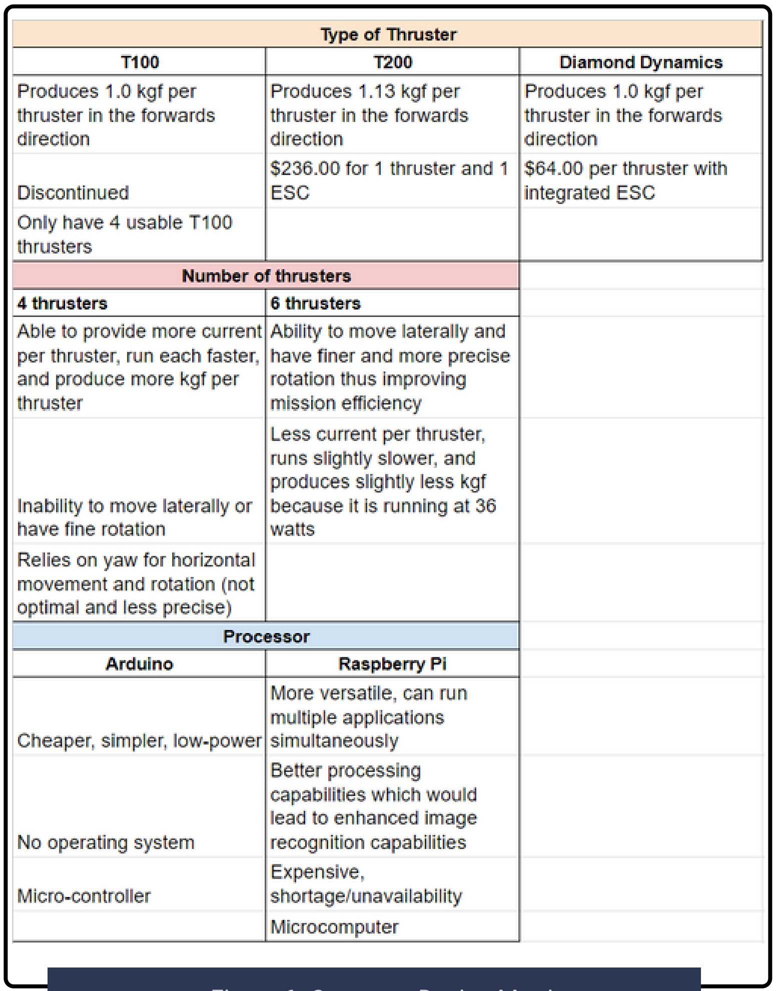
The *Geneseas* Leadership Board set key design objectives at the start of the season, informed by insights from the previous year's ROV. The primary goals for 2023 were to improve pilotability, enhance image processing capabilities, and upgrade the control system to a microcomputer. These objectives guided the production process, influencing sourcing and design decisions. 3D printing custom parts reduced costs while maintaining precision and reliability. These cost savings allowed for investments in components like the Raspberry Pi microcomputer. A design decision matrix (Figure 6) helped evaluate tradeoffs and critical factors before proceeding with decisions.

Opting to 3D print custom parts yielded more precise, dependable components at a significantly lower cost. This enabled the company to allocate funds towards other components, such as the Raspberry Pi microcomputer, that were previously outside of the budget. The creation of a design decision matrix (Figure 6) allowed *Geneseas* to carefully evaluate the tradeoffs and critical factors of these decisions before pursuing them.

B. *Geneseas* Design Methodology

Geneseas' design methodology focuses on iteration, continuous improvement, and team collaboration to ensure the success of the ROV and its components. Key design objectives were established, and a decision matrix was created to evaluate features. Multiple design options were developed, objectively compared, and modified iteratively based on testing and feedback. The design methodology placed a strong emphasis on rigorous testing and validation to ensure the designs met their objectives. Feedback from previous projects was incorporated to enhance the approach through collaboration and iterative modifications.

The Geneseas Design Cycle (Figure 7) develops specialized ROV components by understanding and empathizing with the environmental impact on oceans, marine life, and society. The problem, parameters, and constraints are clearly defined before ideation and collaborative decision-making. A prototype is built and rigorously tested for functionality, strengths, and weaknesses. Tradeoffs are evaluated during the iteration stage, prompting a new cycle that approaches the problem from an alternate perspective. The continuous design cycle iterates upon previous designs to develop robust and reliable engineering components.



Type of Thruster		
T100	**T200**	**Diamond Dynamics**
Produces 1.0 kgf per thruster in the forwards direction	Produces 1.13 kgf per thruster in the forwards direction	Produces 1.0 kgf per thruster in the forwards direction
Discontinued	$236.00 for 1 thruster and 1 ESC	$64.00 per thruster with integrated ESC
Only have 4 usable T100 thrusters		

Number of thrusters	
4 thrusters	**6 thrusters**
Able to provide more current per thruster, run each faster, and produce more kgf per thruster	Ability to move laterally and have finer and more precise rotation thus improving mission efficiency
Inability to move laterally or have fine rotation	Less current per thruster, runs slightly slower, and produces slightly less kgf because it is running at 36 watts
Relies on yaw for horizontal movement and rotation (not optimal and less precise)	

Processor	
Arduino	**Raspberry Pi**
Cheaper, simpler, low-power	More versatile, can run multiple applications simultaneously
No operating system	Better processing capabilities which would lead to enhanced image recognition capabilities
Micro-controller	Expensive, shortage/unavailability
	Microcomputer

Figure 6. *Geneseas* Design Matrix
by Morgan Jones

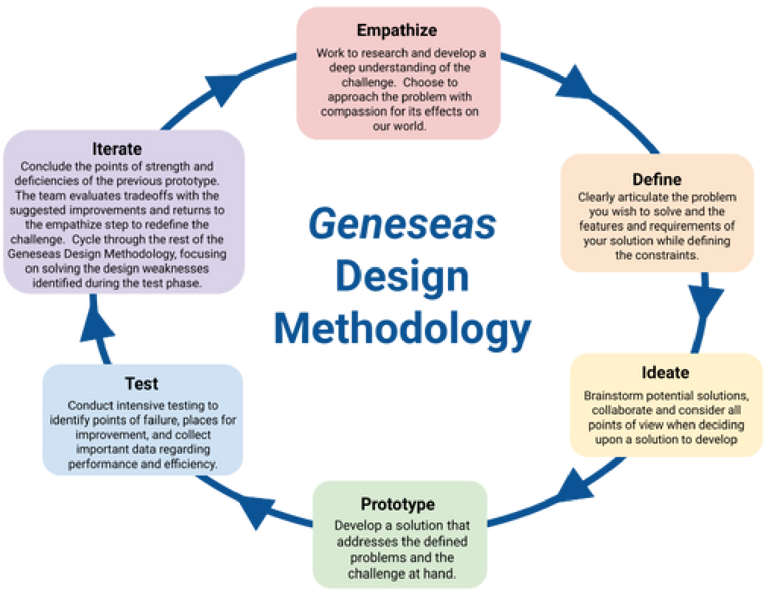


Figure 7. *Geneseas* Design Methodology
by Morgan Jones

C. Sourcing Decisions

Geneseas strategically sourced components for *Medusa*, ensuring affordability, sustainability, and effectiveness. Sourcing decisions were made based on a matrix (Figure 31) evaluating prices, shipping considerations, and the feasibility of reuse.

As an example, *Geneseas* had to source a new thruster for the ROV. The prior Blue Robotics T100 thrusters were discontinued, and *Geneseas* did not have sufficient safety stock to reuse these thrusters. *Geneseas* researched the Blue Robotics T200 and Diamond Dynamics TD1.2 thrusters. Based on size, power consumption, and cost, *Geneseas* tentatively chose the Diamond Dynamics thrusters. The team created a thruster test bench with custom software and ordered one Diamond Dynamics thruster to test to confirm its suitability and reliability. *Geneseas* developed custom test software that ran a pattern including full-forward, full-reverse, rapid forward/reverse cycling and other similar patterns for over an hour. Passing this test confirmed the decision to use the Diamond Dynamics TD1.2 thrusters. *Geneseas* followed a similar process of deliberation, research, and evaluation for components to determine whether it is optimal to buy, build, or reuse them and how these sourcing decisions would impact the ROV's functionality, performance, and overall cost.

Geneseas prioritizes mission requirements when making sourcing decisions, carefully considering whether to buy or build parts. This was exemplified in the decision-making process for *Medusa's* gripper. While purchasing a gripper had its advantages, *Geneseas* ultimately chose to custom design and manufacture a gripper specifically tailored to the mission objectives. This decision enabled the creation of a manually rotatable gripper capable of performing a wide range of tasks, from servicing inter-array power cables to installing long-term cameras. *Geneseas* carefully assessed mission objectives when determining whether to reuse or use new components, such as the RPS and thrusters. Components that have been tested, confirmed to be in good condition, and aligned with the mission requirements were reused. This was the case for the previous year's RPS which was reused due to its good condition and slightly modified to better suit the new *Medusa* ROV.

D. Mechanical Systems

Frame

Geneseas' newest ROV, *Medusa*, features a rectangular frame that is compact, hydrodynamic, and easily maneuverable in marine environments. Compared to previous designs, this frame reduces the ROV's overall cost and size by 23%, resulting in a solution that is both cost-effective and optimized for underwater environments.

Geneseas utilized CAD software to create and iterate upon the design prior to manufacturing, resulting in an ROV engineered to meet predetermined design objectives. These objectives included optimizing the positioning of the electronics housing and the six thrusters, providing adjustability, and reducing the ROV's overall size, weight, and cost.

The ROV's outer frame is 309 x 333 x 295 mm and constructed from 15 x 15 mm extruded aluminum, which features channels that allow for the attachment of tools, cameras, and thrusters using T-slot nuts, making it highly adaptable. The frame incorporates custom-designed water-jetted brackets, ensuring durability and reliability. This simple rectangular frame (Figure 8) was selected over an alternative trapezoidal frame to reduce *Medusa's* weight by 122.4 grams and decrease the frame production cost by $7.03 while improving the ROV's overall versatility through its hydrodynamic design.

The frame was specifically designed to position the center of thrust and the center of buoyancy close to each other to provide increased stability. This was accomplished by using adjustable 3D printed polycarbonate cradles to mount the 6" Blue Robotics electronics housing at the top of the ROV to use the housing's positive buoyancy to generate stability. The six thrusters are located close to the electronics housing, with four thrusters mounted at *Medusa's* upper four corners and the two vertical thrusters mounted to vertical bars on either side of the ROV.

Medusa's frame was also designed to provide space in the lower tool deck beneath the electronics housing for two rotatable horizontal grippers, cameras, and mission-specific tools, resulting in an adjustable ROV that is easily customized to fulfill various mission requirements. *Medusa* was designed and manufactured with safety in mind, equipped with two polycarbonate handles for safe retrieval and secure, detachable strain relief to ensure the safety of employees while operating, servicing, or repairing the ROV. This latest frame design has resulted in an affordable, hydrodynamic, and robust ROV that features enhanced maneuverability in mission environments due to its

Figure 8. *Medusa's* Frame (Front and Back)
CAD Model by Lauren Grindstaff

Electronics Housing

Medusa's bottom-side electronics are housed in a 6" Blue Robotics watertight acrylic tube with an outer diameter of 165 mm and a length of 298 mm that is rated to a depth of 65 meters (Figure 9). This transparent acrylic tube allows for quick and efficient visual inspection of the electronic components within the housing. A transparent front-end cap allows the navigation camera to have a large field of view, making it easier to navigate *Medusa* underwater. The cylindrical tube also creates space for a more organized electronics tray and end plate.

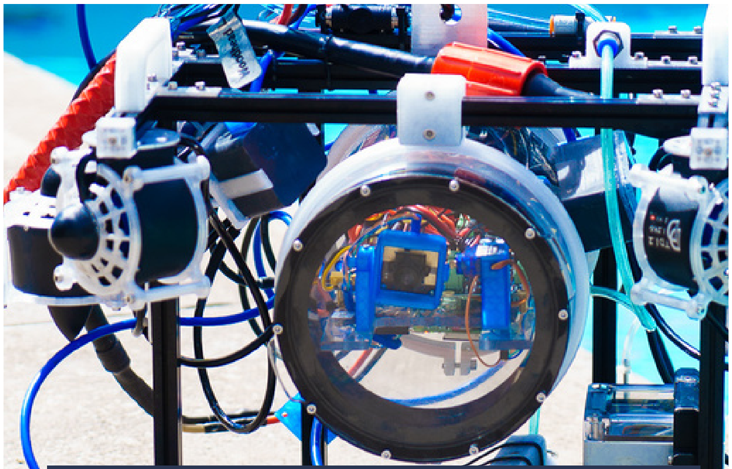


Figure 9. *Medusa's* Electronics Housing
Photo by Lauren Grindstaff

For the back of the enclosure, *Geneseas* chose to manufacture an endplate as opposed to purchasing one. Custom-making the endplate provided *Geneseas* with the ability to optimize the layout of the connectors (Figure 10) while reducing production costs. This custom-designed aluminum endplate was engineered to fit the Blue Robotics tube and features 18 holes for panel-mount connectors.

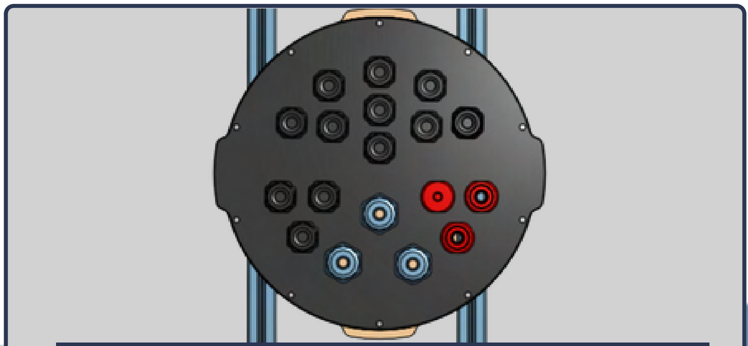


Figure 10. *Medusa's* Endplate
CAD Model by Lauren Grindstaff

Medusa's endplate uses a combination of McMaster-Carr cord grips and Blue Robotics WetLink penetrators for watertight connections between the electronics inside the housing and the thrusters, tools, and camera systems mounted on the ROV. To maximize space on the endplate, the power connector and ethernet connector are in-line connectors that are mounted on the ROV frame, and their corresponding wires are connected to the electronics through McMaster-Carr cord grips.

A pressure testing vent, allows for the enclosure to be vacuum tested and deemed airtight before being placed in the water. This vacuum test verifies that the tube is maintaining a stable pressure of 10 mm Hg for ten minutes.

Geneseas designed and manufactured a custom tray inside the housing to maximize serviceability and safety. This tray was designed in CAD to optimize the placement of components and make manufacturing easier (Figure 11). A custom electronics tray also allows for easy accessibility without the time-consuming removal of the flange system. The tray is connected to the aluminum endplate by a custom 3D printed bracket with four holes for reliable fastening. At the front, the electronics tray sits in another custom bracket designed to provide stability during transportation and mission operations. *Medusa's* electronics tray utilizes both sides to maximize space, allowing the tray to be compact and hold all necessary electrical systems while separating the different components for serviceability. The top-side of the electronics tray includes a custom ESC printed circuit board, two dual SSR relays, two XT30 power distribution blocks, a 5V to 12V converter, and the main navigation camera. The bottom-side of the electronics tray is designated for the Raspberry Pi, 4-port USB hub, and USB-to-Ethernet transceiver. The navigation camera is located at the end of the tray on a servo-driven mount that rotates 90 degrees upwards and 90 degrees downwards, increasing the field of view and allowing for more efficient piloting. The positioning of these components was carefully evaluated to create an efficient layout that optimizes space and provides convenient and easy access to the Raspberry Pi's SD card.

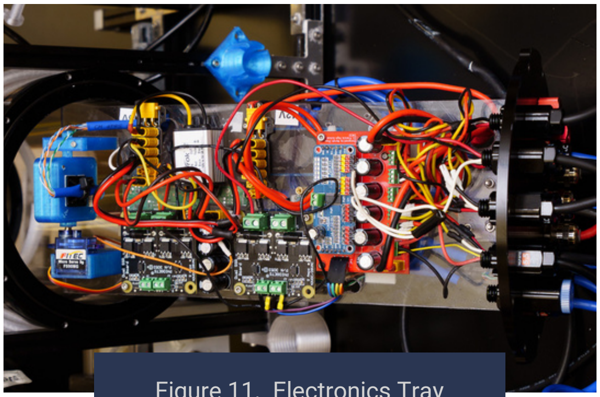


Figure 11. Electronics Tray
Photo by Norah Zhou

Thrusters

For the 2023 season, *Geneseas* aimed to enhance its movement capabilities by increasing the number of thrusters from 4 to 6, which adds lateral movement and enhanced rotational capabilities. The inclusion of left and right translation capabilities provides *Medusa* the ability to perform refined movements allowing mission tasks to be completed faster and with a greater degree of precision.

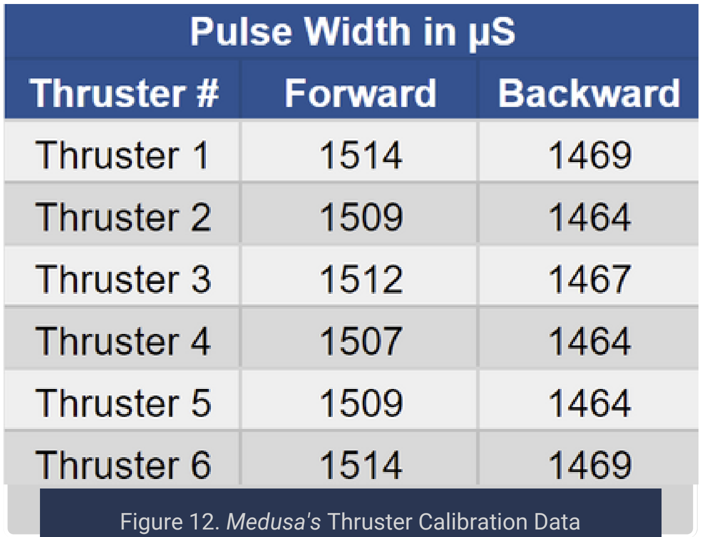
Geneseas conducted a thorough analysis of the potential advantages and drawbacks of switching to a six-thruster system. Employees carefully considered the impact on the design of the ROV's frame, its power requirements, and its maneuverability underwater.

The company researched different options for thrusters, evaluating whether to reuse old Blue Robotics T100 thrusters, buy Blue Robotics T200 thrusters, or purchase a new model of Diamond Dynamics thrusters. The company ordered one of the Diamond Dynamics thrusters, tested it, and compared its performance to that of the T100. *Geneseas* compared the amount of thrust for the Diamond Dynamics thrusters, T100 thrusters, and T200 thrusters at 12 volts and 25 amps. *Geneseas* found that the Blue Robotics T100s and Diamond Dynamics thrusters both produce 1.0 kgf when operating at 36 watts,[1] whereas the Blue Robotics T200s produce 1.13 kgf at 36 watts. *Geneseas* decided to use the Diamond Dynamics thruster due to its availability and affordable price. These thrusters are readily available where the T100s are not due to their discontinuation. Despite the increased thrust capacity of the T200 thrusters, the price of the T200 thrusters is 3.7 times that of the Diamond Dynamics which is only $64; thus, the Diamond Dynamics thrusters present a more optimal propulsion solution. Another benefit of the Diamond Dynamics thruster was the integrated ESC feature. Where the Blue Robotics T100 and T200 thrusters feature separate ESCs that were formerly stored within the electronics housing, the Diamond Dynamics thrusters feature integrated ESCs that allow for the dissipation of heat from the ESCs into the surrounding environment and create extra room in the electronics housing.

Four thrusters are mounted on the top four corners of the ROV underneath the upper frame bars and allow for forward, backward, and lateral movement as well as horizontal rotation. Two thrusters, each mounted in an upward position on vertical bars on the right and left sides of the frame, allow for vertical movement. This mounting configuration was selected over alternative configurations because it maximizes movement and speed while directing thrust away from *Medusa's* tools.

Geneseas chose to reuse an Extreme 3D Pro joystick from previous years to control thruster movement. *Geneseas* employees developed custom code to deliver power to the thrusters and provide all necessary movement. Power calculations from the previous year were adapted to the requirements of a six-thruster ROV. To ensure all thrusters turn on simultaneously and receive an accurate amount of power, employees tested thruster calibration to determine the most accurate range for pulse-width modulation values.

Based on the thruster calibration testing data, employees wrote and implemented a power-limiting function that maps joystick input values to the adjusted pulse-width modulation range (Figure 12). This function helps to avoid abrupt power failures caused when high-power joystick movements are used by dynamically reducing power to the thrusters. Through testing in the pool, employees used feedback provided by the pilot to implement effective dead zones that limit power output to the thrusters to avoid unintentional movement when the joystick is in the neutral position.

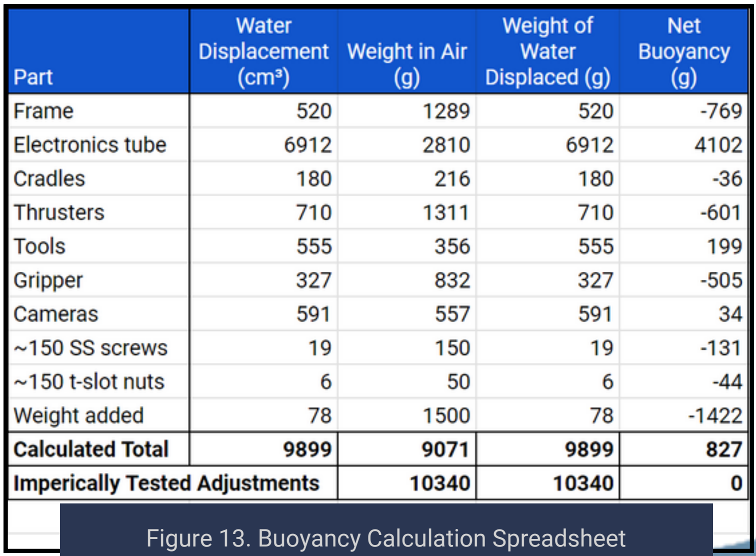


Pulse Width in µS		
Thruster #	**Forward**	**Backward**
Thruster 1	1514	1469
Thruster 2	1509	1464
Thruster 3	1512	1467
Thruster 4	1507	1464
Thruster 5	1509	1464
Thruster 6	1514	1469

Figure 12. *Medusa's* Thruster Calibration Data
by Siena Marois

Buoyancy

Geneseas employees utilized a Buoyancy Calculation Spreadsheet (Figure 13) to regulate *Medusa*'s weight and buoyancy and Archimedes' Principle[2] to calculate the displacement and buoyant force.



Part	Water Displacement (cm³)	Weight in Air (g)	Weight of Water Displaced (g)	Net Buoyancy (g)
Frame	520	1289	520	-769
Electronics tube	6912	2810	6912	4102
Cradles	180	216	180	-36
Thrusters	710	1311	710	-601
Tools	555	356	555	199
Gripper	327	832	327	-505
Cameras	591	557	591	34
~150 SS screws	19	150	19	-131
~150 t-slot nuts	6	50	6	-44
Weight added	78	1500	78	-1422
Calculated Total	**9899**	**9071**	**9899**	**827**
Impercially Tested Adjustments		**10340**	**10340**	**0**

Figure 13. Buoyancy Calculation Spreadsheet
by Lauren Grindstaff

The calculations determined the appropriate materials to use for different parts of *Medusa*. Comparing the buoyant force to the weight of the ROV allowed *Geneseas* to establish whether the ROV would be positively or negatively buoyant. At 6912 cm3, the Electronics Housing is *Medusa's* largest buoyancy component, which makes the overall ROV positively buoyant.

Geneseas employees adjusted the buoyancy by adding two 250-gram weights to the ROV's bottom extrusion to offset the positive buoyancy, making it neutrally buoyant. *Geneseas* employees customize and adjust the buoyancy when different tools are added or removed by varying the amount of weight on the ROV's bottom extrusion based on the Buoyancy Calculation Spreadsheet to achieve neutral buoyancy.

Medusa's tether is another component that affects the overall buoyancy. *Geneseas* engineered an adjustable buoyancy system for the tether system that features stainless steel water bottles attached along the length of the tether. A water bottle is attached to the carabiner clip on the tether's ROV-side strain relief to provide highly customizable and removable buoyancy. The deck crew can modify the position and weight of these bottles by increasing or decreasing the amount of water within each bottle to adjust the overall buoyancy of the tether. This minimizes the tether's impact on *Medusa* while keeping the tether afloat above the ROV, preventing it from becoming entangled during mission operations.

E. Electrical Systems

RPS

The Remote Piloting System (RPS) (Figure 14) was designed with safety, serviceability, and reliability as key principles. The RPS is the top-side control box used to power and control *Medusa* and its pneumatically powered tools. *Genseas* improved the previous year's RPS to enhance sustainability and cost-efficiency by redesigning specific aspects to accommodate recent improvements.

Figure 14. *Medusa's RPS*
Photo by Norah Zhou

For reliability, the RPS was designed and custom-built inside a DEWALT Tough System® DS130 toolbox. This configuration permits a straightforward deck setup that protects the RPS's components during transport. *Geneseas* designed the RPS with industry-standard ports, identifiable controls, and an effective layout that includes a top panel and an easily accessible bottom compartment. The top control panel displays voltage, current, pneumatic pressure, and power indicator lights.

These sensors allow the co-pilot to monitor the power and pressure status during the mission to ensure efficient and safe operations. The top panel includes the emergency power-off switch and two buttons that allow the pilot to easily operate *Medusa's* grippers.

The top control panel's handle reveals the serviceable bottom compartment, which houses the shunt for the amp meter and wiring connected to the top panel's buttons and indicators, enhancing serviceability. This year's RPS features pneumatic solenoids in the bottom compartment due to previous reliability and waterproofing issues when the solenoids were mounted on the ROV. The back and side panels of the RPS feature panel mount connectors that allow for connections to the MATE power supply, computer, and tether. The tether attaches to a secure strain relief on the back panel and connects an Anderson Powerpole 45 for power, two 6.35mm (0.25 inch) pneumatic airlines, and one CAT 6 Ethernet connector.

The new addition or installation of a Raspberry Pi in *Medusa's* electronics housing allows for the control of piloting and electrical tools via a top-side laptop computer, which displays all 6 camera feeds and connects to a USB joystick for ROV control. Genseas' Graphical User Interface (GUI) also allows for control of *Medusa's* electrical tools via specialized buttons. An external monitor can also be connected to display *Medusa's* high-quality camera feeds. A test bench (Figure 15) and System-Integration Designs (SID) (Figure 16) simulate and document the ROV, respectively, and ensure correct wiring of the electronics in the RPS. The test bench replicates the ROV's electronic system and is used to test code compatibility and verify functionality before testing is performed. *Medusa's* RPS testing and planning, utilizing the test bench and SID, has yielded a reliable and serviceable top-side control station that efficiently supports mission operations.

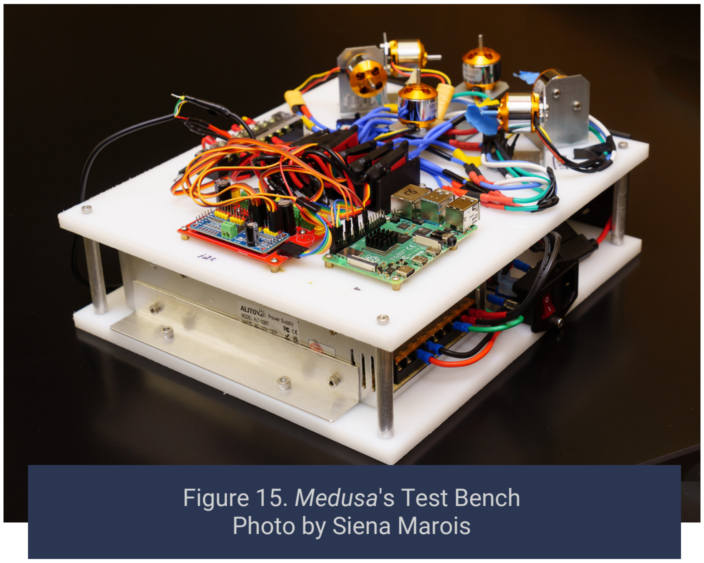
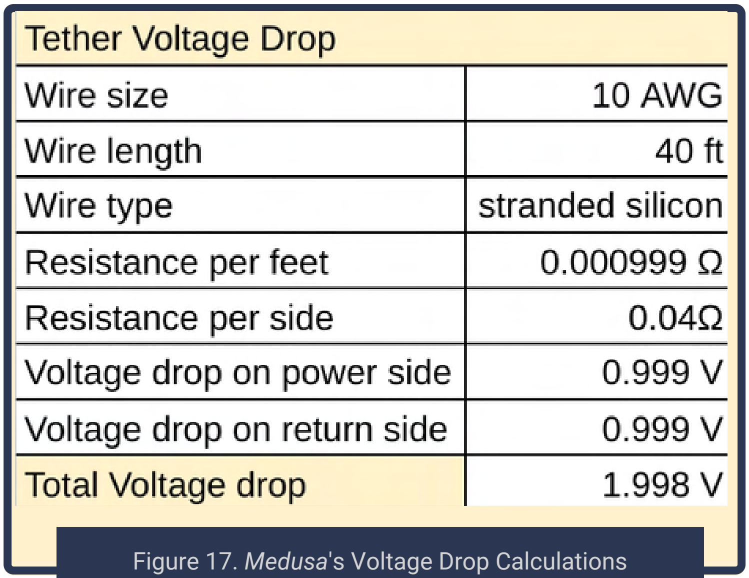


Figure 15. *Medusa*'s Test Bench
Photo by Siena Marois

Tether

Medusa's tether features one CAT6 Ethernet cable, 10 AWG power cables, and two pneumatic lines. The length of the tether was determined by using a Voltage Drop Calculator (Figure 17) to find the optimal length, wire gauge, and wire type. *Geneseas*' employees concluded that a 12-meter, 10-gauge power cable is necessary to optimize the 25-amp fuse-limited current draw. As shown in Figure 17, the voltage drop across the tether is just under 2 V. This design provides efficient and reliable transfer of power and signals from the RPS to the ROV while allowing sufficient tether length for the ROV to successfully perform mission tasks.



Tether Voltage Drop	
Wire size	10 AWG
Wire length	40 ft
Wire type	stranded silicon
Resistance per feet	0.000999 Ω
Resistance per side	0.04Ω
Voltage drop on power side	0.999 V
Voltage drop on return side	0.999 V
Total Voltage drop	1.998 V

Figure 17. *Medusa*'s Voltage Drop Calculations
by Norah Zhou

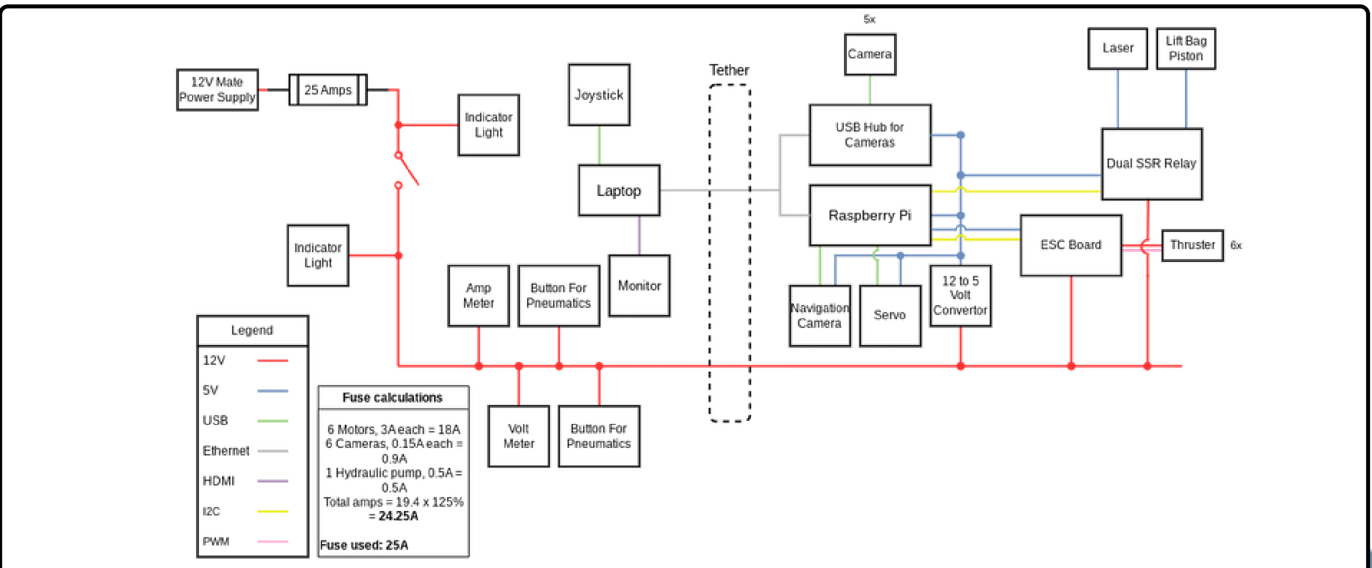


Figure 16. *Medusa*'s Top-side and Bottom-side Electronics
by Norah Zhou

Medusa's tether (Figure 18) includes two separate pneumatic lines, which connect the ROV's grippers to the solenoids within the RPS. The tether includes one CAT-6 Ethernet cable, split to transmit data signals from the Raspberry Pi, and the navigation camera feed between the RPS and the ROV. The two 10-gauge silicone power lines maintain great flexibility while minimizing the voltage drop throughout the tether. With a projected 16.5 amp current draw from the ROV, it was necessary to select 10 AWG wires to maintain a minimum of 10 volts to the ROV. A durable woven nylon sheathing protects the tether components while allowing for disassembly if service is needed. The bright neon yellow sheathing was selected to increase visibility in the water and prevent entanglement.

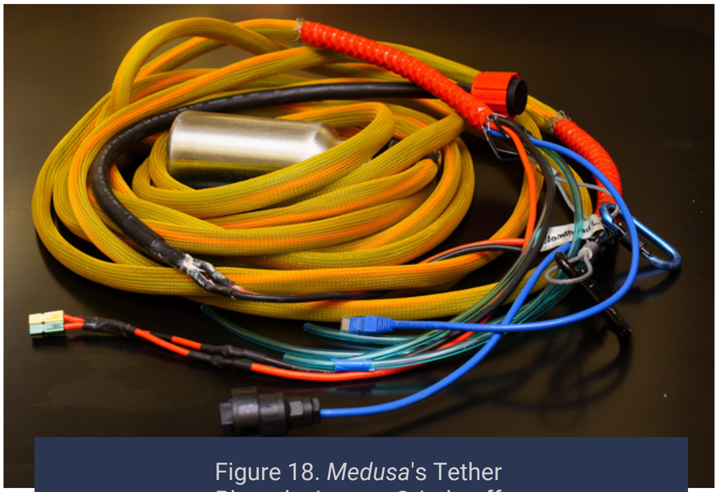


Figure 18. *Medusa*'s Tether
Photo by Lauren Grindstaff

The *Geneseas* tether manager is responsible for storing, maintaining, and handling the tether during mission operations. The tether manager begins their duties during mission set-up by uncoiling the tether and connecting the top-side of the tether to the RPS and the bottom-side of the tether to the ROV beginning with the strain relief. When connecting the rest of the tether to the ROV, the tetFher manager attaches the in-line power connector, in-line Ethernet connector, and two pneumatic lines sequentially. After *Medusa* is successfully deployed, the tether manager provides slack to enable ROV movement and adjusts the tether length as needed to prevent entanglement. Water bottles are attached along the length of the tether to create neutral buoyancy and prevent entanglement during missions. An empty water bottle located at the end of the tether close to the ROV connection point helps position the tether directly above the ROV, allowing for easier ROV maneuverability. The tether manager inserts and removes the ROV from the water by placing one hand on the strain relief and the other on the upper handle. Upon mission completion, the tether manager safely disconnects the tether from both the top-side RPS and bottom-side ROV and carefully coils it for compact and safe storage in the tether bag.

ROV Electronics

Medusa's electronics system was designed with the priorities of serviceability and reliability. This year, *Geneseas* switched from an Arduino to a Raspberry Pi 4B+ microcomputer which was selected over alternative microcomputers because of its high versatility, libraries, and ability to run multiple applications simultaneously. Since the Raspberry Pi 4B+ only has 2 sets of PWM pins and 6 are required to operate *Medusa's* 6 thrusters, *Geneseas* designed a custom-printed circuit board for the thrusters, which allows for the connection of all thruster wires to one board. An Adafruit servo driver on the custom PCB allows the Raspberry Pi to control the thrusters. The servo driver is connected with pin headers and can be replaced if needed, increasing serviceability and reliability. The PCB contains screw terminals for the thrusters' power, ground, and signal wires, preventing accidental shorts and increasing serviceability. The board includes capacitors to reduce any sudden voltage drop when the thrusters turn on and XT30 connectors to reliably power the thrusters.

Medusa's electronics housing contains a Raspberry Pi, two XT30 distribution blocks, a 5V to 12V converter, and two dual SSR relays. The XT30 power distribution block was selected because its efficient design optimizes the space on the electronics tray while ensuring ease of removal and high serviceability of all connected components. The X30 power distribution block also connects the 12V to 5V converter, which connects to a second XT30 distribution block that powers tools and the navigation camera. The Raspberry Pi signals the dual SSR relays to efficiently power the electrical tools.

Submersible Connectors

Medusa’s endplate features three McMaster-Carr cord grips used for power and Ethernet, one Blue Robotics vent, and fourteen 5.5 mm Blue Robotics WetLink penetrators used for thrusters, tools, and cameras. This year, *Geneseas* switched from using Blue Robotics cable penetrators to Blue Robotics wet link penetrators because of their serviceability and reliability. *Geneseas* chose to replace the previous panel-mount Ethernet connector with an in-line Bulgin Ethernet connector to address waterproofing concerns. This in-line connector delivers signal and power to the ROV. *Medusa* also features a three-pin inline SubConn power connector that is used to distribute power through the tether. Subconn and Bulgin connectors enable disconnection of the tether from the ROV and RPS, allowing for safe storage and transportation, which prevents damage to the ROV system components.

F. Top-side and Bottom-side Software

Medusa’s top-side and bottom-side platforms, which were previously programmed in C/C++, have now been switched to Python 3 as a result of the transition from Arduino to Raspberry Pi. *Geneseas* chose Python 3 as it is a prevalent language and having one main language for the ROV system simplifies learning for team members, increasing their ability to develop fluency in Python.The bottom-side software, located in the ROV’s electronics housing, is programmed on a Raspberry Pi 4B+. The top-side software, which collects all inputs, is run on a laptop that is in constant communication with the bottom-side Raspberry Pi. The ROV's bottom-side platform receives information from the top-side to update its thrusters, controllers, and actuators. The top-side laptop communicates with the bottom-side Raspberry Pi via TCP-based sockets. Joystick values and other inputs are streamed over these sockets, based on their IP address and port number, and are then processed by the Raspberry Pi.

ROV thrusters are controlled from a single joystick, allowing for efficient rotation and smooth movement forwards, backwards, left, right, and vertically. In order to prevent power failure to the ROV, *Geneseas* uses functions that may limit the amount of power thrusters receive when *Medusa’s* pilot accelerates the ROV. The function calculates a gradual increase in power based on the joystick movements. The thruster values are then assigned and sent to each thruster.

Last year, *Geneseas’* GUI (Graphical User Interface) was programmed in Python 3 to display the camera system and perform various autonomous tasks. *Geneseas* employees decided to adapt all software systems to run on the same language, Python 3. Having one main language for the ROV system simplifies learning for team members, allowing for the integration of all software systems, enabling a single user to have control over all the software while using ROV.

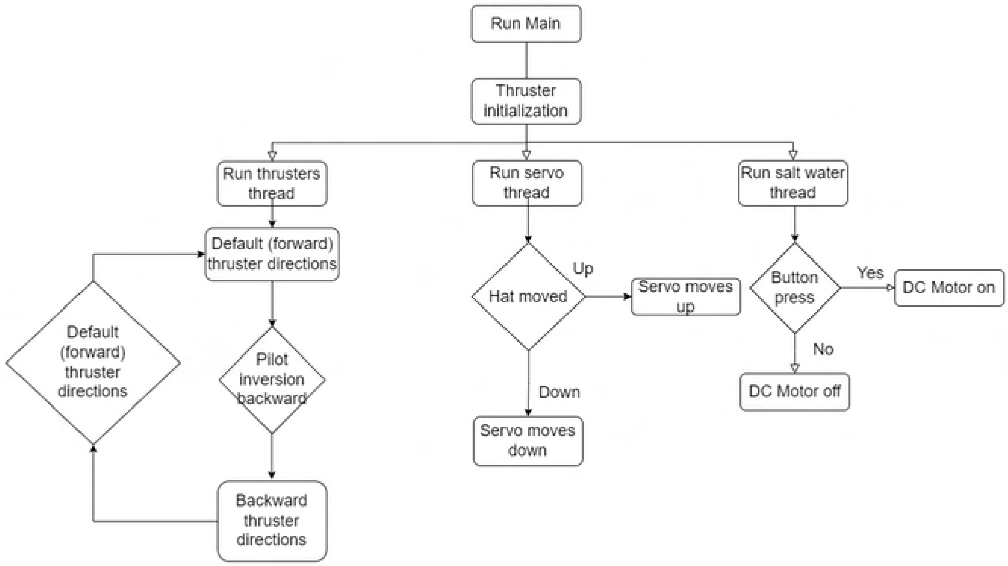


Figure 19. *Medusa*'s Bottom Software
by Siena Marois

G. Digital Camera System

Medusa features a multi-stream, low-latency, fully digital camera system. This 5 camera system provides the pilot extremely clear video for navigation and tool usage, along with a digital video stream for advanced image processing.

The development began with a design review of the previous year's camera system. The team determined the new design goals of integrating the camera system to stream from the new Raspberry Pi computer and reducing the size of the individual camera enclosures. *Geneseas* decided to continue using the Megapixel USB camera due to its low average latency of 127 milliseconds.

Medusa's vision system is highly robust and reliable resulting from the separation of the mission cameras and the main navigation camera. The main navigation camera, mounted at the front of the electronics housing on a servo to provide and adjustable field of view, transmits video directly over ethernet whereas the four mission cameras connect to the Raspberry Pi via mini-PCB connector boards and stream from the Raspberry Pi. This vision system architecture ensures highly reliable video streaming and low latency of the main navigation camera.

This year, a key objective was to reduce the size of the individual camera enclosures. CNCing custom camera enclosures made from type II PVC sealed to a polycarbonate lens with silicone yielded a compact, durable, and highly specialized camera enclosures. *Geneseas* achieved a 46% reduction in size by custom designing and machining camera enclosures. The four mission cameras are affixed to the frame by custom 3D printed polycarbonate mounts providing views of the saltwater tool, both grippers, and a downwards facing view for flying the transect. The m navigation camera is a wide angle camera that is able to be rotated 180 degrees via the joystick to display a forward facing view, upwards view, and visibility of the front gripper and lasers.

Medusa's camera mounts combine fixed and adjustable features, enabling easy adjustments during missions. This innovative camera system allows for high quality video streams at multiple viewpoints, enhancing the overall maneuverability of the ROV, and ensuring mission tasks can be completed with increased accuracy and precision.

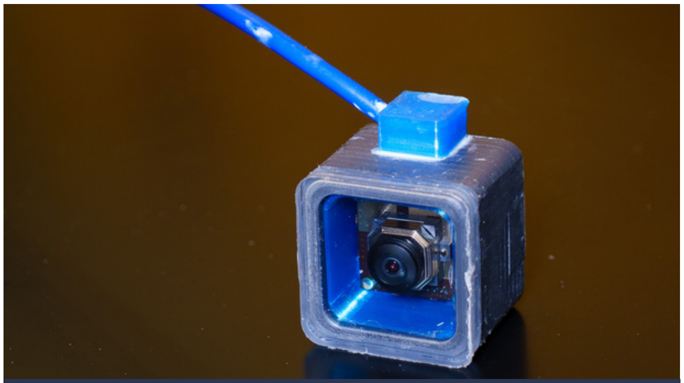


Figure 20. One of *Medusa's* Mission Cameras and Enclosure
Photo by Morgan Jones

H. Pneumatics

Medusa features three pneumatic tools: two pneumatic grippers and one lift bag. To power these tools, *Medusa*'s pneumatic system receives air from MATE, regulated to 2.76 bar (40 psi). The air is sent through a ¼-inch pneumatic line, which is split and controlled by two solenoids housed inside the RPS. These solenoids are opened and closed by the copilot using buttons on the RPS. When the solenoids are opened, the pneumatics lines are pressurized and the associated tools are activated. *Medusa*'s pneumatics SID is shown in Figure 21.

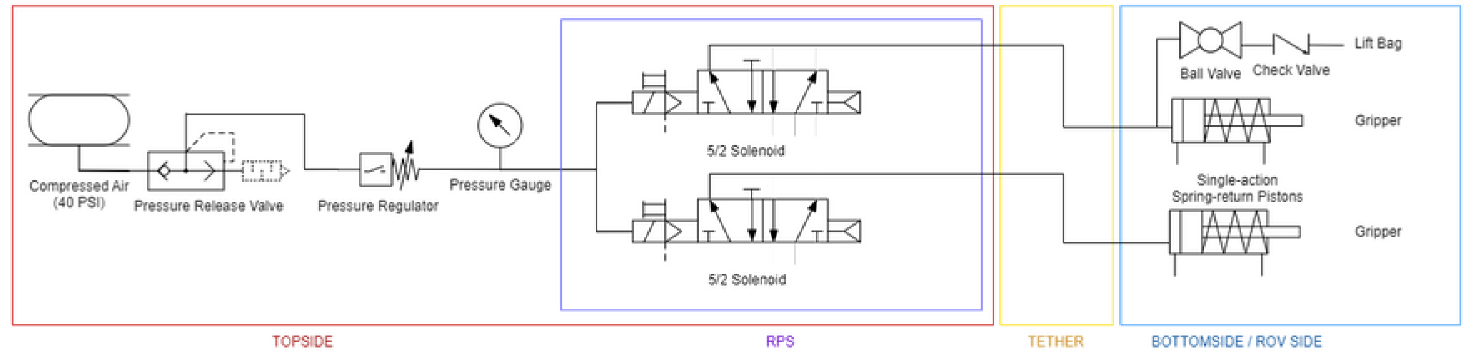


Figure 21. *Medusa*'s Pneumatic SID
by Isa Gutierrez

I. Mission Tasks

Pneumatic Gripper

Medusa is equipped with two identical parallel-jaw pneumatic grippers. These grippers include a rack and pinion system, a single-action spring return piston, interchangeable gripper arms, and custom rotating mounts. By adding a second gripper, *Medusa* is capable of completing tasks more efficiently by increasing the ROV's carrying load, reducing the need to surface. *Geneseas* team members designed each gripper in CAD, modifying the size and design to meet the needs of each task. Key decisions include a) ensuring the grippers open to at least 4 inches to manipulate larger objects such as the lift bag, b) creating interchangeable gripper arms to complete various tasks such as installing long term cameras and a floating solar panel array and c) developing custom mounting to enable rotation of the grippers' orientation.

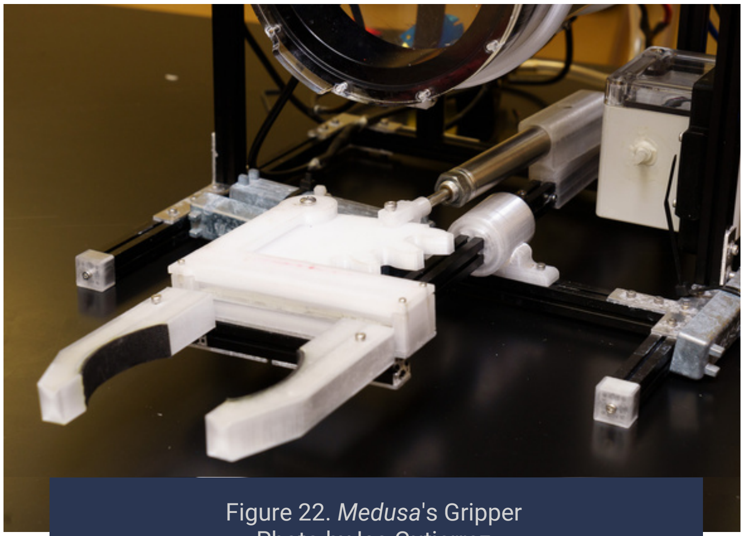


Figure 22. *Medusa*'s Gripper
Photo by Isa Gutierrez

To ensure the smooth operation of all moving parts, *Geneseas* members conducted calculations in order to properly manufacture correct rack and pinion ratios.[3, 4] All gripper parts were 3D printed in polycarbonate and reinforced with an aluminum base to guarantee a durable and reliable tool. To improve pilotability, the parallel-jaw grippers consist of one moving arm and one fixed arm. The gripper is operated under co-pilot control through the activation of a toggle button to open a solenoid in the RPS, pressurizing the pneumatic lines in the tether and extending the pistons. The linear piston extension causes the pinion to rotate approximately 90°. This rotation is then converted to a 4 inch linear translation of the rack and moving arm, closing the parallel jaws. Having one fixed arm makes it more intuitive for the pilot to precisely manipulate objects. *Medusa's* newly modified gripper design is one of Geneseas' most versatile and reliable tools. These grippers are used to service solar panels (Task 1.1), remove biofueling (Task 1.2), install an eco-mooring system (Task 2.4), install a long-term camera (Task 2.7), and perform other tasks such as servicing inter-array power cables.

eDNA Tool

The eDNA tool is used to collect a DNA sample and return it to the surface for DNA analysis. For this mission, *Geneseas* identified three important design principles for the eDNA tool: reliability, collection speed, and pilotability.

To address the challenges of waterproofing underwater pumps and maintaining contamination-free collections during DNA collection, *Geneseas* opted for a self-priming peristaltic pump that moves liquid through a silicone tube without any contact with the sample. This pump is enclosed inside a highly reliable off-the shelf Polycase enclosure. Initially, *Geneseas* chose a pump based on a flow rate specification of 3.6ml/sec to ensure *Medusa* could collect the sample in approximately 15 seconds. *Geneseas* tested the flow rate of the pump and recorded a flow rate of 4.1ml/sec, exceeding the pump's specifications. *Geneseas* designed a custom, replaceable alignment system that features a replaceable polycarbonate alignment cone with a sharpened metal straw (Figure 23) to maximize efficiency when collecting the DNA sample. The straw is connected to the peristaltic pump and a 80mL collection bag which safely stores the sample onboard the ROV. The replaceable alignment cone enables iterative improvements in pilot usability and adaptability for future tasks. The *Geneseas* eDNA tool is an efficient, easily pilotable, and highly reliable tool used to successfully complete Task 2.2 by collecting the eDNA sample from the coral head.

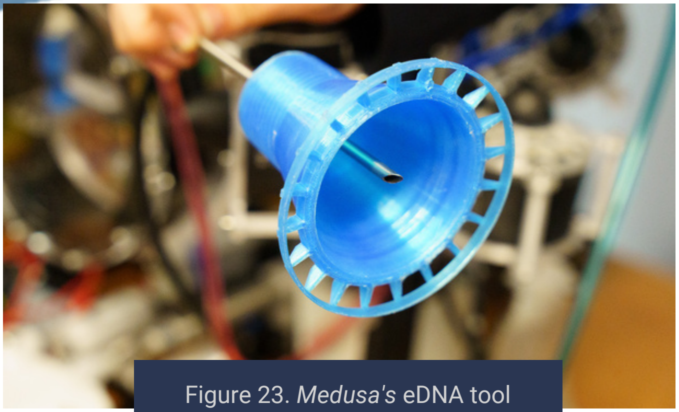


Figure 23. *Medusa's* eDNA tool
Photo by Audrey Mayo

Lift Bag Tool

Medusa's lift bag tool is designed to float a heavy object, weighing up to 60-newtons in water, to the surface. *Geneseas* selected a eight-liter nylon dry bag to float the object to the surface since the object's weight exceeds the ROV's lift capacity. The lift bag inflates in approximately 22 seconds at 40 psi and a depth of 13 feet and surfaces the object in less than 30 seconds (See Figure 24). This tool effectively completes Task 2.6 and is capable of lifting heavy objects of varying weights and sizes due to its robust design.

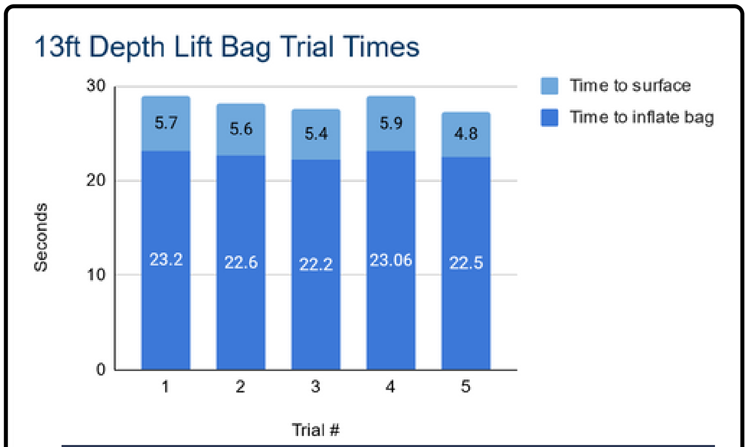
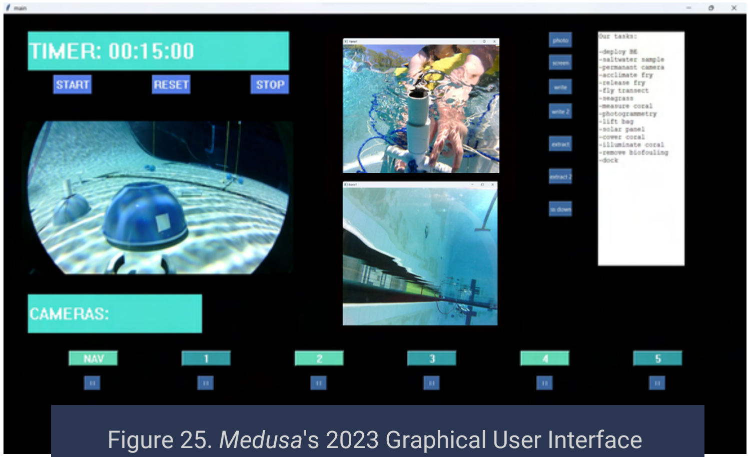


Figure 24. Lift Bag Testing Data
by Laila Shamshad

Graphical User Interface (GUI)

Geneseas developed a custom graphical user interface (GUI) for the control of all vision, movement, and image recognition systems. This GUI, developed in Python, provides an easily-operable control center to ensure a user-friendly experience for the crew. The GUI displays *Medusa's* five cameras–the core navigation camera as well as four tool cameras. Through this multi-perspective display, the pilot is able to effectively control the ROV and view its surroundings from many angles. The GUI consistently displays the navigation camera stream in its main window and allows the user to view any number of the tool cameras individually. These tool camera windows are able to be manipulated in size and placement, with the option to be displayed on a separate monitor for better pilot visibility based on each unique task's specifications. A task panel—located on the side of the GUI—is available to aid the user in calculations, image recognition tasks, and other various mission needs. Some features of this panel include a text editor to organize notes and keep track of mission task order, buttons to digitally view the Coral Reef Fish Species and Northern Redbelly Dace Release Handbooks, a 15-minute timer to aid in mission run productivity, and functions to record camera feeds for later analysis.



```
Our tasks:

-deploy BE
-saltwater sample
-permanant camera
-acclimate fry
-release fry
-fly transect
-seagrass
-measure coral
-photogrammetry
-lift bag
-solar panel
-cover coral
-illuminate coral
-remove biofouling
-dock
```

Figure 25. *Medusa*'s 2023 Graphical User Interface
Photo by Sydney Goodall

Photogrammetry

Geneseas selected RealityCapture, to create a 3D model of the coral head. RealityCapture was chosen for its cost, ability to operate without an internet connection and speed, completing this task two minutes faster than the other software tested. *Geneseas* collects the images to construct the model by taking a continuous video of the coral head while the pilot maneuvers around the object. The video is then split frame-by-frame using a custom Python script and imported into

RealityCapture. The software pieces together the frames to construct a 3D model.

Lasers are used to measure the diameter and height of the coral head, as well as the total diseased area. Two lasers are mounted so they will converge 45 cms from the main ROV camera. The pilot secures the ROV on the ground with the lasers converging. A photo is taken and an image is uploaded into a measurement Python script, where the users can select the coral's boundaries. Once the boundaries have been marked, the program counts the number of pixels between the user's selections. Using a known ratio, the program converts the number of pixels into absolute measurements in centimeters.

This photogrammetry system delivers accurate renderings of the coral head, successfully completing Task 2.1 and can also be utilized for other underwater applications like constructing 3D models of shipwrecks.

Buoyancy Engine

Geneseas developed *Aurita,* a buoyancy engine, to complete vertical profiles and transmit data back to the mission control station. The buoyancy engine's main design goals were to efficiently increase and decrease overall buoyancy, improve power reliability and longevity, optimize sensor usage, and incorporate wifi signaling. These objectives were informed by lessons learned from the previous year's design, resulting in design modifications.

Geneseas' buoyancy engine utilizes powerful C-cell batteries, chosen for their long run time over previously used AA batteries. When designing the storage compartment, *Geneseas* chose to separate the batteries from the control electronics for serviceability. This separate, watertight enclosure for batteries allows *Geneseas* to easily replace batteries when necessary and features a pressure relief plug for safety.

Aurita features an ESP32 microcontroller, a cost efficient component selected for its integrated WiFi capabilities and low-power consumption. A low-power system improves the reliability of the buoyancy engine and allows *Geneseas* to better allocate power to the sensors and servo.

The float completes vertical profiles by adjusting the device's buoyancy via a 300 mL syringe that ingests and expels water. The 300 mL syringe allows *Aurita* to adjust its buoyancy significantly, ensuring reliable and efficient vertical profiles. To avoid the addition of unnecessary positive buoyancy, *Geneseas* placed a large portion of the syringe's volume outside the main compartment. The float features a servo motor and lead screw that work together to adjust the volume of the syringe and ingest and expel water in the syringe when triggered by the pressure sensor.

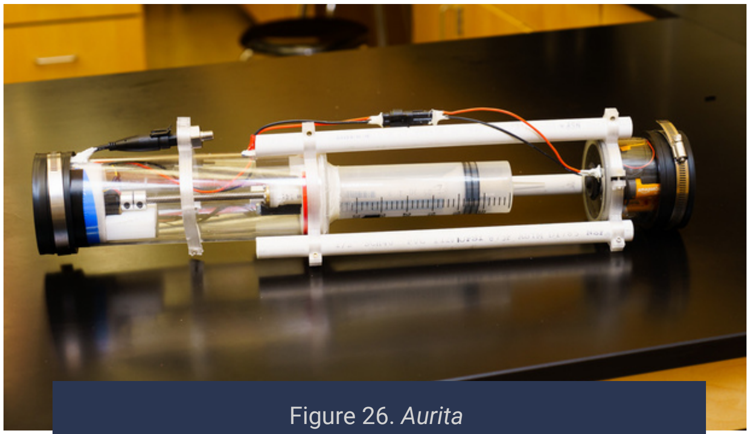


Figure 26. *Aurita*
Photo by Isa Gutierrez

Aurita begins the mission at the surface and transmits the time via wifi from the ESP32 to the axis point in the RPS, beginning its mission run. After transmitting the time, the float ingests water, decreasing the buoyancy, causing it to sink. Once the pressure stops increasing, the float has reached the bottom of the pool. The ESP32 triggers the servo to move the plunger and expel water from the syringe, increasing the buoyancy and bringing the device to the surface. When the buoyancy engine reaches the surface, the ESP32 transmits the time of surfacing in UTC which can be read from the monitor. This cycle repeats twice.

Geneseas engineered *Aurita*, a robust and reliable buoyancy engine, capable of completing vertical profiles and transmitting data to the mission control station. The design incorporates lessons learned from the previous model and achieves high efficiency through these enhancements.

Fry Container

Geneseas designed the fry container tool with a focus on simplicity and efficiency. The tool utilizes a small open box and a two-hinge system. The box was designed in CAD and 3D printed to optimize the shape to best suit *Medusa's* grippers. The fry container is positioned upside down in the gripper before the mission. During the mission, the pilot places the fry in the designated release area, allowing the fish to acclimate for twenty seconds before the gripper is released. By releasing the gripper, the plastic wings connected to the hinges collapse. When the pilot regrips the fry container and maneuvers upwards, the fish are released into the designated area. This simple and versatile tool effectively completes Task 2.5 by safely transporting the fry fish to the safe release area. This container can be easily scaled and modified to accommodate the transport of larger marine life.

Light Source

Genseas developed the UV light source to be highly adjustable and interchangeable. This tool is designed to irradiate diseased coral and consists of two parts: the light source and the lamp shade. The light source features a green LED light chosen because it emits light at 520 nm which is optimal for a photoresistor with a spectral peak of 540 nm. This LED light was chosen for its high luminosity.[5, 6] This LED light is positioned in a custom 3D printed holder with external threading. The lamp shade is 3D printed in black PETG to block out light from reaching the photoresistor. The lamp shade had internal threading, allowing it to be easily attached to the light source portion of the tool. The ability to interchange the lampshades allows for a high level of adaptability, resulting in greater mission precision to facilitate the successful irradiation of the diseased coral and completion of Task 2.3.

J. Design Evolution

Medusa, *Geneseas'* fourth-generation ROV, features design improvements and innovations from prior generations, which were further refined throughout the season. Valuable insights from the prior year served as the foundation for primary design objectives, which informed major build decisions. *Geneseas* improved ROV performance through the addition of a Raspberry Pi microcomputer, six Diamond Dynamics thrusters, and five compact digital cameras, yielding an improved ROV that is highly reliable and efficient during missions.

Medusa's design was more than an evolution from previous designs, but a progression throughout the season as *Geneseas* employees continuously iterated the designs to develop more efficient components and more effective tools. *Geneseas*' design philosophy prioritizes iteration, leading to specialized and mission-specific ROVs, exemplified by *Medusa's* design evolution.

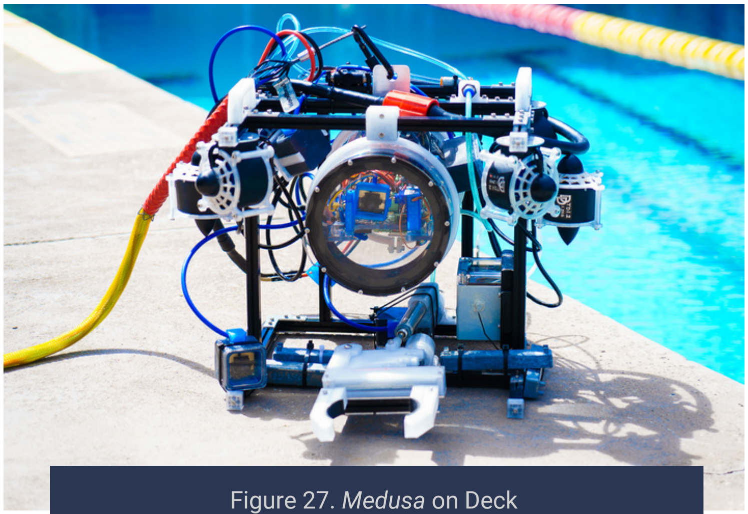


Figure 27. *Medusa* on Deck
Photo by Isa Gutierrez

Geneseas' design philosophy emphasizes iteration, with employees conducting numerous design reviews and producing multiple iterations of tools and main ROV components , resulting in a highly robust and specialized ROV. Through ongoing identification of areas for enhancement, *Medusa's* design underwent continuous refinement, adapting its camera, frame, and tool configurations. Across the season, the ROV progressed into an agile and mission-centric system, featuring modularity and interchangeability, with the capability to irradiate diseased coral, construct accurate 3D models of coral heads, and service marine solar panels with agility and precision.

IV. TESTING AND TROUBLESHOOTING

Geneseas tests individual components and the ROV as a whole throughout the development process to ensure reliability and functionality. Various elements of the core ROV were tested and employees spent extensive time testing new features on the test bench and in the pool. Employees tested thruster reliability this year because *Geneseas* purchased new Diamond Dynamics thrusters. To test reliability, employees wrote custom code that ran continuously, sending a single Diamond Dynamics thruster 2000us (forward) for five seconds and 1000us (backward) for five seconds. This preliminary test checked for motor reliability as well as efficiency. *Geneseas* employees also verified thruster calibration. Using a custom program, employees input various pulse width values to determine the exact pulse width required to turn on each thruster in both directions. Verifying thruster calibration enabled the team to adjust the movement software to ensure all thrusters turned on simultaneously. *Geneseas* uses a two-step testing process on all tools. Once the tools were developed, employees dry tested the components to check for design flaws and verify reliability. This includes testing the saltwater pump for functionality and to ensure sufficient suction. The second step was to test the tool in the water to verify its success and for the pilot to suggest adjustments to the tool that will improve mission performance.

Geneseas employees created a new test bench, a mobile replication of the ROV, which includes improved wire management, a new six-thruster layout and a new Raspberry Pi 4 board to mimic the changes made to the ROV. The test bench allowed the *Geneseas* software team to test code on the test bench while other members of the team worked on *Medusa* directly. This allowed simultaneous development and testing of *Medusa's* movement software, navigational camera servo software, and socket communication between the GUI and Raspberry Pi. After software was developed for the ROV, employees dry tested all software prior to testing it in the pool to ensure general functionality of the developed software. When the dry run test was successful, employees then moved to the pool, where various software elements were tested. In-Pool testing was necessary for movement software to ensure proper functionality of the thrusters in the water. This test bench was critical to the code troubleshooting process enabling *Geneseas* employees to isolate and debug the code independently from the ROV while allowing for parallel development of *Medusa's* hardware and software.

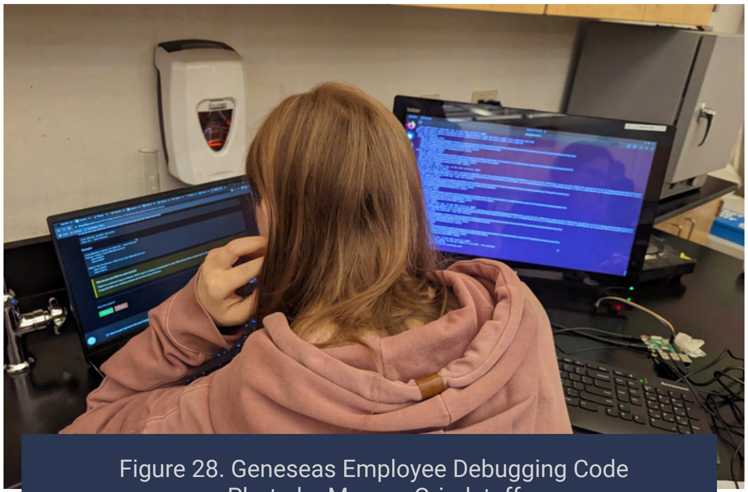


Figure 28. Geneseas Employee Debugging Code
Photo by Marcus Grindstaff

V. SAFETY

A. Safety Philosophy

Safety is *Geneseas*' highest priority. The company places the utmost importance on safety and prioritizes the well-being of its employees, customers, and the public. *Geneseas* enforces rigorous safety protocols across all stages of its product development, testing, and operation. *Geneseas* continues to exceed the safety guidelines outlined by MATE, creating and implementing its own safety policies to foster a safe and supportive learning and working environment.

Detailed and informative safety training instructs employees and mentors on how to avoid injuries and prevent accidents. All employees receive basic training that covers critical topics, including lifting safety, electrical safety, tool safety, hazardous materials handling, and housekeeping. *Geneseas*' deck crew is required to receive additional operations-based training to ensure safe operation of the ROV in accordance with safety policies and the JSA.

The core principle of safety guided *Medusa*'s design and structure which includes numerous safety features in all aspects of the design from the frame to the tether to RPS. For *Geneseas*, safety is not simply a policy but a core value that guides every action and decision.

B. Safety Protocols

Geneseas requires all employees to practice basic safety by wearing closed-toe shoes, tied hair, and PPE when machining, soldering, or working with the ROV. Safety glasses are a constant in the lab, in addition to gloves, masks, and ear plugs that are required to operate tools and handle certain materials and machines while working in the lab.

Geneseas' mentors and senior team members train and supervise new employees on safe machine usage. This includes securing equipment, planning and organizing the workspace to prevent accidents, and following safety protocols. New employees may work independently after demonstrating their ability to operate machines safely. All employees prioritize safety by helping and reminding each other to uphold the highest safety standards.

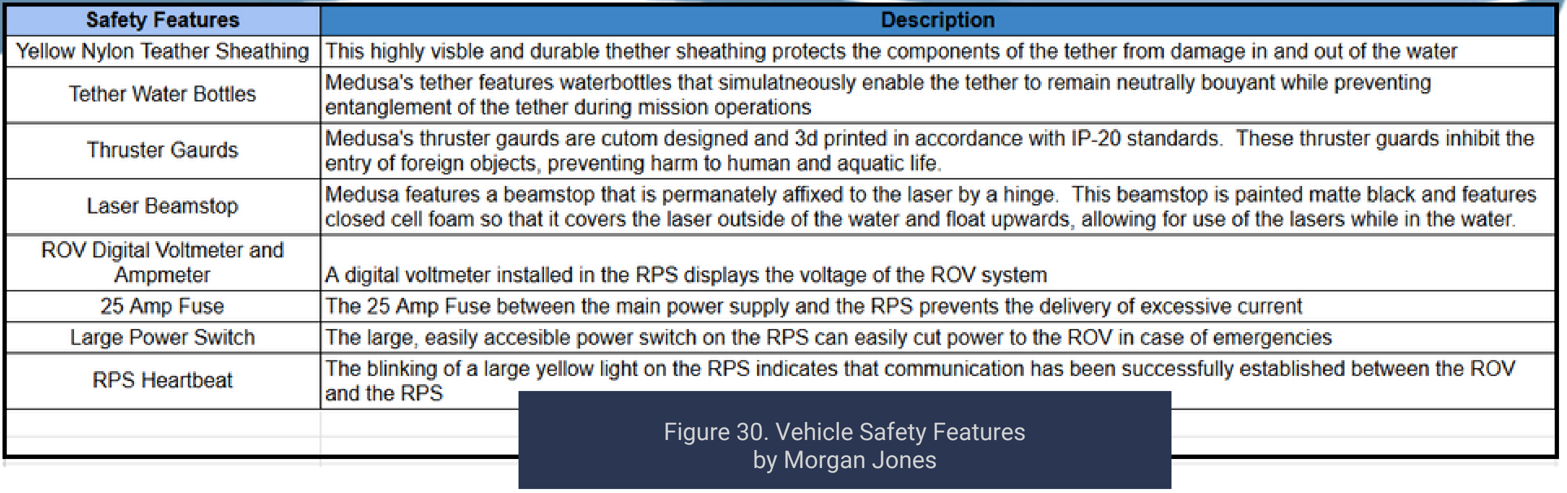
To ensure safety during pool practices, *Geneseas* team members follow a detailed checklist and adhere to protocols outlined in the Job Safety Analysis. When working near water, employees exercise safety by keeping electrical cords and electronic devices away from moisture. To minimize the risk of harm, the Deck Crew communicates clearly with the pilot and tether manager, and the ROV is thoroughly dried after all operations. The RPS, laptops, and pilot station are placed on an elevated platform during pool operations to reduce potential risks. *Geneseas*' detailed operations safety training prepares members of the deck crew to identify and minimize any on-deck hazards through safe operation procedures and practice. Deck crew members extensively practice set-up, mission operations, and breakdown to ensure effective communication and operations procedures that create a safe and efficient deck environment.

Geneseas emphasizes the importance of an organized workspace to ensure the efficiency and safety of all employees. Upon completing a task, employees promptly discard waste materials and scraps and return tools and reusable materials to their designated places. First aid kits and fire extinguishers are easily accessible, and preemptive safety measures are implemented through proper employee training. These safety measures have been highly effective in educating employees about potential hazards and preventing avoidable accidents or injuries.

Figure 29. Geneseas Employees in the Lab
Photos by Marcus Grindstaff

C. Vehicle Safety Features

Geneseas' integration of safety into their design process is reflected in *Medusa's* numerous safety features. These safety features (Figure 30) are present on the physical ROV including thruster guards and thruster safety labels to protect operators and safety features such voltmeters and ammeters for monitoring voltage and current built into *Medusa's* RPS. The ROV and RPS are well-organized and designed to enhance the efficiency of inspection, maintenance, and serviceability of the ROV system and include safety features that prevent accidents, avoid injuries, and enable swift responses to potentially dangerous situations.



Safety Features	Description
Yellow Nylon Teather Sheathing	This highly visble and durable thether sheathing protects the components of the tether from damage in and out of the water
Tether Water Bottles	Medusa's tether features waterbottles that simulatneously enable the tether to remain neutrally bouyant while preventing entanglement of the tether during mission operations
Thruster Gaurds	Medusa's thruster gaurds are cutom designed and 3d printed in accordance with IP-20 standards. These thruster guards inhibit the entry of foreign objects, preventing harm to human and aquatic life.
Laser Beamstop	Medusa features a beamstop that is permanately affixed to the laser by a hinge. This beamstop is painted matte black and features closed cell foam so that it covers the laser outside of the water and float upwards, allowing for use of the lasers while in the water.
ROV Digital Voltmeter and Ampmeter	A digital voltmeter installed in the RPS displays the voltage of the ROV system
25 Amp Fuse	The 25 Amp Fuse between the main power supply and the RPS prevents the delivery of excessive current
Large Power Switch	The large, easily accesible power switch on the RPS can easily cut power to the ROV in case of emergencies
RPS Heartbeat	The blinking of a large yellow light on the RPS indicates that communication has been successfully established between the ROV and the RPS

Figure 30. Vehicle Safety Features
by Morgan Jones

D. Operations and Safety Checklists

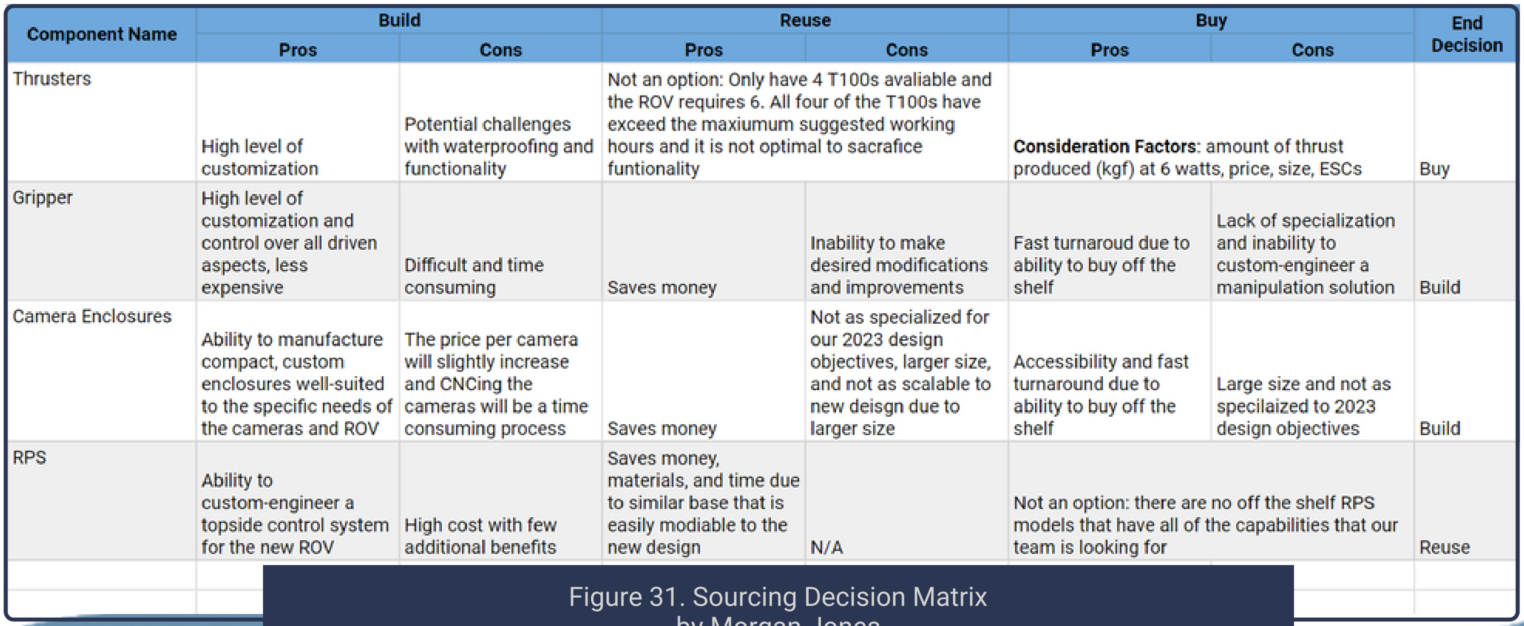
Geneseas develops and utilizes operations and safety checklists (Appendix A) to ensure the safety of employees, customers, and bystanders in the launch, operation, and retrieval of *Medusa*.

VI. ACCOUNTING

A. Budget

Geneseas prepares a budget for ROV development based on the previous year's build expenses and considering the 2023 MATE competition requirements. Income is based on funding from St. Francis High School to cover materials and operations. Awards and donations are also included as sources of income. At the start of the year, each subteam creates and submits a project proposal that includes projected expenses for ROV design improvements and new tool development.

All purchases are made with mentor approval, and the team utilizes a tracking system to manage orders and inventory, resulting in more detailed budget monitoring. The budget is referenced throughout the manufacturing phase to ensure the project remains within budget. *Geneseas* employees are responsible for their travel and meal costs, which are categorized separately in the competition budget. Refer to Appendix B.



Component Name	Build		Reuse		Buy		End Decision
	Pros	Cons	Pros	Cons	Pros	Cons	
Thrusters	High level of customization	Potential challenges with waterproofing and functionality	Not an option: Only have 4 T100s avaliable and the ROV requires 6. All four of the T100s have exceed the maxiumum suggested working hours and it is not optimal to sacrafice funtionality		**Consideration Factors:** amount of thrust produced (kgf) at 6 watts, price, size, ESCs		Buy
Gripper	High level of customization and control over all driven aspects, less expensive	Difficult and time consuming	Saves money	Inability to make desired modifications and improvements	Fast turnaroud due to ability to buy off the shelf	Lack of specialization and inability to custom-engineer a manipulation solution	Build
Camera Enclosures	Ability to manufacture compact, custom enclosures well-suited to the specific needs of the cameras and ROV	The price per camera will slightly increase and CNCing the cameras will be a time consuming process	Saves money	Not as specialized for our 2023 design objectives, larger size, and not as scalable to new deisgn due to larger size	Accessibility and fast turnaround due to ability to buy off the shelf	Large size and not as specilaized to 2023 design objectives	Build
RPS	Ability to custom-engineer a topside control system for the new ROV	High cost with few additional benefits	Saves money, materials, and time due to similar base that is easily modiable to the new design	N/A	Not an option: there are no off the shelf RPS models that have all of the capabilities that our team is looking for		Reuse

Figure 31. Sourcing Decision Matrix
by Morgan Jones

B. Cost Accounting

The majority of *Geneseas'* costs were allocated for the purchase of Raspberry Pi microcomputers, thrusters, a new laptop computer, and materials for the ROV's frame, electronics, and cameras. A Google Sheet was utilized and updated to accurately track project costs. Refer to Appendix C for detailed Chart of Costs. The 2022–2023 Budget and Project Costing Report is shown in Appendix B and C. Geneseas remained under its budget by $580.48 through efficient cost management techniques, including securing donations and carefully evaluating whether materials should be purchased, manufactured, or reused using the Sourcing Decision Matrix (Figure 31). Implementing these cost management strategies, along with building custom components and purchasing reliable materials, ensured *Geneseas* remained on budget. The result is a highly specialized and cost-effective ROV.

VII. CONCLUSION

A. Acknowledgements

Geneseas would like to express our appreciation and gratitude for the opportunity to participate in the MATE program. Thank you to MATE Center and Marine Technology Society, Sponsor of the 2023 competition along with MATE II, the National Science Foundation, Oceaneering International, Ocean Infinity, and Reach the World for their continued support of the MATE competition and for providing this incredible educational opportunity. We would like to acknowledge the following for contributing to the success of our company:

- St. Francis Catholic High School for the generous donation of funding, support, and laboratory space.
- St. Francis Coaches: Marcus Grindstaff, Kitara Crain, Dean Eugenio, Karen Jones, and Maurice Velandia, and for your time, experience, dedication, knowledge, and guidance. Your patience and commitment fostered a team environment focused on learning and fun.
- Jesuit mentors who have supported us with technical and non-technical advice through our design process. Thank you Jesuit Rovotics for the use of your pool and lab facilities.
- To Kitara Crain and Cheryl Kiyama for being role models who inspire and guide us to be “Women who change the world”.
- To our families, our heartfelt gratitude for all of their guidance and support.

B. References

- 1 – https://chart-studio.plotly.com/~rjehangir/128/t100t200-thrusters-power-vs-thrust-comparison.embed
- 2 –https://www.brightstorm.com/science/physics/solids-liquids-and-gases/archimedes-principle/
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- 4 – https://khkgears.net/new/gear_knowledge/abcs_of_gears-b/basic_gear_terminology_calculation.html
- 5 – https://www.liteonled.com.au/buying-guide/understanding-led-lighting/led-lux-levels
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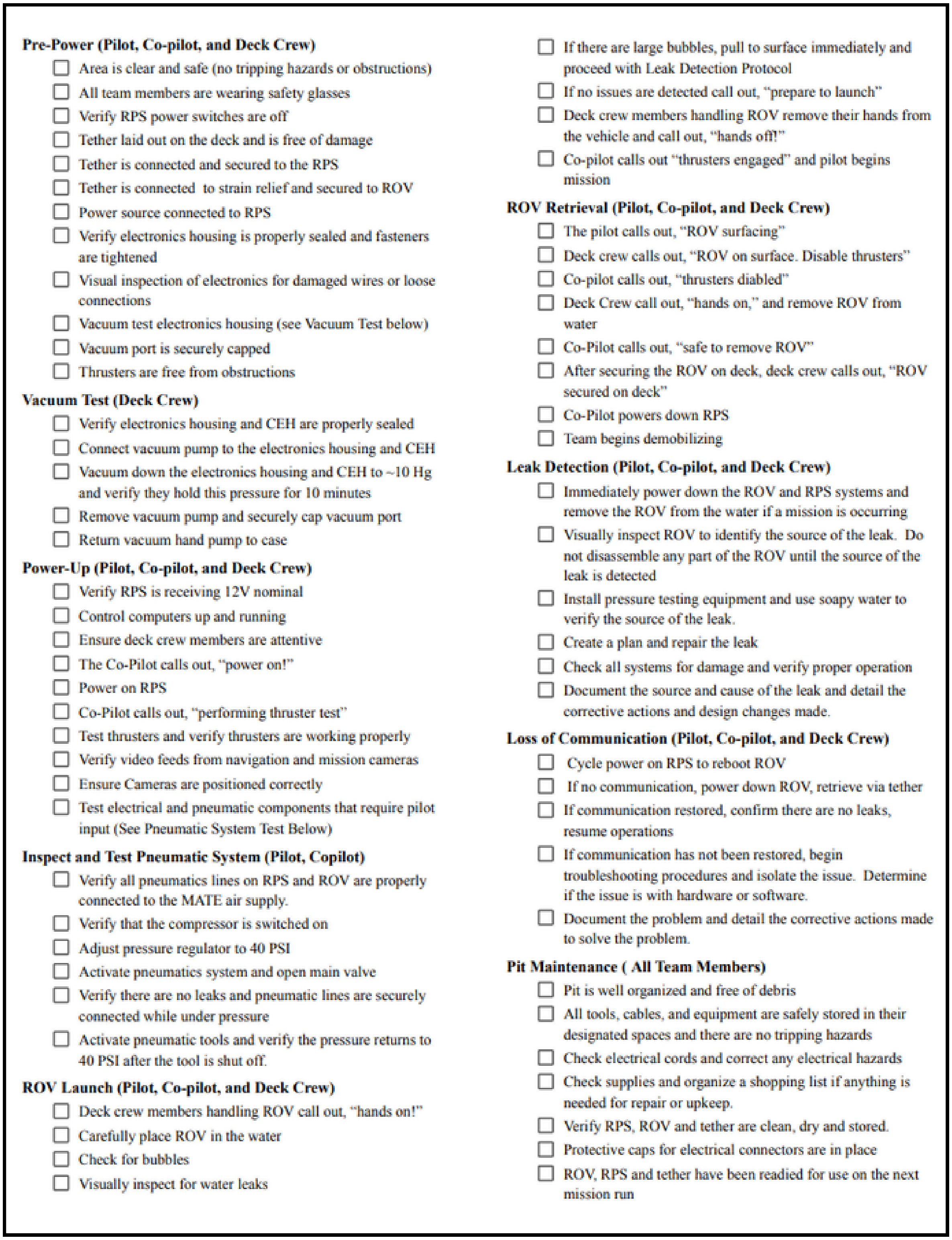
VIII. APPENDICES

Appendix A: Operations and Safety Checklist



Pre-Power (Pilot, Co-pilot, and Deck Crew)

- ☐ Area is clear and safe (no tripping hazards or obstructions)
- ☐ All team members are wearing safety glasses
- ☐ Verify RPS power switches are off
- ☐ Tether laid out on the deck and is free of damage
- ☐ Tether is connected and secured to the RPS
- ☐ Tether is connected to strain relief and secured to ROV
- ☐ Power source connected to RPS
- ☐ Verify electronics housing is properly sealed and fasteners are tightened
- ☐ Visual inspection of electronics for damaged wires or loose connections
- ☐ Vacuum test electronics housing (see Vacuum Test below)
- ☐ Vacuum port is securely capped
- ☐ Thrusters are free from obstructions

Vacuum Test (Deck Crew)

- ☐ Verify electronics housing and CEH are properly sealed
- ☐ Connect vacuum pump to the electronics housing and CEH
- ☐ Vacuum down the electronics housing and CEH to ~10 Hg and verify they hold this pressure for 10 minutes
- ☐ Remove vacuum pump and securely cap vacuum port
- ☐ Return vacuum hand pump to case

Power-Up (Pilot, Co-pilot, and Deck Crew)

- ☐ Verify RPS is receiving 12V nominal
- ☐ Control computers up and running
- ☐ Ensure deck crew members are attentive
- ☐ The Co-Pilot calls out, "power on!"
- ☐ Power on RPS
- ☐ Co-Pilot calls out, "performing thruster test"
- ☐ Test thrusters and verify thrusters are working properly
- ☐ Verify video feeds from navigation and mission cameras
- ☐ Ensure Cameras are positioned correctly
- ☐ Test electrical and pneumatic components that require pilot input (See Pneumatic System Test Below)

Inspect and Test Pneumatic System (Pilot, Copilot)

- ☐ Verify all pneumatics lines on RPS and ROV are properly connected to the MATE air supply.
- ☐ Verify that the compressor is switched on
- ☐ Adjust pressure regulator to 40 PSI
- ☐ Activate pneumatics system and open main valve
- ☐ Verify there are no leaks and pneumatic lines are securely connected while under pressure
- ☐ Activate pneumatic tools and verify the pressure returns to 40 PSI after the tool is shut off.

ROV Launch (Pilot, Co-pilot, and Deck Crew)

- ☐ Deck crew members handling ROV call out, "hands on!"
- ☐ Carefully place ROV in the water
- ☐ Check for bubbles
- ☐ Visually inspect for water leaks
- ☐ If there are large bubbles, pull to surface immediately and proceed with Leak Detection Protocol
- ☐ If no issues are detected call out, "prepare to launch"
- ☐ Deck crew members handling ROV remove their hands from the vehicle and call out, "hands off!"
- ☐ Co-pilot calls out "thrusters engaged" and pilot begins mission

ROV Retrieval (Pilot, Co-pilot, and Deck Crew)

- ☐ The pilot calls out, "ROV surfacing"
- ☐ Deck crew calls out, "ROV on surface. Disable thrusters"
- ☐ Co-pilot calls out, "thrusters diabled"
- ☐ Deck Crew call out, "hands on," and remove ROV from water
- ☐ Co-Pilot calls out, "safe to remove ROV"
- ☐ After securing the ROV on deck, deck crew calls out, "ROV secured on deck"
- ☐ Co-Pilot powers down RPS
- ☐ Team begins demobilizing

Leak Detection (Pilot, Co-pilot, and Deck Crew)

- ☐ Immediately power down the ROV and RPS systems and remove the ROV from the water if a mission is occurring
- ☐ Visually inspect ROV to identify the source of the leak. Do not disassemble any part of the ROV until the source of the leak is detected
- ☐ Install pressure testing equipment and use soapy water to verify the source of the leak.
- ☐ Create a plan and repair the leak
- ☐ Check all systems for damage and verify proper operation
- ☐ Document the source and cause of the leak and detail the corrective actions and design changes made.

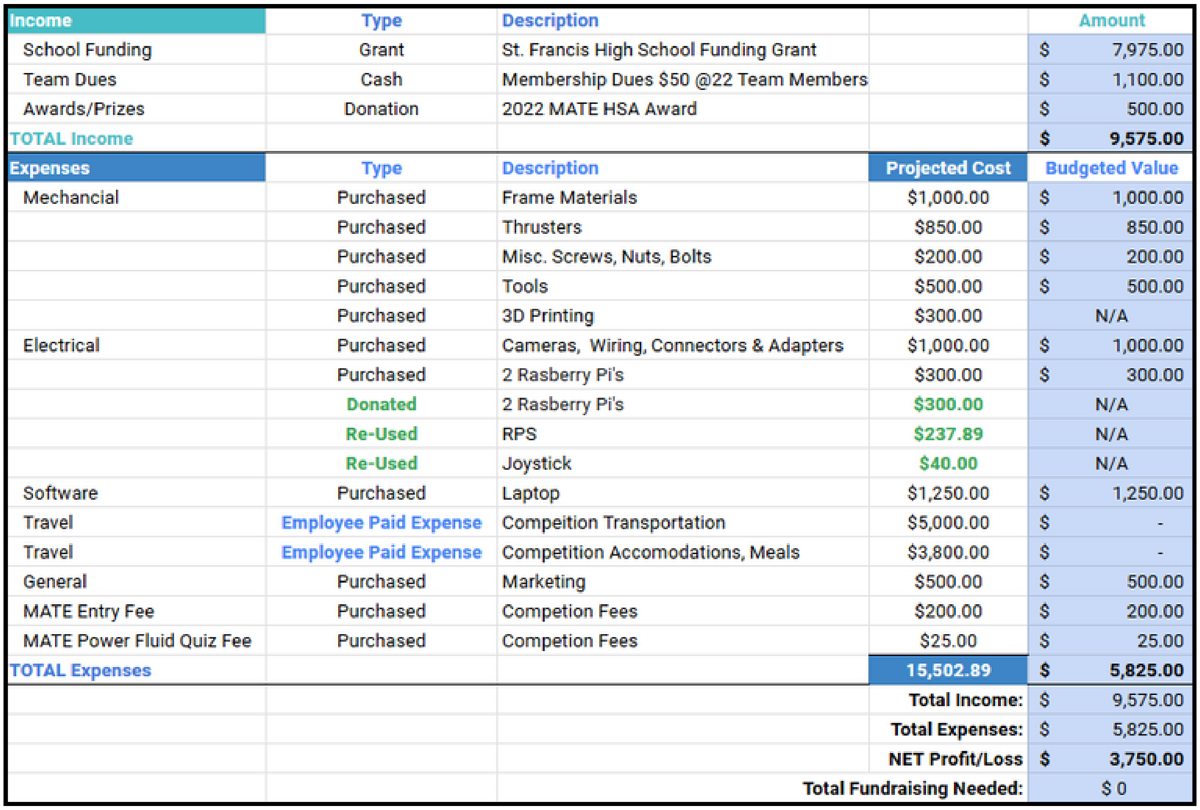
Loss of Communication (Pilot, Co-pilot, and Deck Crew)

- ☐ Cycle power on RPS to reboot ROV
- ☐ If no communication, power down ROV, retrieve via tether
- ☐ If communication restored, confirm there are no leaks, resume operations
- ☐ If communication has not been restored, begin troubleshooting procedures and isolate the issue. Determine if the issue is with hardware or software.
- ☐ Document the problem and detail the corrective actions made to solve the problem.

Pit Maintenance (All Team Members)

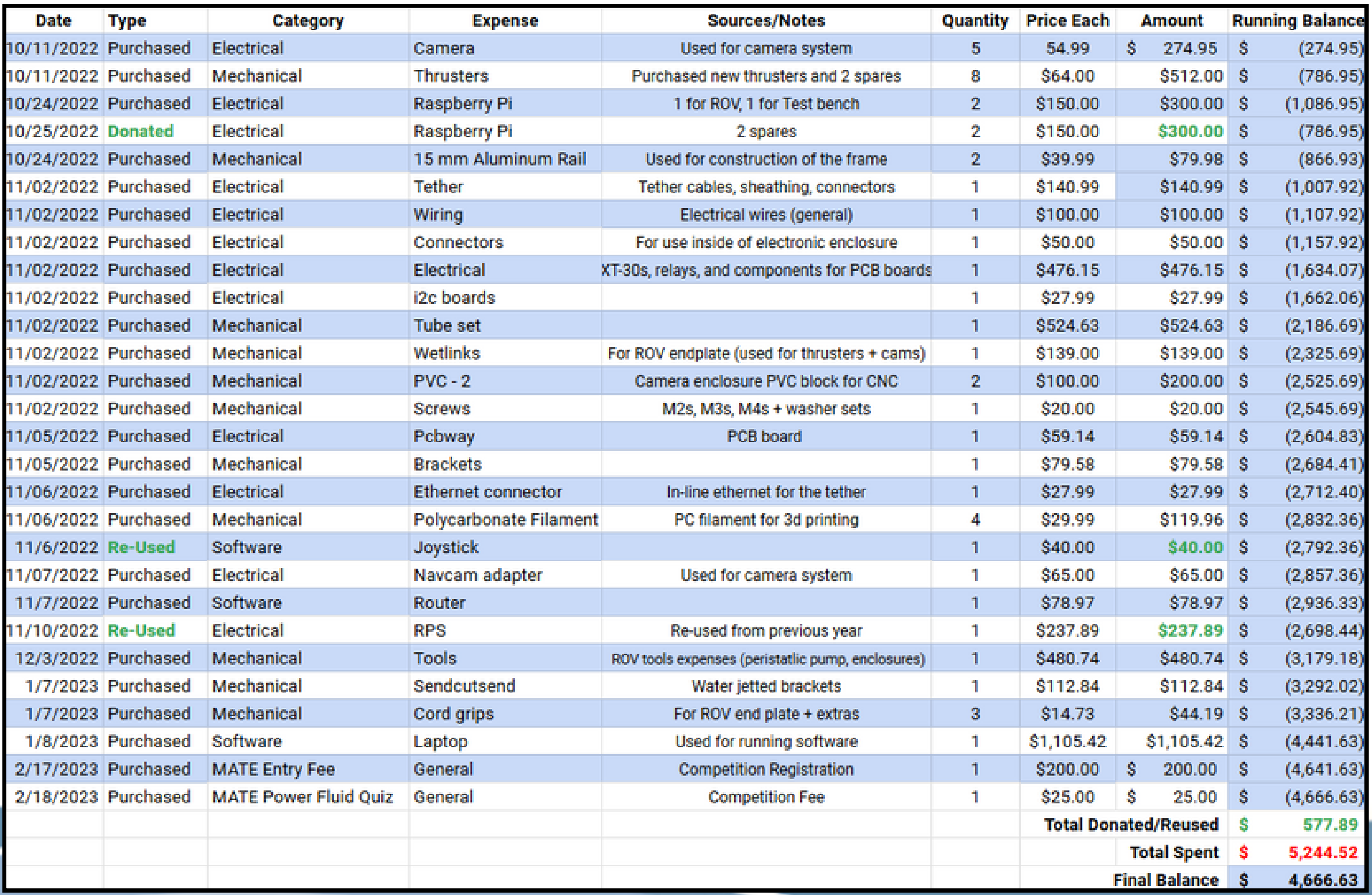
- ☐ Pit is well organized and free of debris
- ☐ All tools, cables, and equipment are safely stored in their designated spaces and there are no tripping hazards
- ☐ Check electrical cords and correct any electrical hazards
- ☐ Check supplies and organize a shopping list if anything is needed for repair or upkeep.
- ☐ Verify RPS, ROV and tether are clean, dry and stored.
- ☐ Protective caps for electrical connectors are in place
- ☐ ROV, RPS and tether have been readied for use on the next mission run

Appendix B: Budget



Income	Type	Description		Amount
School Funding	Grant	St. Francis High School Funding Grant		$ 7,975.00
Team Dues	Cash	Membership Dues $50 @22 Team Members		$ 1,100.00
Awards/Prizes	Donation	2022 MATE HSA Award		$ 500.00
TOTAL Income				**$ 9,575.00**
Expenses	**Type**	**Description**	**Projected Cost**	**Budgeted Value**
Mechancial	Purchased	Frame Materials	$1,000.00	$ 1,000.00
	Purchased	Thrusters	$850.00	$ 850.00
	Purchased	Misc. Screws, Nuts, Bolts	$200.00	$ 200.00
	Purchased	Tools	$500.00	$ 500.00
	Purchased	3D Printing	$300.00	N/A
Electrical	Purchased	Cameras, Wiring, Connectors & Adapters	$1,000.00	$ 1,000.00
	Purchased	2 Rasberry Pi's	$300.00	$ 300.00
	Donated	2 Rasberry Pi's	$300.00	N/A
	Re-Used	RPS	$237.89	N/A
	Re-Used	Joystick	$40.00	N/A
Software	Purchased	Laptop	$1,250.00	$ 1,250.00
Travel	Employee Paid Expense	Compeition Transportation	$5,000.00	$ -
Travel	Employee Paid Expense	Competition Accomodations, Meals	$3,800.00	$ -
General	Purchased	Marketing	$500.00	$ 500.00
MATE Entry Fee	Purchased	Competion Fees	$200.00	$ 200.00
MATE Power Fluid Quiz Fee	Purchased	Competion Fees	$25.00	$ 25.00
TOTAL Expenses			**15,502.89**	**$ 5,825.00**
			Total Income:	$ 9,575.00
			Total Expenses:	$ 5,825.00
			NET Profit/Loss	**$ 3,750.00**
			Total Fundraising Needed:	$ 0

Appendix C: Cost Accounting



Date	Type	Category	Expense	Sources/Notes	Quantity	Price Each	Amount	Running Balance
10/11/2022	Purchased	Electrical	Camera	Used for camera system	5	54.99	$ 274.95	$ (274.95)
10/11/2022	Purchased	Mechanical	Thrusters	Purchased new thrusters and 2 spares	8	$64.00	$512.00	$ (786.95)
10/24/2022	Purchased	Electrical	Raspberry Pi	1 for ROV, 1 for Test bench	2	$150.00	$300.00	$ (1,086.95)
10/25/2022	Donated	Electrical	Raspberry Pi	2 spares	2	$150.00	$300.00	$ (786.95)
10/24/2022	Purchased	Mechanical	15 mm Aluminum Rail	Used for construction of the frame	2	$39.99	$79.98	$ (866.93)
11/02/2022	Purchased	Electrical	Tether	Tether cables, sheathing, connectors	1	$140.99	$140.99	$ (1,007.92)
11/02/2022	Purchased	Electrical	Wiring	Electrical wires (general)	1	$100.00	$100.00	$ (1,107.92)
11/02/2022	Purchased	Electrical	Connectors	For use inside of electronic enclosure	1	$50.00	$50.00	$ (1,157.92)
11/02/2022	Purchased	Electrical	Electrical	XT-30s, relays, and components for PCB boards	1	$476.15	$476.15	$ (1,634.07)
11/02/2022	Purchased	Electrical	i2c boards		1	$27.99	$27.99	$ (1,662.06)
11/02/2022	Purchased	Mechanical	Tube set		1	$524.63	$524.63	$ (2,186.69)
11/02/2022	Purchased	Mechanical	Wetlinks	For ROV endplate (used for thrusters + cams)	1	$139.00	$139.00	$ (2,325.69)
11/02/2022	Purchased	Mechanical	PVC - 2	Camera enclosure PVC block for CNC	2	$100.00	$200.00	$ (2,525.69)
11/02/2022	Purchased	Mechanical	Screws	M2s, M3s, M4s + washer sets	1	$20.00	$20.00	$ (2,545.69)
11/05/2022	Purchased	Electrical	Pcbway	PCB board	1	$59.14	$59.14	$ (2,604.83)
11/05/2022	Purchased	Mechanical	Brackets		1	$79.58	$79.58	$ (2,684.41)
11/06/2022	Purchased	Electrical	Ethernet connector	In-line ethernet for the tether	1	$27.99	$27.99	$ (2,712.40)
11/06/2022	Purchased	Mechanical	Polycarbonate Filament	PC filament for 3d printing	4	$29.99	$119.96	$ (2,832.36)
11/6/2022	Re-Used	Software	Joystick		1	$40.00	$40.00	$ (2,792.36)
11/07/2022	Purchased	Electrical	Navcam adapter	Used for camera system	1	$65.00	$65.00	$ (2,857.36)
11/7/2022	Purchased	Software	Router		1	$78.97	$78.97	$ (2,936.33)
11/10/2022	Re-Used	Electrical	RPS	Re-used from previous year	1	$237.89	$237.89	$ (2,698.44)
12/3/2022	Purchased	Mechanical	Tools	ROV tools expenses (peristaltic pump, enclosures)	1	$480.74	$480.74	$ (3,179.18)
1/7/2023	Purchased	Mechanical	Sendcutsend	Water jetted brackets	1	$112.84	$112.84	$ (3,292.02)
1/7/2023	Purchased	Mechanical	Cord grips	For ROV end plate + extras	3	$14.73	$44.19	$ (3,336.21)
1/8/2023	Purchased	Software	Laptop	Used for running software	1	$1,105.42	$1,105.42	$ (4,441.63)
2/17/2023	Purchased	MATE Entry Fee	General	Competition Registration	1	$200.00	$ 200.00	$ (4,641.63)
2/18/2023	Purchased	MATE Power Fluid Quiz	General	Competition Fee	1	$25.00	$ 25.00	$ (4,666.63)
							Total Donated/Reused	$ 577.89
							Total Spent	$ 5,244.52
							Final Balance	**$ 4,666.63**