TECHNICAL DOCUMENTATION 2024

Geneseas

St. Francis Catholic High School
Sacramento, CA USA

CEO
Lauren Grindstaff ‘24

Cameras
Laila Shamshad ‘26 (Lead)
Mae Alvarez ‘24
Kat Murillo ‘25
Minna Brindle ‘27

Coaches
Marcus Grindstaff
Kitara Crain
Dean Eugenio
Maurice Velandia

Electrical
Isa Gutierrez ‘24 (Co-lead)
Siena Marois ‘24 (Co-lead)
Dar Eugenio ‘25
Eliza Yee ‘25
Katie Koo ‘27

Mechanical
Yogja Singla ‘26 (Lead)
Audrey Mayo ‘24
Grace Chavez ‘24
Izzy Ramos ‘25
Hanna Wysoczynska ‘26

Software
Kin Tirumala ‘25 (Lead)
Alyssa Renomeron '25
Gabby Rosario '25
Sona Prasad ‘26
Angelyn Gonzales ‘27

Tools
Azul Kupperman ‘25 (Lead)
Maddi Sundermier ‘24
Cate Hanly ‘26
Morgane Bertran ‘27
Kate Hwang ‘27

TABLE OF CONTENTS

1. ABSTRACT

Geneseas is an underwater robotics company based in Sacramento, California. The company comprises 25 highly skilled female engineers who are driven to develop technology that addresses complex global problems.

Atolla, *Geneseas*' fifth-generation ROV, is our newest and most technically advanced product. Atolla's advancements improve reliability and mission efficiency by adding powerline communications, an upgraded electronics housing, and a buoyancy engine with data processing capabilities. Atolla is engineered through detailed planning, prototyping, analysis, and testing, resulting in a custom-built ROV designed to meet the challenges outlined in the 2024 Marine Advanced Technology Education (MATE) Request for Proposal (RFP). Just plug it in and go!

This technical document details Atolla's design and development process as well as the ROV's capabilities. Atolla's meticulously engineered features make it capable of assisting the global community by rebuilding telecommunications cables, tending to diseased coral, identifying healthy habitats, and collecting data to monitor ocean health.

Figure 1. *Geneseas* Team Photo

2. TEAMWORK & PROJECT MANAGEMENT

A. Company Profile

Geneseas is a six-year-old company based in Sacramento, California, that engineers submersible robots designed to address the radical effects of climate change and their impact on global marine ecosystems. The company's all-female workforce of 25 engineers has experience in ROV design and operation, CAD, 3D printing, manufacturing, printed circuit board design, and software. The team is organized into five departments: mechanical, electrical, tool development, cameras, and software.

Geneseas has a two-tier leadership structure. Each department is mentored by an experienced member of the Functional Leadership Team (FLT). Each FLT member is responsible for their departments' successful delivery. In addition, *Geneseas* has an Executive Leadership Team (ELT). The ELT is responsible for the program's overall success, including this year's performance, and ensuring the team is set up for future success. The leadership team works together to perform design reviews, conduct testing, and promote cross-team collaboration to produce robust and reliable components.

This year, *Geneseas* welcomed 12 new members to the team. All new employees underwent a training semester, culminating in a mock competition similar to a MATE competition. They were introduced to the ROV's five subsystems and gained knowledge in a multitude of engineering abilities including coding, CAD, and soldering. New members also gained an understanding of the level of teamwork, project management skills, and attention to detail needed to be an effective member of *Geneseas*.

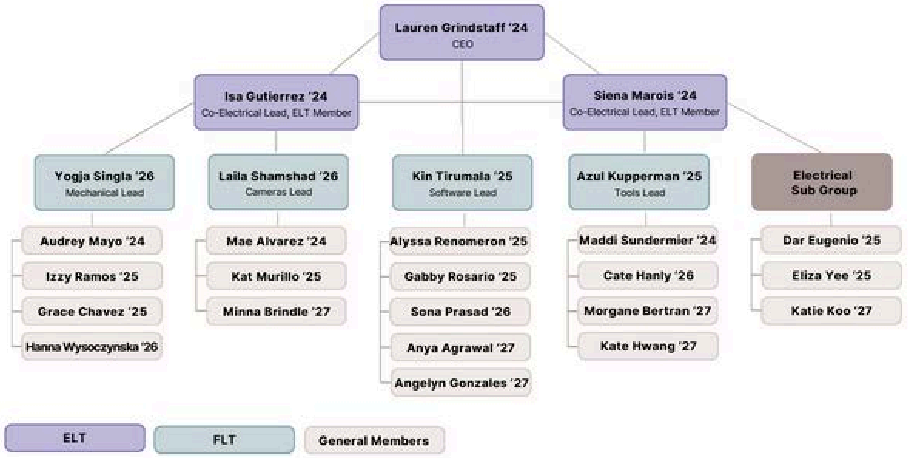


Figure 2. *Geneseas* Company Org Chart

Figure 3. New members building a simple ROV for the mock competition

Following the competition, new members assisted with mission tool development. Geneseas' leadership team facilitated a pleasant and efficient working environment by fostering a culture of learning and collaboration. ELT members assigned new members to design mission tools that aligned with the interests they discovered by doing the mock competition. However, if members decided that they were not as interested in the tool they were designing, ELT provided them with opportunities to design other mission tools that would better build up their curiosity and enthusiasm for engineering. As new members designed tools, they were directly mentored by FLT members who worked to provide an environment in which members can freely make mistakes, learn from those mistakes, and comfortably seek design insight from senior members. *Geneseas*' peer-to-peer training system provides all employees with a solid foundation of knowledge and experience, paving the way for long-term growth and success.

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

B. Project management

This year, *Geneseas* implemented a comprehensive project management approach to effectively manage department assignments and achieve key milestones. This helps keep the project organized, on time, and on budget. Starting in September, the team met every Saturday to design, build, test, and deliver the ROV. The *Geneseas* Leadership Team, which consists of the ELT and FLT, meets for two hours every Monday to track progress, conduct design reviews, reassign resources, and refine plans for the Saturday meetings. The ELT prepares a presentation to kick off each Saturday meeting. This presentation includes the day's objectives for each functional team and individual, as well as any other key messages for the team. The kick-off session is facilitated by the ELT.

Despite the heavy time commitment expected of *Geneseas* members, *Geneseas* ensures the well-being of all employees by scheduling designated break periods throughout the day. An hour-long team lunch period is accompanied by meals generously provided by *Geneseas*' parents. These scheduled breaks provide the perfect work-life balance so members can work productively and meet deadlines while still having fun.

Using *Geneseas*' Project Management Tool (PMT), department heads created project schedules at the beginning of the year. The PMT (Figure 4) includes individual department project timelines, meeting objectives, overall project deadlines, 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 use of the PMT, weekly leadership meetings, and Saturday meeting kick-off presentations facilitated the achievement of key design objectives and provided a structure for day-to-day operations. This management strategy set the example for a disciplined approach and improved the ROV production process.

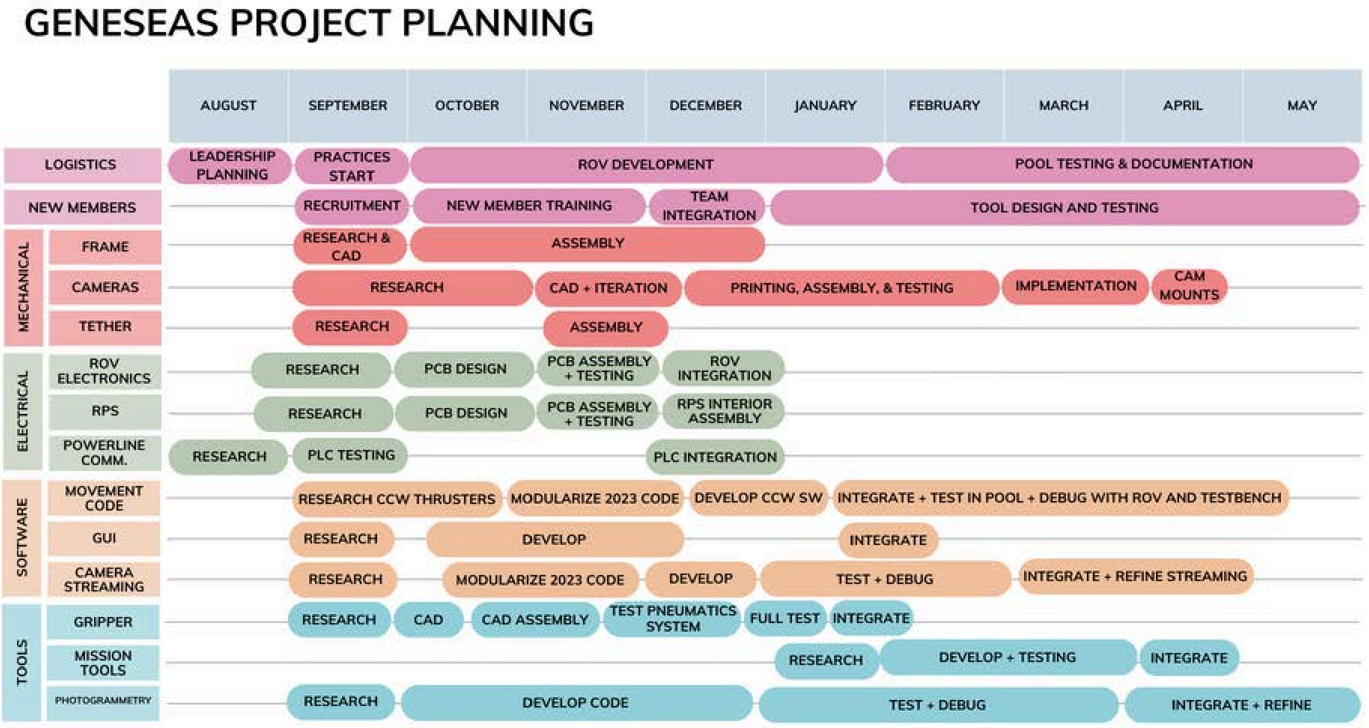
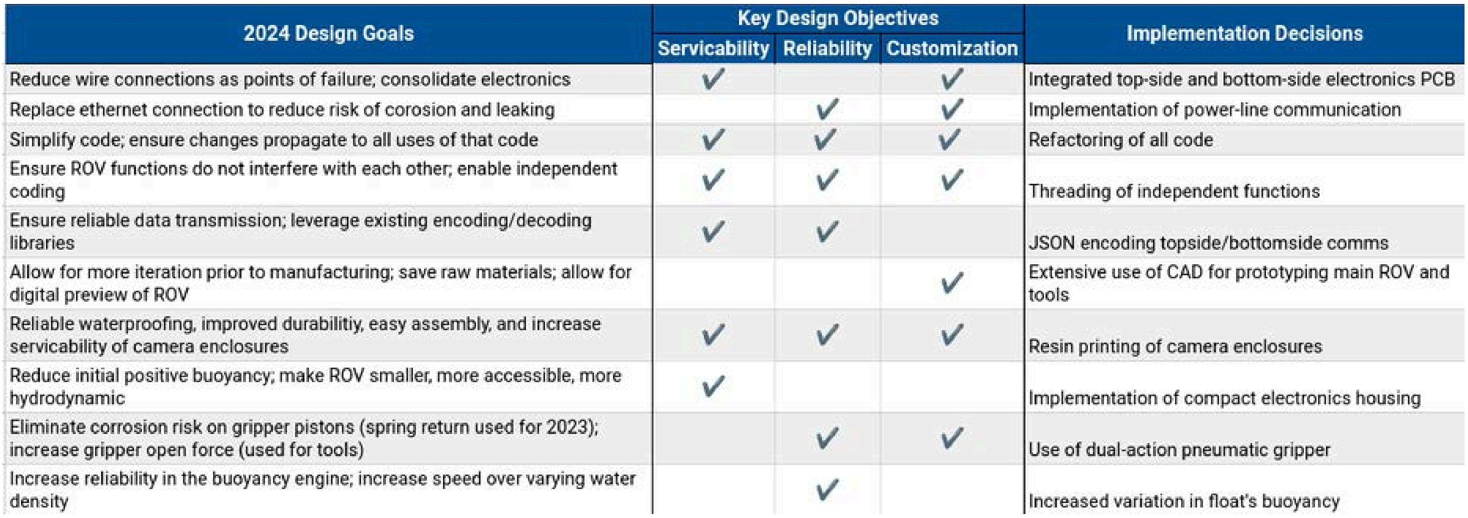


Figure 4. *Geneseas* Project Management Gantt Chart

3. DESIGN RATIONALE

The ELT met in August to set key design objectives to create fundamental goals for the team to enhance all parts of this year's ROV. Overall, the primary goals for 2024 were to improve reliability, serviceability, and customization throughout all aspects of the ROV. The leadership team then met to translate these key design objectives into tactical prototyping and implementation decisions.

These prototyping and implementation decisions included:



2024 Design Goals	Key Design Objectives			Implementation Decisions
	Servicability	Reliability	Customization	
Reduce wire connections as points of failure; consolidate electronics	✓		✓	Integrated top-side and bottom-side electronics PCB
Replace ethernet connection to reduce risk of corosion and leaking		✓	✓	Implementation of power-line communication
Simplify code; ensure changes propagate to all uses of that code	✓	✓	✓	Refactoring of all code
Ensure ROV functions do not interfere with each other; enable independent coding	✓	✓	✓	Threading of independent functions
Ensure reliable data transmission; leverage existing encoding/decoding libraries	✓	✓		JSON encoding topside/bottomside comms
Allow for more iteration prior to manufacturing; save raw materials; allow for digital preview of ROV			✓	Extensive use of CAD for prototyping main ROV and tools
Reliable waterproofing, improved durabilitiy, easy assembly, and increase servicability of camera enclosures	✓	✓	✓	Resin printing of camera enclosures
Reduce initial positive buoyancy; make ROV smaller, more accessible, more hydrodynamic	✓			Implementation of compact electronics housing
Eliminate corrosion risk on gripper pistons (spring return used for 2023); increase gripper open force (used for tools)		✓	✓	Use of dual-action pneumatic gripper
Increase reliability in the buoyancy engine; increase speed over varying water density		✓		Increased variation in float's buoyancy

Figure 5. 2024 Design Decision Matrix

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, previously outside the budget. Creating a design decision matrix (Figure 5) allowed *Geneseas* to carefully evaluate the tradeoffs and critical factors of these decisions before pursuing them.

3.1 Design Evolution

Atolla, *Geneseas*' fifth-generation ROV, features design improvements across all major systems with an increased emphasis on safety, serviceability, reliability, and customization. After re-evaluating the previous ROV, Medusa, *Geneseas* identified the improvements necessary to make Atolla the optimal solution to fulfill MATE's RFP. Once these improvements were identified, *Geneseas*' system leads brainstormed and decided on the major build decisions capable of completion within the season. These included improving communication capabilities, streamlining electronic systems, and improving camera serviceability. With these goals in mind, *Geneseas*' employees began developing Atolla, an ROV highly capable of supporting the restoration and protection of aquatic ecosystems under varying conditions.

Atolla's design was more than an improvement of previous designs but was a progression as employees continuously iterated the designs to produce components and tools with the utmost efficiency and effectiveness. *Geneseas*' previous design philosophy prioritizes iteration; however, employees determined that an emphasis on serviceability was necessary throughout the design process to yield specialized and mission-specific ROVs that can be adapted to complete a variety of tasks. Throughout development, employees identified areas of improvement based on intensive testing and pilot feedback. This meticulous process resulted in multiple iterations of Atolla's tools, core electronic systems, software, and cameras.

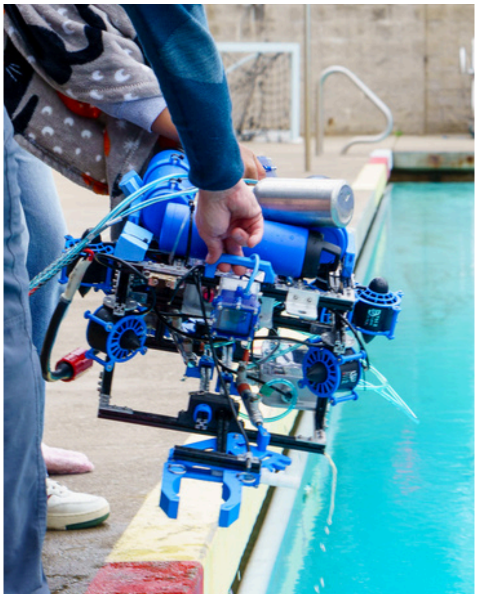
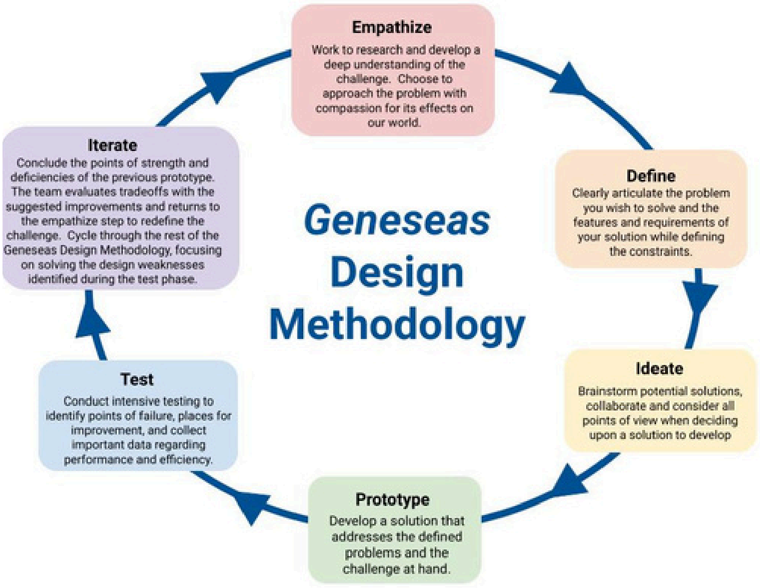


Figure 6. Atolla on Deck

A. *Geneseas* Design Methodology

Geneseas' design methodology (Figure 7) emphasizes rapid iteration, sustainable design choices, and collaboration between team members to ensure improved and successful ROV production. Throughout the design process, employees developed multiple design options, objectively compared designs, and made iterative modifications to ensure the design objectives were met and exceeded.

Geneseas' design methodology underlines rigorous testing and pilot feedback on the design objectives and overall ROV efficiency and success. Employees continuously receive feedback at weekly design reviews, determining the needed improvements and a strategy for developing the next iteration. At these design reviews, design feedback from all members is welcomed and considered. This collaborative approach effectively delivers a highly specialized ROV, specifically engineered o solve specific missions, all while meeting the key design objectives.



Empathize Work to research and develop a deep understanding of the challenge. Choose to approach the problem with compassion for its effects on our world.

Define Clearly articulate the problem you wish to solve and the features and requirements of your solution while defining the constraints.

Ideate Brainstorm potential solutions, collaborate and consider all points of view when deciding upon a solution to develop

Prototype Develop a solution that addresses the defined problems and the challenge at hand.

Test Conduct intensive testing to identify points of failure, places for improvement, and collect important data regarding performance and efficiency.

Iterate Conclude the points of strength and deficiencies of the previous prototype. The team evaluates tradeoffs with the suggested improvements and returns to the empathize step to redefine the challenge. Cycle through the rest of the Geneseas Design Methodology, focusing on solving the design weaknesses identified during the test phase.

Figure 7. *Geneseas* Design Methodology

The success of *Geneseas*' design methodology is founded on understanding the problem at hand. Employees are required to research and understand the issues impacting global marine ecosystems and their influence on marine life and society. By understanding the problem, employees can clearly define the problem, parameters, and constraints before the first stage in the design process, where employees collaborate to determine a solution.

B. Innovation

Atolla's key innovative features include the implementation of powerline communication (PLC), dual action pneumatic pistons, software multi-threading, and counter-rotating thrusters.

The decision to utilize powerline communication technology[1, 2] addressed past reliability issues involving the waterproofing of ethernet cables in the tether. PLC enables ethernet connections over the 12V power wires. Two PLC boards are housed inside the topside and bottom-side electronics enclosures. This eliminates the need for an ethernet cable in the tether (Figure 8), allows all ethernet connections to be made in contained electronic housings, and increases reliability by reducing the risk of corrosion and leakage.

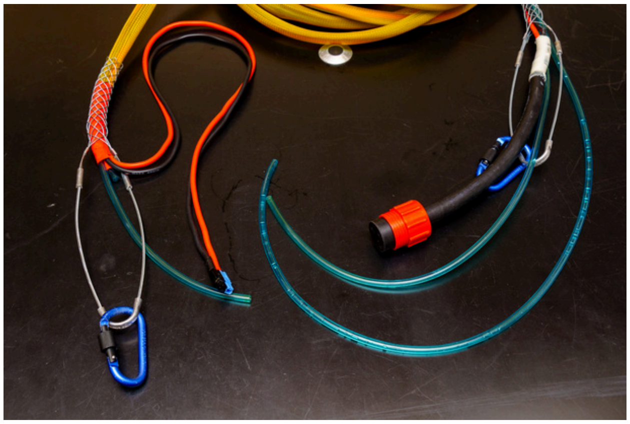


Figure 8. Atolla's Tether that Eliminates the Need for Ethernet

Geneseas chose to control this year's grippers using dual action pistons to increase reliability. Dual-action pistons eliminate the risk of internal corrosion, which occurred in last year's gripper that utilized single-action spring return pistons. Thus, dual-action pistons have greater longevity and improve the operation of Atolla's grippers.

Geneseas transitioned to an optimized counter-rotating thruster arrangement to eliminate opposite roll. Two pairs of clockwise and counterclockwise thrusters are mounted on the corners of the ROV in a diagonally opposed arrangement (Figure 10), and across from each other (Figure 10), enabling smoother rotation and ensuring the ROV is balanced correctly when moving in the water.

Atolla's software solution is multi-threaded, taking advantage of the processing power of the Raspberry Pi computer and Linux operating system. This multi-threading approach allows for modular software. Each major function operates in its own thread and uses unique ports for network communication, allowing the functions to operate independently. This allows for future expansion, modular feature delivery and parallel software development across the software team members.

3.2 Vehicle Structure and Systems

A. Vehicle Structure and Frame

This year, *Geneseas* implemented a significant change in Atolla's frame design by reducing its size and shape by 30%. This change resulted in a more portable, serviceable, cost-effective, and hydrodynamic product in marine environments.

Figure 9. Atolla's Frame

The ROV's outer frame is rectangular and measures 310 x 335 x 207 mm–88 mm shorter than our previous frame. It is constructed from 15 x 15 mm extruded aluminum T-slot rail, which features channels that allow for the flexible attachment of tools, cameras, and thrusters using T-slot nuts. Each aluminum rail is connected using custom-designed L-shaped and T-shaped aluminum brackets, ensuring durability. This smaller, rectangular frame improves mobility and optimizes mission tasks.

Geneseas utilized Onshape CAD software to create and iterate on the frame design prior to manufacturing, resulting in an ROV engineered to meet the predetermined design objectives. These objectives included optimizing the positioning of the electronics housing, six thrusters, four cameras, and two grippers.

The frame was designed to position the center of thrust and center of buoyancy closest to the center of the ROV to provide increased stability when piloting. This was achieved by attaching additional rails horizontally around the sides and back of the frame to allow all six thrusters and the electronics housing to be mounted on these rails near the center of the ROV.

Atolla's frame is designed with safety in mind, equipped with three custom 3D-printed polycarbonate handles on top of the frame. These handles are used during ROV pool deployment and recovery, and allow for efficient transportation to the mission site. Such specialized devices ensure the safety of employees while operating, servicing, or repairing the ROV.

B. Propulsion

Geneseas maintained the ROV's six thruster layout from previous years and used the same reliable, compact, and cost-effective Diamond Dynamics thrusters. Three pairs of counter-rotating thrusters were selected to eliminate opposite rotation. Four of Atolla's six thrusters are mounted horizontally, providing lateral translation and rotation. The remaining two vertical thrusters on the left and right sides provide efficient vertical movement for a total of four degrees of freedom. While it would be possible to gain a fifth, or even sixth, degree of freedom with these six thrusters, the team determined that the "four degrees of freedom" arrangement provides for optimal performance and stability. The thrusters are angled at 45 degrees to efficiently and effectively direct thrust away from the main electronics housing.

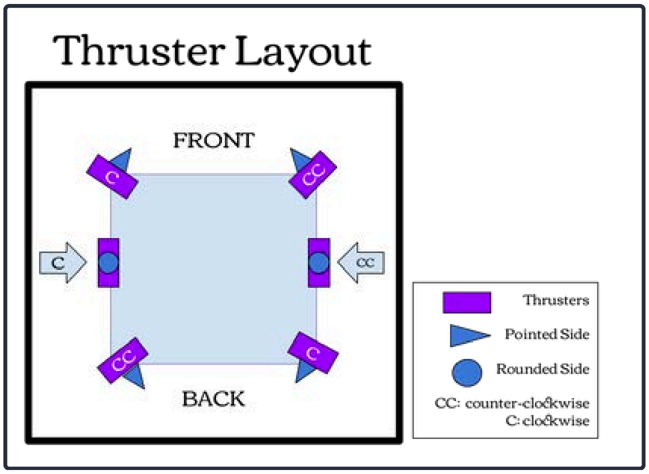


Figure 10. Thruster Diagram

C. Buoyancy and Ballast

Based on a volume-efficient design, and as initially predicted by the CAD model, Atolla was initially negatively buoyant. *Geneseas* utilized a hanging scale to empirically determine the volume of buoyant material required to bring Atolla to neutral buoyancy. This resulted in the addition of water bottles displacing 2.25L of volume providing approximately 2.2KG of net buoyancy.[3]

ROV Weight in Water	Added Buoyancy	Net Buoyancy
-2.1 kg	3 x 700 mL waterbottles = +2.1 kg	-2.1+2.1 = 0 kg

Figure 11. Buoyancy Calculations

The water bottles were chosen specifically to increase Atolla's serviceability as they can be filled or emptied to adjust ballast. In order to prevent water movement in the water bottles, a light water-absorbing sponge was added to them.

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

This approach reflects *Geneseas*' practical and effective method for fine-tuning ROV buoyancy, optimizing Atolla's performance in aquatic environments.

D. Submersible Connectors

Atolla's rectangular electronics housing features a total of 16 submersible connectors spread across all four vertical sides of the housing.

Quantity	Type	Use
2	McMaster Carr Cord Grip (6907K11)	Power
11	5.5 mm Blue Robotics WetLink Penetrators	Thrusters, Cameras, and Pneumatics
1	Blue Robotics Vacuum Plug	Vacuum Testing
2	Blue Robotics Plug	Future Expansion

Figure 12. Submersible Connectors Used

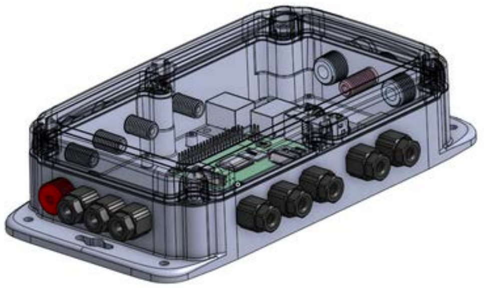


Figure 13. Electronics Housing CAD

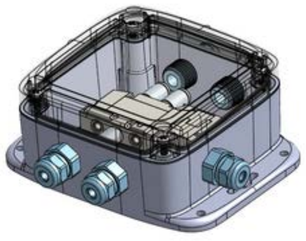


Figure 14. Pneumatics Enclosure CAD

In addition, Atolla's pneumatic solenoid housing, which supplies pneumatic pressure to the gripper, features seven McMaster-Carr cord grips (5084N111). These cord grips, typically used for electrical connections, are used in an innovative application: the pneumatic tubing is run through the cord grips to enter and exit the pneumatic housing. These connectors were chosen to provide maximum serviceability and waterproofing reliability. Atolla also features a "wet-mateable", three-pin, inline SubConn power connector to distribute power to the ROV. Subconn and Anderson 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.

3.3 Electrical and Control Systems

A. ROV Electronics

Atolla's electronics system emphasizes serviceability and reliability through its modular design using only three circuit boards: a Raspberry Pi 4B+, a custom Raspberry Pi "hat" printed circuit board (PCB), and a Powerline Communications Board (PLC).

A major innovation is the use of power-line communications. Using a TCP/IP based network architecture provides maximum flexibility and robust communication; however, it presents an electrical challenge. Traditional, cost-effective RJ45 ethernet connections are prone to corrosion due to their copper pins. Even when using a waterproof coupling, water inevitably contacts the copper when opening and closing the enclosure, resulting in corrosion and lack of connectivity. Specialized connections for submersible ethernet are available, however they are expensive. Using power-line communication allows Atolla to use the existing wet-mateable power connector to provide for ethernet networking and TCP/IP communication. In addition, this reduces the number of connections required to connect the ROV — resulting in a tether with one power connector, one pressurized pneumatics hose, and one pneumatic vent. Just plug it in and go!

Figure 15. Atolla's Bottom-side PCB

To address past reliability issues due to many wired connections on the ROV, *Geneseas* designed a new PCB[4] (Figure 15) that consolidates most of Atolla's electronics system onto a single board. This year's PCB contains a thruster driver microcontroller, four solid-state relays to power mission tools, a 12V to 5V convertor to accommodate varying voltage requirements, and a 40-pin header to connect to the Raspberry Pi. The board includes screw terminals for the thrusters' power, ground, and signal wires to prevent accidental shorts and increase serviceability. This year's PCB also contains capacitors to reduce any sudden voltage spikes when the thrusters are powered on. The PCB serves as a Pi "hat", utilizing a 40-pin female header to plug into the Raspberry Pi's pin header.

B. RPS

Geneseas employees determined that remaking the Remote Piloting System (RPS) in Figure 16 was necessary to achieve the design objectives to make the RPS smaller and lighter. Employees began the design process by assessing the previous year's RPS and identifying key areas for improvement, including serviceability, modularity, and ease of operations. Employees researched and purchased a new box to house the RPS components that would weigh less to improve modularity and ease of operations, improving transportation and set-up efficiency. *Geneseas* chose to buy a Hart Stack System Tool box, which has an empty weight that is approximately 5 pounds lighter than the previously used DeWalt ToughSystem tool box. As the team developed the RPS, a priority was placed on preserving a simple set-up for operations.

Figure 16. RPS Outer Panel

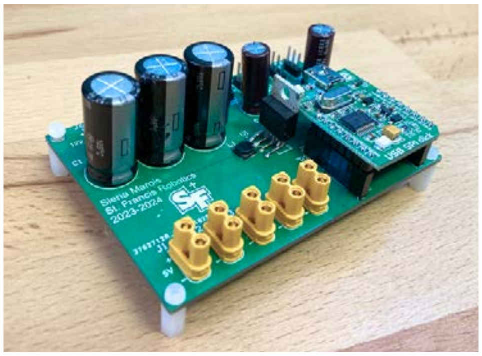


Figure 17. Top-side PCB

Employees determined that serviceability was a necessary improvement and determined that a custom printed circuit board (PCB) was an effective way to achieve this. *Geneseas* designed, manufactured, and assembled a top-side PCB (Figure 17) with key features such as a 12V to 5V converter, two power indicator lights, five 12V XT30s and five 5V XT30 power ports, connections for control buttons, and a MIKRO board used to communicate with the top-side laptop. This PCB consolidated the RPS electronics onto one, 89mm by 64mm board, improving both serviceability and modularity. Due to the implementation of a PCB, many components had to be purchased. However, employees were able to reuse some critical components such as the power-on switch, strain relief, and voltmeter and ammeter.

Employees decided to sheath sets of wires in the RPS to further improve reliability and serviceability. Using wire sheathing, employees grouped wires that were routed to the same place together. This decision, along with the PCB, greatly improved employees' abilities to quickly and accurately troubleshoot any issues with top-side electronics. By sheathing the wires within the RPS, employees could quickly navigate all connections and ensure that all wires were routed correctly. Additionally, sheathing the wires made accessing other components within the RPS, such as the powerline communications board and PCB, easy to reach and check for possible issues.

Once employees chose a new box and developed a top-side electronics SID, as seen in Figure 18, *Geneseas* began designing the structure and organization of the RPS. Employees used CAD software to design the topside panel and bottom side mounting panel, hinges and rods for lifting the top panel, and a divider, which were then laser cut for assembly. Employees maximized space by making the RPS multi-functional, dedicating the right half of the box for electronics, and the left half for storage of required cables and tools. This improved ease of operations from the previous year's RPS, which required external storage, by keeping all co-pilot required tools for RPS set-up and ops tasks in a single, compact location.

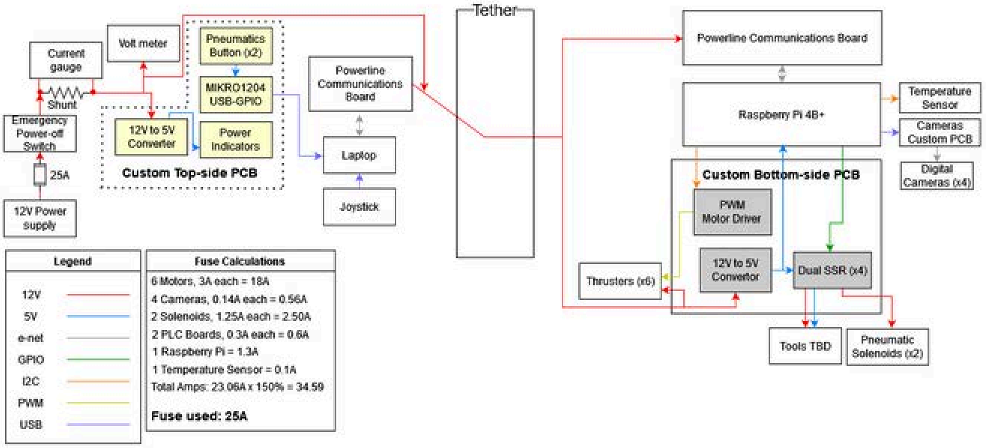


Figure 18. Atolla's Electronic SID

C. Tether

Atolla's tether is 12.2 meters in length and consists of two 10-gauge silicone power cables and one pneumatic line for the ROV's grippers. There are only two connections required: the power cable (includes power-line communication) and the pneumatics hose. Setup is extremely fast and simple. Just plug it in and go!

All tether features are contained in a durable woven nylon sheathing with a reliable strain relief on both ends. The bright neon yellow sheathing was chosen to provide safety against abrasive surfaces and increase visibility in the water, while maintaining flexibility. Two water bottles are attached along the tether to create neutral buoyancy and prevent entanglement in the water, ensuring a safe mission environment. One empty water bottle is placed at the end of the tether closest to the ROV to give it a positive buoyancy and help keep the tether directly above the robot at all times, allowing for more effortless piloting.

Figure 19. Atolla's Tether

Calculation Factors	2024 Tether	2023 Tether
Current	25 A	25 A
Wire	10 AWG	10 AWG
Wire length	40 ft	36 ft
Wire type	Stranded silicone power wire	
Resistance per feet	0.000999 Ω	0.000999 Ω
Resistance per side	0.03996 Ω	0.035965 Ω
Voltage drop on power side	0.999 V	0.899125 V
Voltage drop on return side	0.999 V	0.899125 V
Total Voltage Drop	1.998 V	1.79825 V
Voltage Difference ('24-'23)	0.19975 V	

Figure 20. Voltage Drop Calculations

Geneseas employees utilized a Voltage Drop Calculator to determine that the 40 feet power cable generates a minimum of 10 volts at the ROV, after the tether voltage drop, ensuring a reliable power supply. This year, *Geneseas* decided to increase the length of the tether by 4 feet to improve ease of maneuverability at the furthest reaches of the competition field.

Even with this tether extension, the voltage drop across the tether is 1.998 V. The ROV is still able to receive sufficient voltage of greater than 10V to power all systems efficiently.

The *Geneseas* tether manager handles, maintains, and stores the tether during mission runs. During mission setup, they must uncoil and connect the top-side of the tether to the RPS and the bottomside to the ROV, beginning with the strain relief. After the ROV is successfully deployed, the tether manager holds the tether giving slack so the ROV can move freely, and adjusts the length accordingly. While the ROV is operating, they must always have contact with the tether and avoid sudden rotations or large movements to ensure a safe mission environment. After the mission completion, the tether manager removes the ROV from the water and disconnects the tether from both the top and bottom sides. They then safely coil the tether and pack it for safe storage in the tether bag.

D. Top-side and Bottom-side Software

Geneseas' top and bottom-side software handles all pilot operations and communication between the top-side and the ROV. The bottom-side software, located in the ROV's main electronics housing, runs on a Raspberry Pi 4 Model B. The top-side software is run on a Windows laptop that is in constant communication with the bottom-side Raspberry Pi. These systems use TCP/IP for all communication between the top-side and bottom-side.

There are three types of traffic communicated:

1. Joystick position (X, Y, Z and Rotate)
2. Gripper open/close[5]
3. Camera streams

Joystick inputs are sent to the Raspberry Pi for further processing, including:

1. Joystick dead zone creation to ensure the robot is stopped when the joystick is neutral
2. Fast-mode / slow-mode adjustments for fast or precise movement modes
3. Vector inversion for counter-rotating propellers
4. Vector adjustment for thrusters' 45-degree positioning
5. Adjustment for asymmetric water resistance
6. Pilot inversion adjustments for operating "backward"
7. Static power limiting to ensure power is not interrupted
8. Dynamic power change limiting to ensure steady voltage
9. Thruster dead zone removal
10. Translation to PWM pulse widths required by ESCs

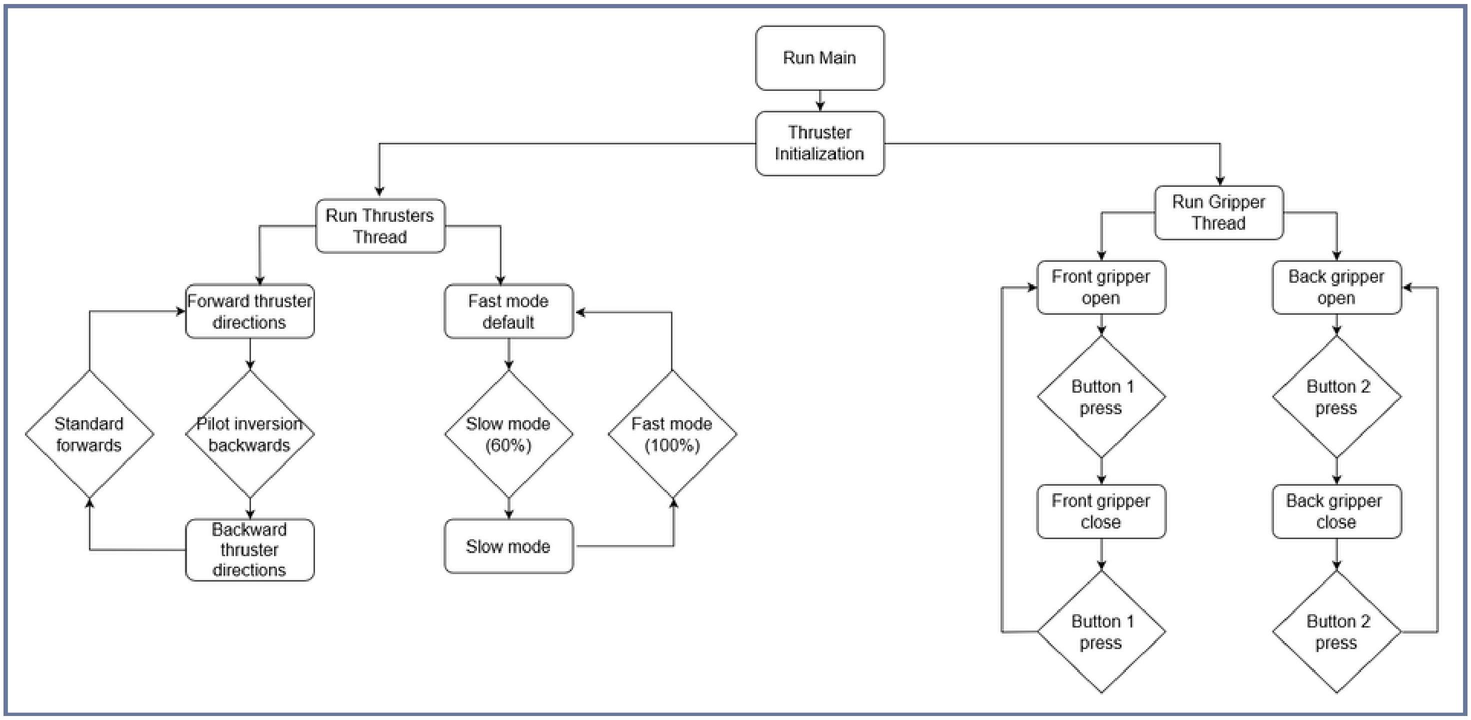


Figure 21. Bottom-side Software Flowchart

This thruster management code is heavily modularized, with each of these processing steps implemented in a separate function. These functions operate on a thruster array. This setup ensures that changes can be made in low-risk and rapid ways. For example, when moving thrusters positions on the robot, adjustment of a single array ensures that the updated thruster arrangement performs properly.

To improve pilotability and runtime efficiency, *Geneseas* created two Graphical User Interfaces (GUIs). Both utilize PyQt5[6], a robust GUI framework, to display interactive elements and perform autonomous tasks. The camera GUI displays four streaming feeds simultaneously, with button inputs to switch between main cameras when the ROV is undergoing pilot inversion (e.g. operating in reverse). The widget GUI holds all calculations, status, and numerical content, including a mission timer, notepad, temperature sensor values, inversion status, and thruster values.

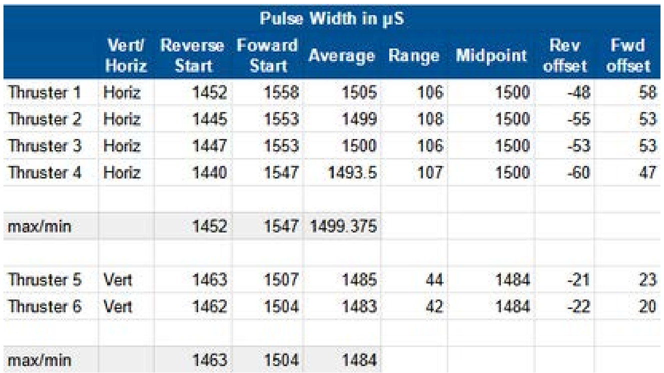
Figure 22. GUI Display

While structuring this year's software, *Geneseas* documented every step of the design and build process to create a framework for newer members to quickly familiarize themselves with software protocols. *Geneseas* designed all bottom-side and top-side programs in Python3 to maintain consistent syntax and documentation. Employees utilized Google Calendar to complete all tasks and documentation on time. To efficiently and effectively iterate through code versions, *Geneseas* employees reconstructed the test bench, which is capable of mimicking ROV hardware and software functionality.

Geneseas' use of GitHub allows an organized workspace among employees, improving accessibility to all programs. Both the top and bottom-side programs run from auto-starting modular bash scripts, enabling ease of use. Just plug it in and go!

E. Control System

Geneseas employees developed custom code to control the thrusters and provide all necessary movement. *Geneseas* built upon calculations from the previous year, making improvements to fit the transition to using counter-rotating thrusters. To ensure that all thrusters turn on simultaneously and receive a safe and optimal 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 23). By dynamically reducing power to the thrusters, this function helps to avoid abrupt power failures from high-power joystick movements. Through pool testing, employees used pilot feedback 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								
	Vert/ Horiz	Reverse Start	Foward Start	Average	Range	Midpoint	Rev offset	Fwd offset
Thruster 1	Horiz	1452	1558	1505	106	1500	-48	58
Thruster 2	Horiz	1445	1553	1499	108	1500	-55	53
Thruster 3	Horiz	1447	1553	1500	106	1500	-53	53
Thruster 4	Horiz	1440	1547	1493.5	107	1500	-60	47
max/min		1452	1547	1499.375				
Thruster 5	Vert	1463	1507	1485	44	1484	-21	23
Thruster 6	Vert	1462	1504	1483	42	1484	-22	20
max/min		1463	1504	1484				

Figure 23. Thuster Values

3.4 Payload & Tools

A. Digital Camera System

Geneseas' Atolla includes a highly modular and reliable fully digital camera system. With this camera system, Atolla is capable of relaying low-latency footage from the robot directly to the team's topside system ready for pilot navigation and image processing.

During the development of our third-generation digital camera system, *Geneseas* team members focused on improving the reliability and serviceability of the cameras. In the second-generation digital system, camera housings were sealed with epoxy, and the camera wiring was not field-replaceable. The third-generation solution enabled independent simple field replacement of the camera, housing lens, and housing using only an Allen key and box wrench.

Atolla's digital cameras, including the MJPEG streaming software, provide low-latency video. The average video latency is 127 ms at 640x480 resolution. Each camera provides for a 170° field of view. Higher resolution, narrower field of view, camera rotation, and basic image adjustment can all be provided through configuration options.

Atolla has two main navigation cameras mounted on the front and rear of the robot. The "pilot inversion" software reverses the pilot controls when using the "back" camera, ensuring consistent pilotability in both forward and reverse directions.

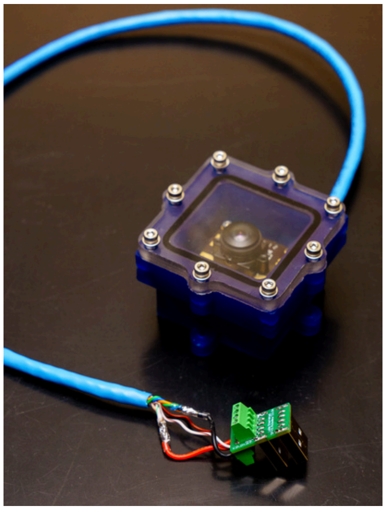


Figure 24. Camera enclosures and PCB (unplugged)

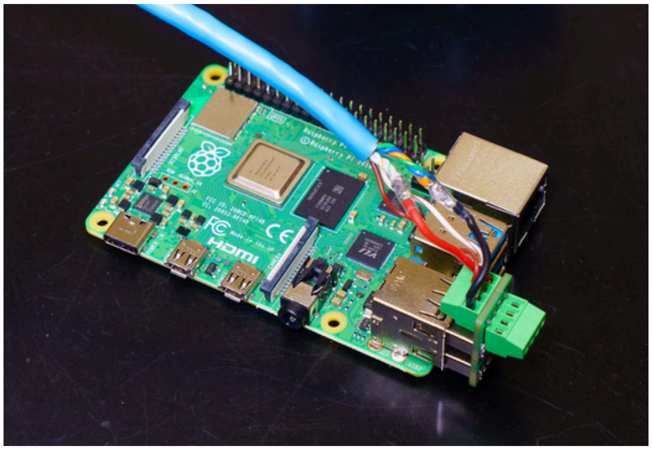


Figure 25. Camera plugged into RPi Via PCB

In addition, Atolla provides two dedicated mission cameras to enable specific visibility of mission tools. All four cameras are connected to a Raspberry Pi using custom-printed circuit boards (Figure 25) which adapt the standard USB port to screw terminal connectors. These boards address the specific challenge of passing large USB connectors through a waterproof bulkhead. With these adapter boards, unterminated wires can be passed through a Blue Robotics WetLink penetrator and terminated to the screw terminals.

To improve mechanical serviceability, *Geneseas* created custom resin-printed camera enclosures that can be efficiently opened and repaired. Using SLA Resin, *Geneseas* team members were able to ensure the enclosures are fully waterproof.

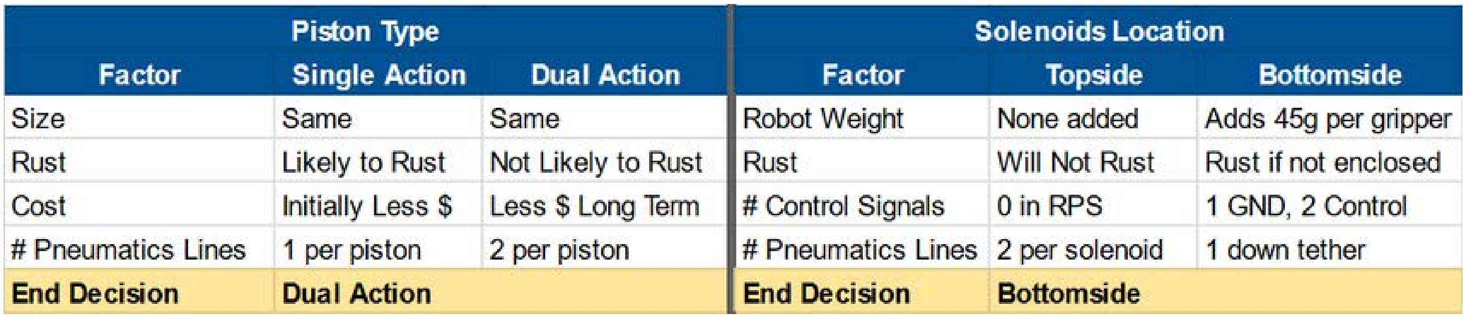
The cameras are mounted to the ROV with interchangeable magnetic mounts. Team members designed and tested custom 3d printed mounts that utilize a block and screw system so the cameras can be tilted depending on the mission. The cameras are attached to the mounts with magnets so they can be moved, and only four cameras are needed to have a full view of the ROV's surroundings.

B. Pneumatic Gripper

Atolla is configured with two parallel jaw, rack-and pinion[7,8] , pneumatically actuated grippers with replaceable jaws. By using rack and pinion gears, employees were able to turn linear motion from a pneumatic piston, to rotational motion created by the pinion, and back to linear motion to open and close the jaws. We chose to use pneumatics due to the low power consumption (2.5W), opening and closing speed, ease of waterproofing and grip strength.

This year, we decided to decrease the number of hoses that ran along the tether to increase tether flexibility and enable better robot maneuverability, allowing us to complete tasks more efficiently. At the same time, we moved from single-action spring-return pneumatic pistons to dual-action pneumatic pistons to eliminate any issues with corrosion of the spring.

Combining the goal of using dual-action pistons, which require two air hoses each, with the goal of reducing the number of air hoses in the tether required a thorough evaluation of the options (Figure 26).



	Piston Type			Solenoids Location	
Factor	**Single Action**	**Dual Action**	**Factor**	**Topside**	**Bottomside**
Size	Same	Same	Robot Weight	None added	Adds 45g per gripper
Rust	Likely to Rust	Not Likely to Rust	Rust	Will Not Rust	Rust if not enclosed
Cost	Initially Less $	Less $ Long Term	# Control Signals	0 in RPS	1 GND, 2 Control
# Pneumatics Lines	1 per piston	2 per piston	# Pneumatics Lines	2 per solenoid	1 down tether
End Decision	**Dual Action**		**End Decision**	**Bottomside**	

Figure 26. Gripper Parts Decision Matrix

The final decision required us to incorporate the pneumatic solenoids on the robot rather than on the surface. To do this, we manufactured a waterproof pneumatics enclosure that houses the pneumatic solenoids. This housing includes the innovative use of cord grips, typically used for electrical connections, to pass pneumatic lines into the enclosure.

Atolla's pneumatic system receives air regulated to 2.76 bar (40 psi) to power the grippers. The air is sent down the tether through a single ¼-inch pneumatic line, which feeds two 5/2-type solenoids housed inside the pneumatics housing. The copilot opens and closes these solenoids using buttons on the RPS. When the solenoids are opened, the pneumatics lines are pressurized, and the associated tools are activated. Atolla's pneumatics SID is shown in Figure 27.

The mechanical design process for the gripper relied heavily on the use of CAD (Computer Aided Design) software to virtually test its capabilities while saving material, resources, and time. *Geneseas*' gripper is completely 3D printed using polycarbonate filament to allow very customizable features such as easily interchangeable claws, and, ultimately, a more cost-efficient option. Polycarbonate is an extremely durable, non-corroding material. It is inexpensive and relatively easy to print while also being exceptionally lightweight. 3D-printed polycarbonate is an excellent alternative to heavier, more expensive, and more challenging to manufacture metals.

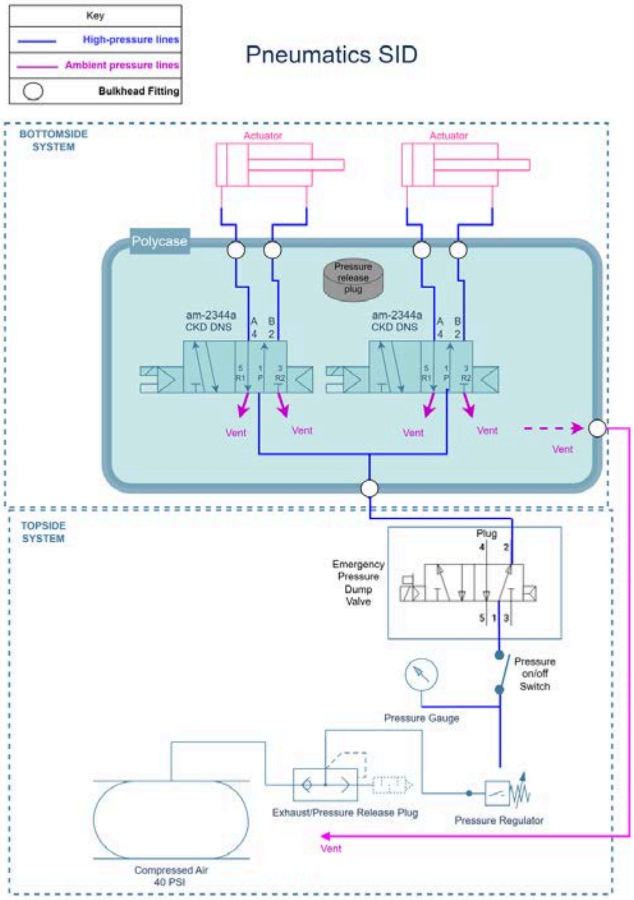


Figure 27. Atolla's Pneumatics SID

Figure 28. Gripper CAD

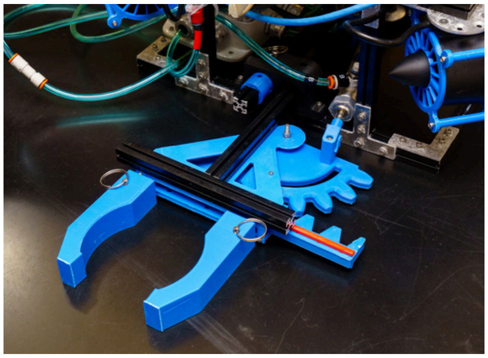


Figure 29. ROV Gripper

C. Smart Cable Winder

The smart cable tool is designed to assist the ROV when bringing the smart cable back to the pool's surface after stationing the smart repeater in its appointed place without any of the wire getting tangled. This tool consists of a 3D printed spool and a holder attached to the ROV, near the gripper. Once the ROV deploys the smart cable through three waypoints and places the smart repeater in its designated area, this tool efficiently returns the cable to the surface. The end of the cable is twisted and wound onto the spool manually until it reaches the smart repeater. Then, the spool is placed into the holder attached to the ROV. This leaves only the wire attached to the smart repeater through a hole in the front of the box. The force the ROV makes by pulling the smart cable away from the smart repeater will unravel the spool. This reliable tool completes Task 2.1 and ensures the cable has no obstacles.

D. Temperature Sensor

Atolla's temperature sensor tool reliably measures pool temperature within 1°C of the SMART repeater's temperature sensor. The sensor is mounted to the front pneumatic gripper for easy access and is connected to the Raspberry Pi via I2C. A custom CAD mount was designed specifically for the temperature sensor. The temperature is displayed on the GUI widget panel.

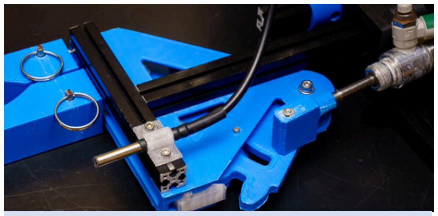


Figure 30. Temperature Sensor

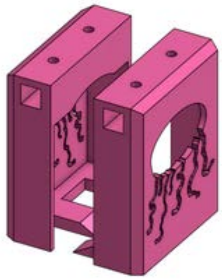


Figure 31 .Sediment Scoop CAD

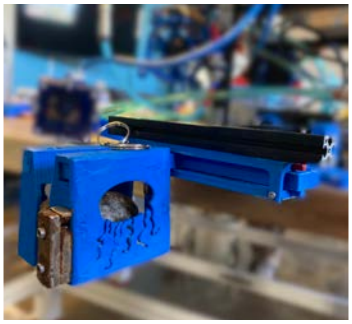


Figure 32. Printed and Mounted Sediment Scoop

E. Sediment Scoop

Inspired by the demolition claw in construction work[9], *Geneseas* designed and built a 3D-printed claw-like attachment for the gripper arms to pick up rocks rapidly. While Atolla's standard gripper arms may be able to collect rocks, this dedicated tool makes collecting rocks faster and more reliable. This box design had many revisions and prototypes, including a downward-facing box and a forward-facing shovel with varying heights and lengths. Through thorough in-pool testing, the ideal design was determined. This tool mainly focused on an enclosure that assures that once the rock is collected, it will remain there as the ROV surfaces.

G. Irrigation Spinner Tool

Geneseas utilized a rack and pinion system for the irrigation spinner tool. This tool consists of a cross-connector receiver and two gripper arm attachments. The pinion is mounted on the stationary arm and the rack is mounted on the moving arm. The pilot directs the cross-connector receiver to the PVC cross on the valve. Once aligned, the co-pilot closes the gripper. As the gripper closes, the arm containing the rack translates, engaging with the pinion, and causing the pinion and receiver to spin 360 degrees, turning on the irrigation system.

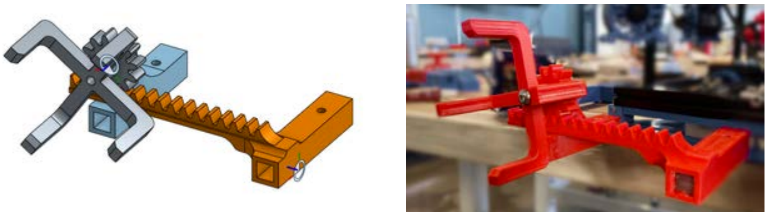


Figure 33. CAD and Printed Irrigation Spinner

F. Recovery Line Tool

Geneseas' recovery line tool is designed to complete task one efficiently. It is an optimized and 3D-printed version of the MATE-provided carabiner tool. The main difference in our tool is the addition of the bottom block and a custom-designed head inspired by the valves in a human vein[10]. The custom-designed head consists of two pieces that curve into each other. These pieces are flexible enough to swiftly snap on to the U-bolt, but secure enough to ensure that the tool will not come off once it's hooked on. The bottom block is custom-created to fit more securely in Atolla's pneumatic gripper. A knot and epoxy attach the rope inside the block, ensuring security.

The purpose of this tool is to serve as a recovery float. The head is to be pressed against the U-bolt, attaching itself to be then let go by the gripper and serve as the recovery line.

Figure 34. Recovery Line Tool CAD

Figure 35. Printed and Mounted Recovery Line Tool

G. Photogrammetry Tool

Atolla's photogrammetry tool creates a fully-dimensioned 3D model of the coral head. *Geneseas* chose pyQt5, TKinter, CV2, and RealityCapture to develop this tool. *Geneseas's* software team developed a Python program to take screenshots of the given coral restoration area, and approximate the coral restoration area's width, height, and size. PyQt5, TKinter, and CV2 were chosen because of their ready-made applicability to the coral head imaging challenge and ease of integration with existing *Geneseas's* software. To measure the coral restoration area, *Geneseas* includes the display of two horizontal bright red bars centered in the live streaming ROV camera. The bright red color is more visible than other colors in the water, enabling the pilot to gain proper alignment of the bars in preparation for screenshots. The pilot lines up the middle 32 centimeter PVC pipe of the coral restoration area between the red bars and screenshots the screen. Using the alignment of the 32 centimeter pipe and the red bars as a reference, a custom Python-based pixel counting measurement tool is used to calculate the remaining height and width of the coral restoration area.

After the measurements are complete, *Geneseas* uses RealityCapture as a means of creating a 3D model of the coral restoration area. Screenshots are taken by the pilot, which are processed into RealityCapture, generating a detailed 3D model of the coral restoration area. RealityCapture was chosen for its convenient functionality, offline capability and cost-effectiveness.

4. BUOYANCY ENGINE

Geneseas' newest vertical profiling float, *Bluefin*, utilizes a buoyancy engine and depth sensor to autonomously complete vertical profiles and collect and output data. The buoyancy engine team's main objectives were to: improve battery life, streamline the electronics and create a robust communication system. These objectives were informed by lessons from the previous year's design and resulted in upgrading to C-cell batteries, developing a custom PCB, and switching to a Raspberry PI Zero for on-board computing.

Bluefin is constructed from 3-inch clear plastic tube, a 500 mL syringe, and a lead screw that work together to adjust the buoyancy of the syringe by ingesting and expelling water upon operator command. The 500 mL syringe and lead screw allow *Bluefin* to adjust its buoyancy significantly, ensuring reliable and efficient vertical profiles. To avoid last year's problem of excess buoyancy, *Geneseas* minimized the volume of the tube and used aluminum dowels for the external frame.

Employees chose to separate the batteries from the electronics and place the weight near the bottom for serviceability. This separate, watertight enclosure allows batteries to be easily replaced without interfering with the main components. Additionally, a pressure release plug is added in the lower compartment to ensure the safety of the float's surroundings should pressure build up in the battery compartment.

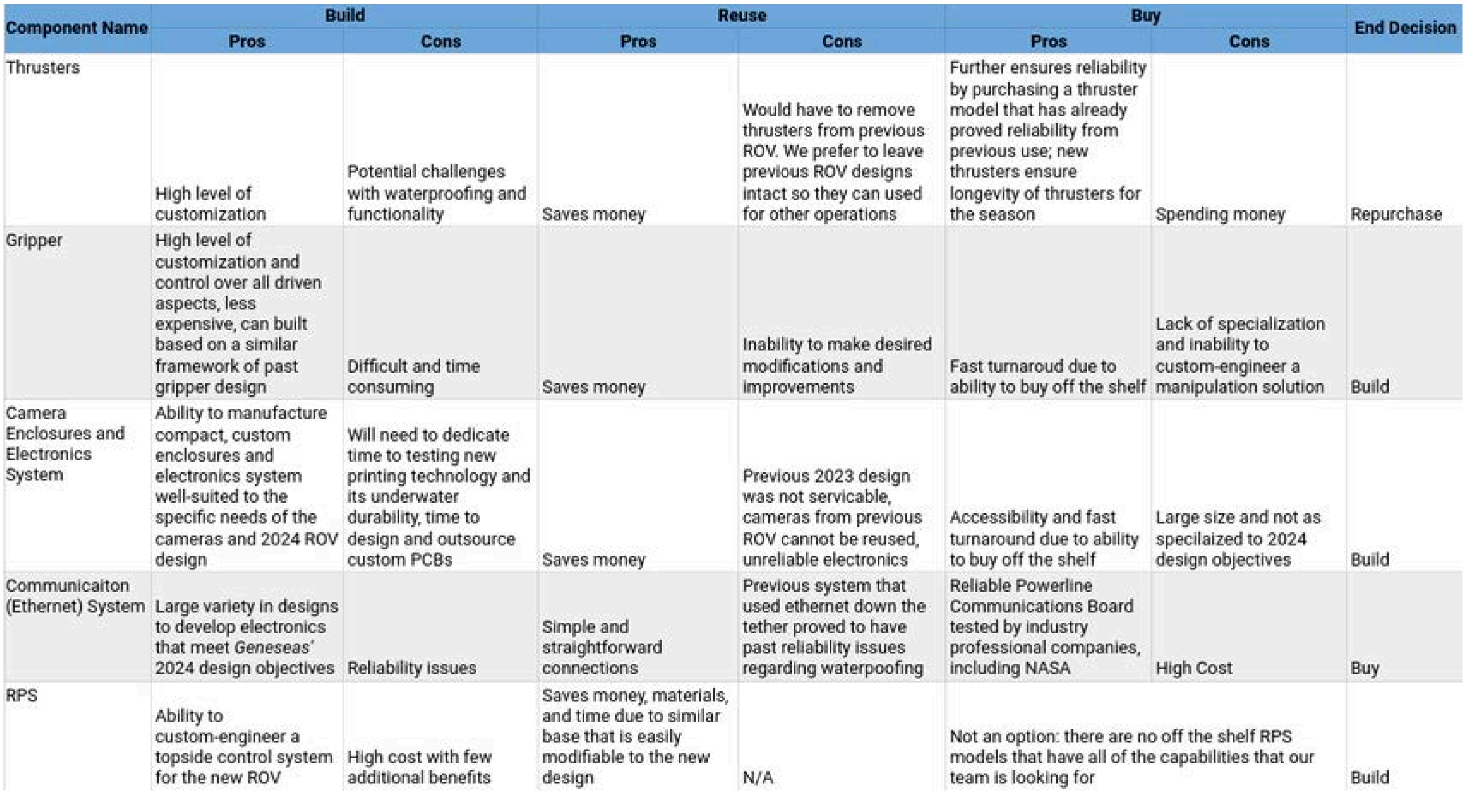
Bluefin's use of a custom PCB and Raspberry Pi Zero provides a compact and powerful set of electronics. The PCB's circular shape maximizes space in the round tube. The PCB serves as a Pi "hat", as it features a 2x20 Pi Zero header to integrate the Raspberry Pi. The PCB also includes three LEDs for the following indications: 1) buoyancy engine powered on, 2) motor is operating, and 3) batteries are low. The PCB features two relays, which allow for the operation of a geared motor which drives the lead screw.

Figure 36. CAD and Completed Float

Bluefin begins the mission at the surface and streams a webpage to a device on deck over a closed WiFi network. The use of a webpage for control and data readout ensures that *Bluefin* can be controlled from a range of devices without any special software. When the 'DIVE' button on the webpage is pressed, *Bluefin* begins ingesting water to decrease buoyancy and starts recording pressure, depth, and time via a Blue Robotics Bar02 pressure sensor. Once the float reaches the bottom of the pool, the Raspberry Pi triggers the motor 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 antenna transmits and displays the pressure and depth data at time of surfacing in UTC on the webpage. A depth versus time graph is also shown. This cycle is repeated twice.

5. BUILD VS. BUY, NEW VS. USED

Geneseas methodically sourced components for Atolla based on evaluating previous ROV features to determine whether to buy, build, or reuse components. We compiled our findings into a matrix (Figure 37) to organize our evaluations. This matrix aids us in effectively optimizing the affordability, sustainability, safety, serviceability, and reliability of each component.



Component Name	Build		Reuse		Buy		End Decision
	Pros	Cons	Pros	Cons	Pros	Cons	
Thrusters	High level of customization	Potential challenges with waterproofing and functionality	Saves money	Would have to remove thrusters from previous ROV. We prefer to leave previous ROV designs intact so they can used for other operations	Further ensures reliability by purchasing a thruster model that has already proved reliability from previous use; new thrusters ensure longevity of thrusters for the season	Spending money	Repurchase
Gripper	High level of customization and control over all driven aspects, less expensive, can built based on a similar framework of past gripper design	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 and Electronics System	Ability to manufacture compact, custom enclosures and electronics system well-suited to the specific needs of the cameras and 2024 ROV design	Will need to dedicate time to testing new printing technology and its underwater durability, time to design and outsource custom PCBs	Saves money	Previous 2023 design was not servicable, cameras from previous ROV cannot be reused, unreliable electronics	Accessibility and fast turnaround due to ability to buy off the shelf	Large size and not as specilaized to 2024 design objectives	Build
Communicaiton (Ethernet) System	Large variety in designs to develop electronics that meet *Geneseas'* 2024 design objectives	Reliability issues	Simple and straightforward connections	Previous system that used ethernet down the tether proved to have past reliability issues regarding waterpoofing	Reliable Powerline Communications Board tested by industry professional companies, including NASA	High Cost	Buy
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 modifiable 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		Build

Figure 37. Build vs. Reuse vs. Buy Decision Matrix

For example, our evaluation process helped us decide to buidl a new camera system. While our previous camera system worked well for the 2023 season, we decided not to reuse this system as it did not fit our 2024 goal – to increase serviceability and reliability. For 2024, *Geneseas* chose to repurchase the same camera modules and redesign the mechanical enclosures and the camera electronics system. Evolving this system involved utilizing resin 3D printing and designing custom PCBs to yield a more reliable and serviceable vision system.

To further meet 2024 design objectives of serviceability and reliability, *Geneseas* conducted thorough testing of newly purchased Powerline Communications (PLC) Boards. After testing, *Geneseas* confirmed that the PLC can effectively be integrated into our electronics system and provide the necessary bandwidth that enables us to remove the ethernet connection from our tether. This addresses past reliability issues that came with waterproofing ethernet connections.

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 Atolla's gripper. *Geneseas* chose to redesign the gripper to yield a more serviceable and reliable design that meets the objectives of the 2024 mission tasks. This decision allowed us to redesign a gripper that is more reliable, highly resistant to corrosion, more precise, and can be easily adapted for any task ranging from retrieving a sediment sample to operating an irrigation system.

Geneseas carefully assessed mission objectives when determining whether to reuse components or design new ones, such as the RPS and thrusters. Components tested, confirmed to be in good condition, and aligned with the mission requirements were repurchased. This was the case for the previous year's thrusters which were repurchased because of their proven reliability and were reprogrammed to allow for more maneuverability. Ultimately, these sourcing decisions made Atolla the most functional and cost-effective ROV for *Geneseas*' needs.

6. TESTING AND TROUBLESHOOTING

Geneseas meticulously tested individual components and the ROV as a whole throughout the development process to ensure the efficacy, safety and reliability of the various systems. Every feature was extensively tested prior to in-pool usage, and new features underwent a testing process of increased rigor. Employees built upon previously established testing practices to produce a functional, safe, and reliable ROV.

Before placing Atolla in the water, *Geneseas* calibrated each thruster to ensure functionality, increase efficiency when getting in the pool, and minimize time spent initializing each thruster. Verifying thruster calibration enabled the team to adjust the movement software to ensure all thrusters turned on simultaneously. *Geneseas* utilizes a custom bash script to check camera functionality and discern potential vision failures. If either the cameras or thrusters fail during a mission run, *Geneseas* employees are able to swiftly recover vision and movement by restarting the cameras or thrusters via this bash script. Additionally, Atolla undergoes a 10-minute vacuum test to ensure there is no leakage before undergoing a dry test.

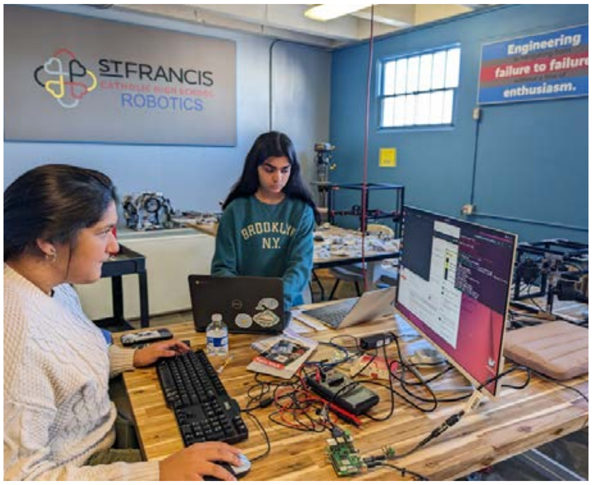


Figure 38. Testing Camera Streaming & PCBs

Geneseas uses a two-step testing process on all tools. Once the tools were developed, employees first dry-tested the components to check for design flaws and verify reliability. The second step is 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. Software tools and movement code were debugged by team members outside of Saturday practices, allowing our pilot to practice with reliable and bug-free code. The debugging process consists of rigorous peer-editing and in-pool analysis during the two-step tool testing process. This yields the development of precision and quality-enhancing features such as fast/slow mode and pilot inversion.

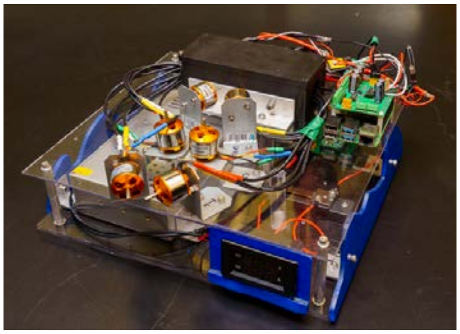


Figure 39. Test Bench

Geneseas employees created a portable replica of the ROV (Figure 39) with a Raspberry Pi 4B, Atolla's Raspberry Pi "hat", 6 thrusters and a camera to mimic the finctionality of Atolla. This test bench enabled the *Geneseas* software team to develop and est code on the test bench while other team members worked directly on the ROV. This allowed simultaneous development and testing of Atolla's movement software, socket communication between the topside GUIs and the bottomside Raspberry Pi, and additional improvements to pilotability. The test bench also ensured the transfer of tested code to the ROV, as any issues could be resolved on the model system before potentially failing on Atolla. After the software was developed for the ROV, employees dry-tested all software prior to pool testing to ensure its basic functionality. After successful dry run tests, employees then moved to the pool, where various software elements were tested. In-pool testing and optimization was particularly necessary for movement software to ensure proper functionality of the thrusters in the water.

7. SAFETY

A. Safety Philosophy

Geneseas is thoroughly dedicated to staff and customer safety at every stage of development, testing, and operation. *Geneseas* implements and enforces safety standards at and above the expected level, carefully planning and executing original safety policies while adhering to those already established by MATE.

Geneseas emphasizes consistent safety policy and makes sustained efforts to educate new and returning employees in safe operation through a rigorous training process. *Geneseas*' safety training covers critical topics, including lifting safety, electrical safety, tool safety, hazardous materials handling, and housekeeping.

Geneseas' safety ethic is extended to Atolla by incorporating safety features into every part of the ROV's design. For *Geneseas*, safety is not just a policy, but a core value that guides every action and decision the company makes.

B. Lab Protocols

Geneseas requires its employees to practice basic safety by wearing close-toed shoes, tying back hair, and using PPE when machining, soldering, or working with the ROV. Safety glasses are required in the lab, in addition to gloves, masks, and ear plugs, which are necessary to operate tools and handle certain materials.

As part of *Geneseas*' training process, mentors and returning team members demonstrate the safe usage of machines to new employees and supervise their use. Mentors and returning members instruct employees in properly securing equipment and parts and arranging their workspace to minimize the potential for accidents or injuries. Even with sufficient training, experienced employees must be present for the operation of more advanced tools, and no employee is permitted to operate tools alone, regardless of experience level. *Geneseas* keeps track of which employees are approved to operate each tool with a detailed, organized labeling system available to all employees whenever they are in the lab. All employees remain vigilant in helping and reminding teammates to uphold the highest safety standards, ensuring everyone's safety.

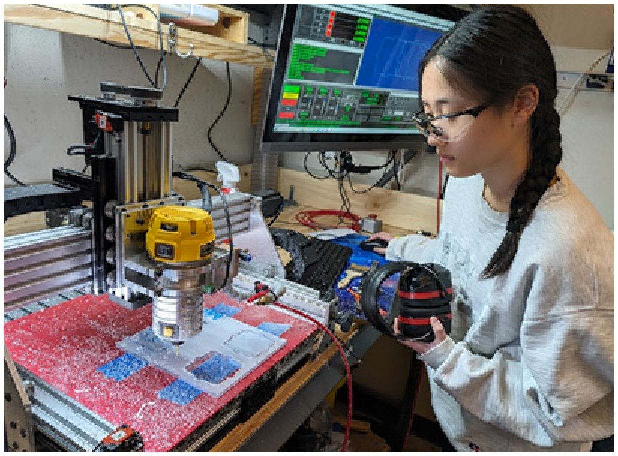


Figure 40. Employee in Lab Preparing CNC

Geneseas team members also follow a detailed safety checklist when practicing in the water. The pilot, co-pilot, and safety manager work together to adhere to the safety checklist and the protocols outlined in the Job Safety Analysis (JSA), ensuring the protection of all crew members. When working near water, employees exercise safety by keeping electrical cords and electronic devices away from moisture.

Figure 41. Lab Safety at the Mill

Geneseas team members also mandate clear and direct communication between the pilot and the tether manager in order to reduce the risk of harm. Multiple team members consistently check and survey the ROV before and after entering the water to ensure proper maintenance and eliminate the possibility of harm when interacting with the ROV. The RPS, laptop, and pilot station are kept on a dry, elevated platform with a roof to minimize potential safety risks during pool operations.

Geneseas further maintains a safe work environment for its employees in the company's lab facility. The lab features a chemical vent hood to reduce employees' fume exposure while soldering, and the use of properly maintained tools with no rust or wear to ensure employee safety. The lab is consistently maintained as a clean, safe environment. *Geneseas* strives to maintain an organized workspace to ensure the efficiency and safety of all its employees. Upon finishing a task, employees must promptly discard waste materials and return tools to their marked places. Geneseas ensures first aid kits and fire extinguishers are readily available, and through proper training, the company implements preemptive safety measures. These safety measures and employee training methods have been extremely effective in educating employees on potential hazards and preventing accidents or injuries.

C. Vehicle Safety Features

Geneseas' integration of safety into their design process is reflected in Atollas's many safety features. The safety features incorporated into the ROV and RPS are essential to prevent accidents, avoid injuries, and enable swift responses to potentially dangerous situations.

In addition to the ROV and RPS safety features, employees have organized and labeled the components and wires to make inspection, maintenance, and serviceability more efficient. Every part of Atolla is intricately crafted around safety. Every tool is tested and safety is ensured before being integrated into the greater ROV. Every individual subteam is held to *Geneseas*' high safety standards and operates under such expectations, ensuring the complete safety of not just the core ROV, but every facet of it, no matter how small.

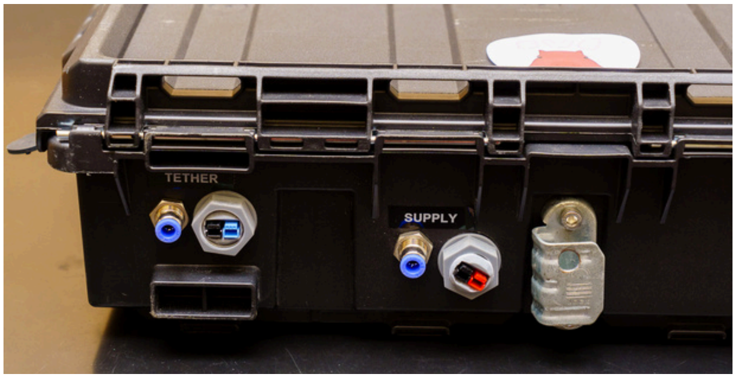


Figure 42. Labeled and Color-coded RPS

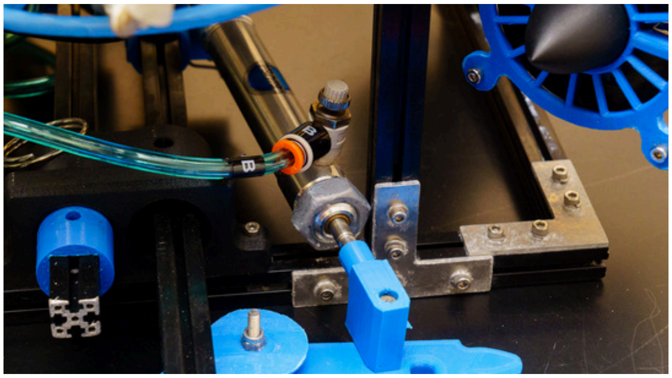


Figure 43. Labeled Pneumatic Line

D. Operations and Safety Checklist

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 Atolla.

8. BUDGET AND COST ACCOUNTING

In addition to a detailed budget for development of Atolla, *Geneseas* took a comprehensive approach to creating a detailed Profit & Loss (P&L) analysis. The P&L includes: all non-recurring engineering (NRE) development costs (including market-rate labor costs) during a one-year development period, unit costs for the manufacturing of each production robot and revenue estimates based on market prices. This required diligent cost and labor tracking for initial development as well as forecasting for production, marketing, and overhead expenses. We have estimated future income streams and costs based on historical data and market trends to determine the project's long-term financial sustainability. The project will break even (recover all up-front costs) at approximately 138 units sold during the first year of production. P&L and budget details can be found in appendices B, C and D.

Geneseas did a complete competitive pricing analysis, considering manufacturing costs, market demand, and competitive positioning. A comparative analysis table was created to compare *Geneseas* products to those of key competitors, allowing for more informed pricing decisions and gaining a competitive advantage while driving profitability. Based on this analysis, pricing for Atolla should be between $6,000 and $9,000 per unit. *Geneseas* chose $7,500 as the initial price.

Similar to earlier inspections, *Geneseas* examined make vs buy decisions to identify the most reliable and cost-effective parts solutions. Additionally, a focus was placed on discovering options for reusing current technologies or components to reduce development costs and improve overall efficiency.

9. 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 and the Marine Technology Society, Sponsor of the 2024 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, Maurice Velandia, Jay Isaacs, Michael Sharp, Steve and Cheryl Kiyama for your time, experience, dedication, knowledge, and guidance. Your patience and commitment fostered a team environment focused on learning and fun.
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- To our families, our heartfelt gratitude for all of your guidance and support
- To Tyler Schilling, Schilling Robotics, Nauticus Robotics, NASA, Green Circuits, Bay Area Circuits, and The Aerospace Museum of California for inspiring the future and showing us real-world applications of our technology.

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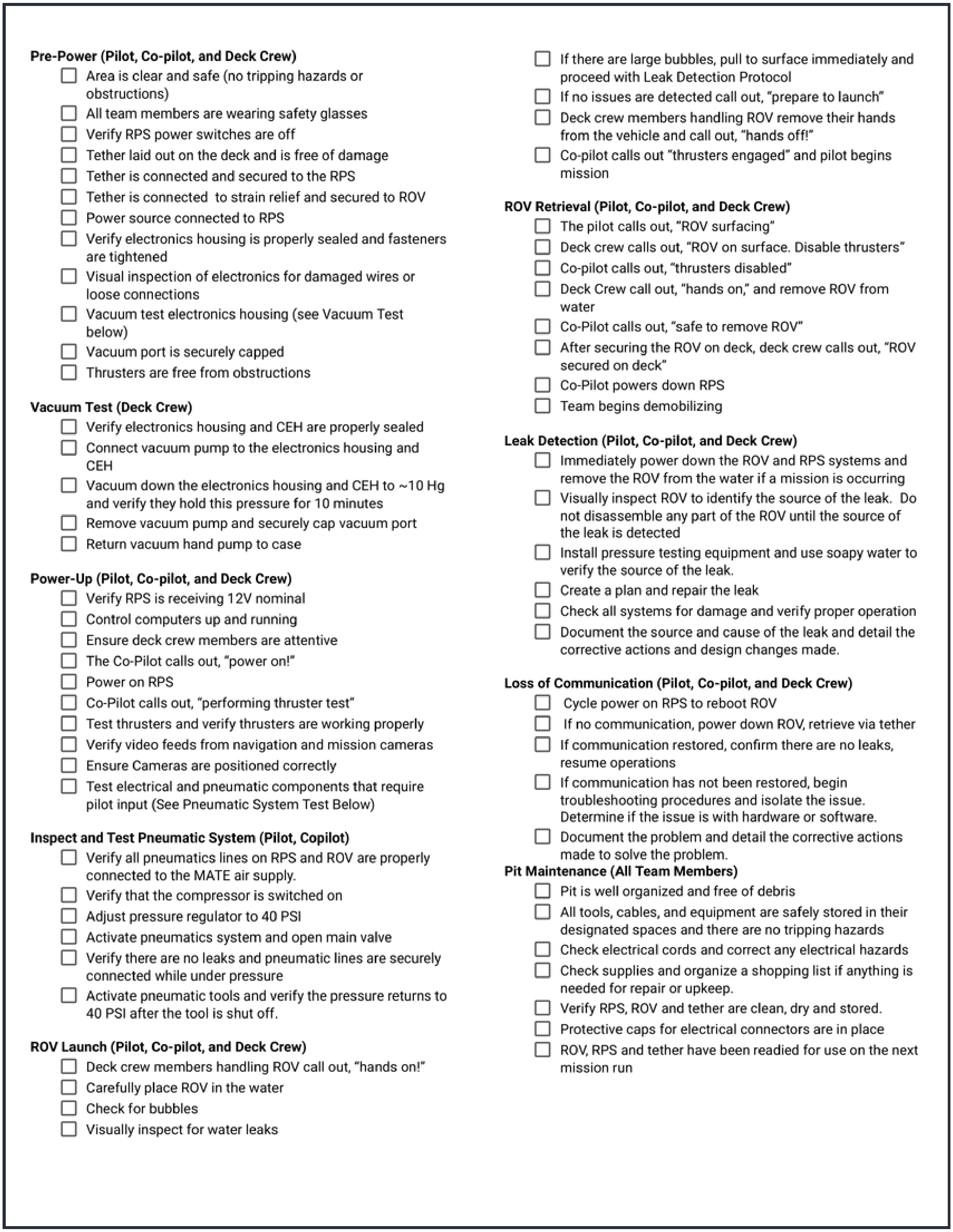
10. APPENDICES

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 disabled"
- ☐ 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.

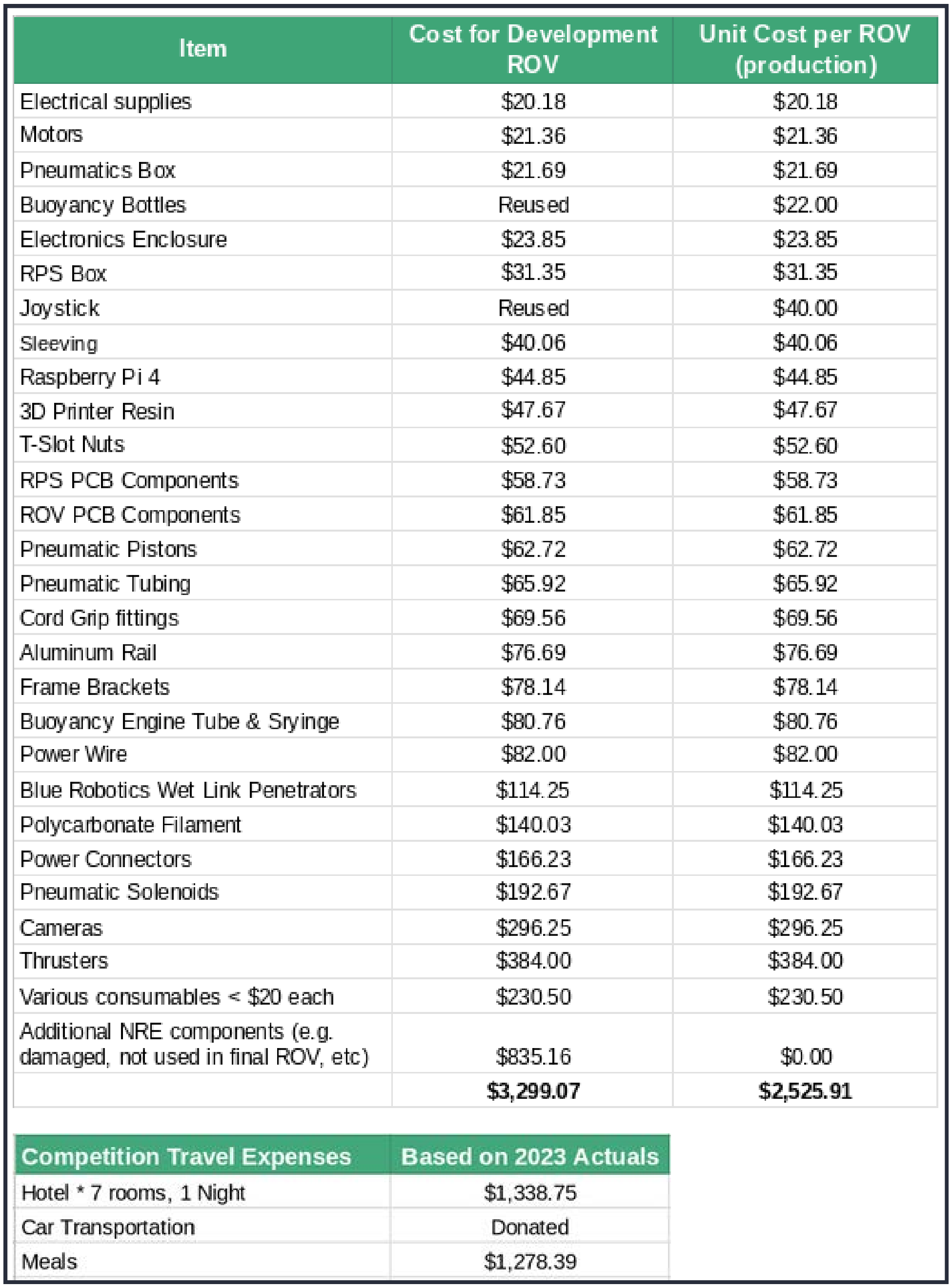
Loss of Communication (Pilot, Co-pilot, and Deck Crew)

- ☐ 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



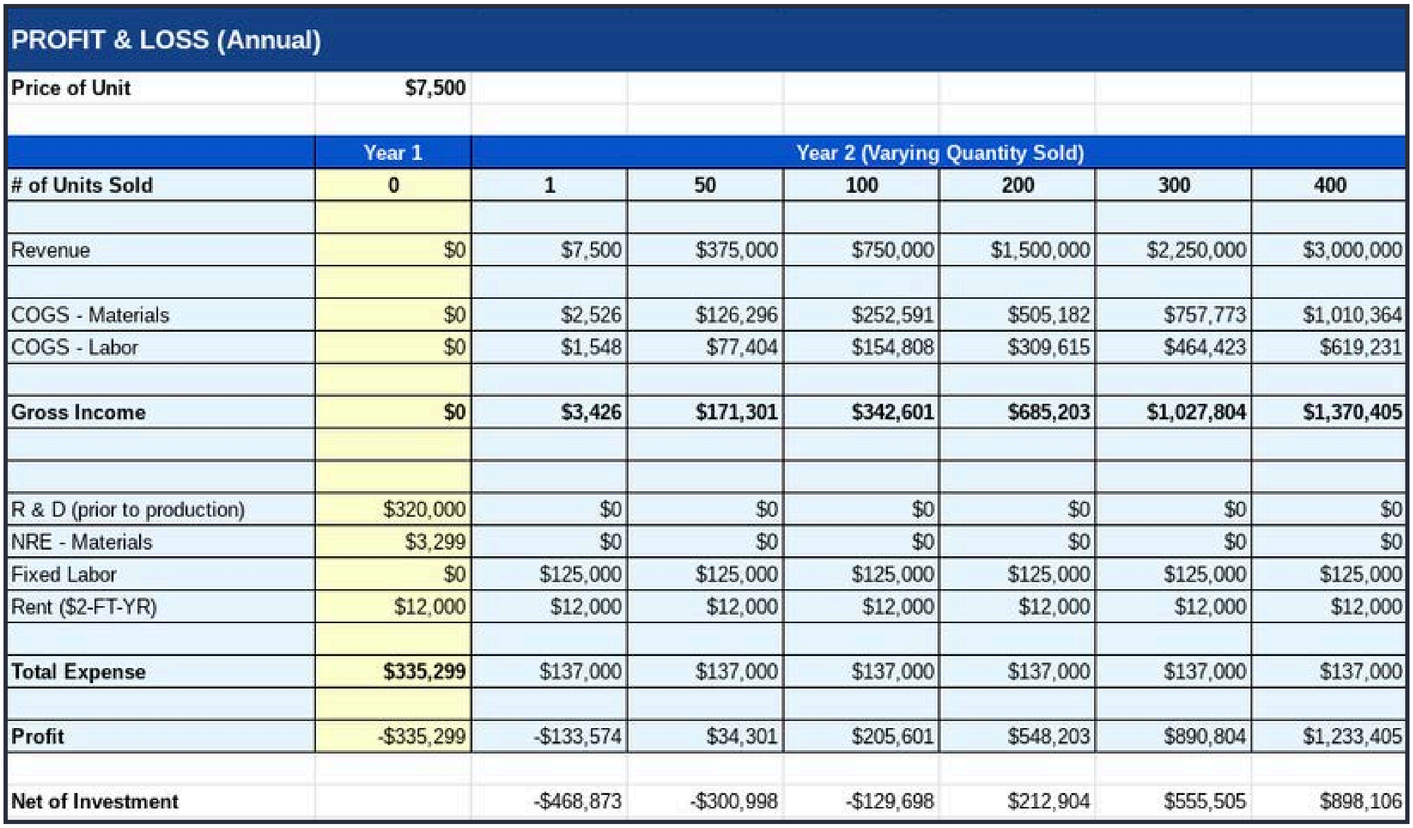
Item	Cost for Development ROV	Unit Cost per ROV (production)
Electrical supplies	$20.18	$20.18
Motors	$21.36	$21.36
Pneumatics Box	$21.69	$21.69
Buoyancy Bottles	Reused	$22.00
Electronics Enclosure	$23.85	$23.85
RPS Box	$31.35	$31.35
Joystick	Reused	$40.00
Sleeving	$40.06	$40.06
Raspberry Pi 4	$44.85	$44.85
3D Printer Resin	$47.67	$47.67
T-Slot Nuts	$52.60	$52.60
RPS PCB Components	$58.73	$58.73
ROV PCB Components	$61.85	$61.85
Pneumatic Pistons	$62.72	$62.72
Pneumatic Tubing	$65.92	$65.92
Cord Grip fittings	$69.56	$69.56
Aluminum Rail	$76.69	$76.69
Frame Brackets	$78.14	$78.14
Buoyancy Engine Tube & Sryinge	$80.76	$80.76
Power Wire	$82.00	$82.00
Blue Robotics Wet Link Penetrators	$114.25	$114.25
Polycarbonate Filament	$140.03	$140.03
Power Connectors	$166.23	$166.23
Pneumatic Solenoids	$192.67	$192.67
Cameras	$296.25	$296.25
Thrusters	$384.00	$384.00
Various consumables < $20 each	$230.50	$230.50
Additional NRE components (e.g. damaged, not used in final ROV, etc)	$835.16	$0.00
	$3,299.07	**$2,525.91**

Competition Travel Expenses	Based on 2023 Actuals
Hotel * 7 rooms, 1 Night	$1,338.75
Car Transportation	Donated
Meals	$1,278.39

Appendix C: Labor Costs

Staff	Salary and Benefits	Cost per Hour	# of Employees	Fixed Cost	Hours / Unit	Cost / Unit	
Electrical Engineer	$90,000	$54			8	$433	
Software Engineer	$90,000	$54			8	$433	
Mechanical Engineer	$90,000	$54			8	$433	
Administrative	$50,000	$30	1	$50,000		$0	
Customer Support	$45,000	$27	1	$45,000		$0	
Sales	$30,000	$18	1	$30,000		$250	Commission
	$395,000			**$125,000**	**Fixed**	**$1,548**	**Variable**

Appendix D: Profit & Loss



PROFIT & LOSS (Annual)							
Price of Unit	**$7,500**						
	Year 1	**Year 2 (Varying Quantity Sold)**					
# of Units Sold	**0**	**1**	**50**	**100**	**200**	**300**	**400**
Revenue	$0	$7,500	$375,000	$750,000	$1,500,000	$2,250,000	$3,000,000
COGS - Materials	$0	$2,526	$126,296	$252,591	$505,182	$757,773	$1,010,364
COGS - Labor	$0	$1,548	$77,404	$154,808	$309,615	$464,423	$619,231
Gross Income	**$0**	**$3,426**	**$171,301**	**$342,601**	**$685,203**	**$1,027,804**	**$1,370,405**
R & D (prior to production)	$320,000	$0	$0	$0	$0	$0	$0
NRE - Materials	$3,299	$0	$0	$0	$0	$0	$0
Fixed Labor	$0	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000
Rent ($2-FT-YR)	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000
Total Expense	**$335,299**	$137,000	$137,000	$137,000	$137,000	$137,000	$137,000
Profit	-$335,299	-$133,574	$34,301	$205,601	$548,203	$890,804	$1,233,405
Net of Investment		-$468,873	-$300,998	-$129,698	$212,904	$555,505	$898,106