NOVA

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TECHNICAL REPORT ‘23

AQUAPHOTON ACADEMY

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1 Introduction

1.1 Abstract

We, Aquaphoton Academy, always strive to go beyond our limits in terms of innovation, technological advancements, and design creativity. In response to the tremendous challenge of saving and conserving our ocean, we created ***Nova*** , a Remotely Operated Underwater Vehicle (ROV) that is the dawn of new beginnings for ocean conservation. ***Nova*** harnesses features and capabilities that go beyond anything our company has achieved before.

Aquaphoton is an entirely student-run company from Alexandria University and has been participating in the positive momentum of conserving our planet from pollution, all while applying our collective experience and knowledge in the field of ROVs, for the past eleven years.

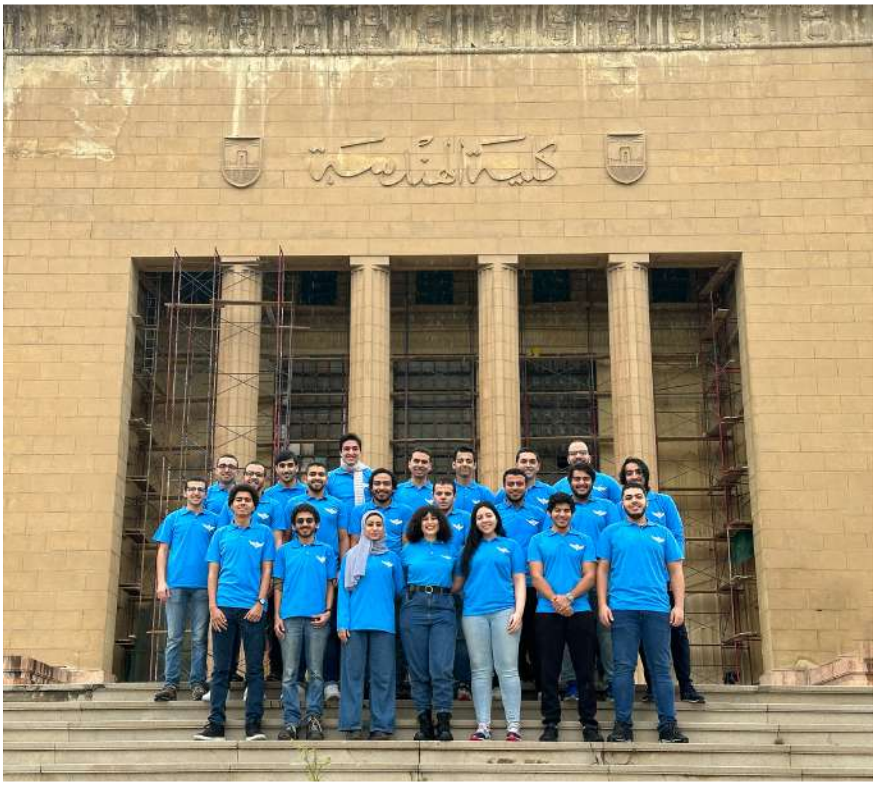


Figure 1: Aquaphoton's Team

Nova is the latest edition of the successive demonstration of Aquaphoton's commitment to this mission. This year, the mechanical design has been upgraded with an aluminum-square canister that allows for the addition of numerous features and the key upgrade from 6 to 8 thrusters. Furthermore, the communication system has also been upgraded to use the Robot Operating System (ROS2), allowing for easier expansion and debugging of the code.

Figure 2: ***Nova***'s Real Life Image

With these enhancements, ***Nova*** is excellently able to perform maintenance and inspections without human intervention while being able to automatically return to its docking station. ***Nova***'s design includes advanced data analytic capabilities that allows it to collect extensive information about the health of the ocean's ecosystem, which is further analyzed using cutting-edge deep learning algorithms. The combination of these features, along with its vertical profiling float, makes ***Nova*** the perfect choice for conserving our ocean.

2 Design Rationale

2.1 Design Evolution

Aquaphoton Academy is continuously striving to upgrade and enhance its own designs; never settling for just an acceptable performance. This year, we decided to broaden our horizons by researching and developing new foreign concepts in ***Nova*** , shown in Figure 3.

Figure 3: ***Nova***'s Rendered Model

Square Canister

The most notable change in the mechanical design is the main canister, which is now an aluminum-square design that replaces the standard acrylic cylinder we used for many years. This change, most remarkably, has a larger surface area where a numerous number of glands can be installed; far greater than in previous designs. This gives us leeway to freely install more features, manipulators, and payloads as needed without restriction, but more significantly, we were able to upgrade the previous thrusters' configuration of six thrusters to eight thrusters.

Not only does the increase in the number of thrusters guarantee better, faster, and smoother motion for ***Nova*** , but it also gives it the sixth degree of freedom: roll. With all the degrees of freedom now available, flexibility and efficiency in performing missions, both manually and autonomously, are better than ever before.

ROS2

The main communication system of ***Nova*** has taken a completely new direction in an effort to achieve simplicity, abstraction, and modularity by using ROS2. While the previously used Controller Area Network (CAN) communication protocol offered adequate adaptability to a large number of nodes and excellent stability, it proved rather difficult to expand in an object-oriented manner as the system became more complex with newer features added. ROS2 allows us to seamlessly add new protocols and features to ***Nova*** while maintaining readable and simple code that is vital for debugging. Moreover, we can simply program the microcontroller remotely without opening the main canister as it is connected to a Raspberry Pi that can be accessed by the Topside Control Station. A process that is as simple as clicking Upload in our IDE; replacing the efficient but comparably tedious process of last year's CAN bootloader.

ESP32

The change in the communication system brings us to our next upgrade, the STM32 microcontrollers have all been replaced with the ESP32 microcontrollers as they have a much larger flash memory size, are relatively lower in cost, and have a larger number of digital multi-purpose pins. On top of that, it supports the ROS2 library that couldn't be integrated into the previous STM32 system.

Our Custom ESC - Neptune

Relying on commercially available Electronic Speed Controllers (ESCs) had many downsides that negatively affected our workflow. Not only was finding an ESC with a suitable current rating difficult, but it was also expensive and challenging to obtain as they are not available locally. To address this problem, the hardware team utilized the R&D phase efficiently to come up with our very own ESC design.

After Neptune was thoroughly tested, it was deemed suitable and reliable enough to replace the previously used commercial ESC which significantly cut down our total cost, as it costs 10$ while the basic ESC by BlueRobotics is 36$. Moreover, our custom design allows for a wide selection of customization options, making the ESC far more compatible with our system.

2.2 Design and Manufacturing Process

2.2.1 Design Process

• Conceptual Design

During the design and deployment of last year's ROV, ***Pisidia***, Aquaphoton realized the system capacity had reached its absolute maximum. Any plans for upgrades, such as increasing the number of cameras, increasing the number of thrusters, or adding unique and new features to the ROV, were practically impossible with the 6-inch acrylic cylindrical canister. To overcome this pitfall, the team focused on holding multiple brainstorming meetings where each member proposed ideas and solutions that were thoroughly discussed. At the end of this phase, three main designs, shown in Figure 4 were selected for further research: A larger 8-inch cylindrical acrylic canister, a double 4-inch acrylic canister, and a novel aluminum square canister.

In parallel, several design ideas for the frame and manipulators were being formulated along with the camera cases. Moreover, a concise plan for the electrical system, detailing the design goals, required features, and trade-offs needed, was reached.

Moreover, during this period the electrical R&D phase was in action, where new ICs and modules, such as the buck converter, ESP32 board, and the custom ESC, were being manufactured and tested. The main goal was to monitor how well we can exploit their advantages, and therefore their readiness to be integrated into our system.

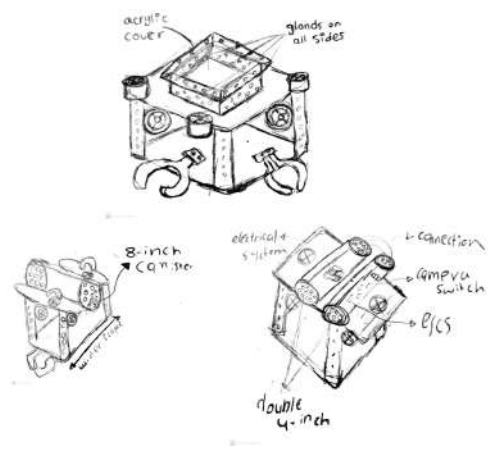


Figure 4: ***Nova***'s Design Sketches

• Preliminary Design

Through conducting flow simulations with SOLIDWORKS on the 3D model, the 8-inch cylindrical canister idea was quickly crossed out due to its huge volume that will pose significant problems to the ROV's buoyancy. The same simulations and 3D modeling were done for the double 4-inch canister and the square canister and both gave optimistically favorable results. However, an issue arose with the double canisters regarding the electrical design, as the connection between the two canisters proved to be unstable and would hinder the communication signals greatly.

The team has then reached the decision to move forward with the square canister design, as it not only proved to have no major drawbacks but also offered a myriad of design possibilities thanks to its exceptionally large surface area.

Moreover, wooden prototypes were made for several manipulators as a proof of concept and to reduce material, cost, and time loss as much as possible.

The main goal of our designs is to provide a flexible system that can adapt to any features needed in future phases. Therefore, the hardware team utilized this phase and started developing the schematics of the new system. The components are carefully selected to have the best compatibility with our system while having the optimum cost.

• Detailed Design

The design of the entire ROV, shown in Figure 5, was finalized on SOLIDWORKS, including the manipulators, camera cases, and the square canister. More accurate flow simulations and stress analysis were done on the entire ROV using SOLIDWORKS simulations to determine any points of weakness and perfect the design for the manufacturing phase.

A trade-off matrix, shown in Table 1, was constructed to quantitatively evaluate the chosen materials based on size, weight, and cost metrics.

The electrical system boards' design was finalized in Altium Designer. The Gerber files were sent for manufacturing while the Bill Of Materials (BOM) was sent to the components supplier. The firmware team uses this period to test new ideas using development boards.

#	Criteria	Weight: Frame	Manipulator	Gland's Plate	Casing	Brackets	Guides, Screws and Nuts	Material Options Score: HDPE	Acrylic	Aluminum	Stainless Steel
1	Cost Effectiveness and Availability	0.2	0.1	0.1	0.1	0.4	0.2	9	7	5	3
2	Machinability	0.1	0.1	0.2	0.3	0.3	0	9	5	9	1
3	Specific Gravity	0.2	0.1	0.1	0.2	0.1	0	9	9	7	1
4	Strength	0.2	0.3	0.6	0.1	0.2	0.8	6	7	8	9
5	Ductility	0.3	0	0	0.1	0	0	7	1	2	3
6	Transparency	0	0.4	0	0.2	0	0	0	9	0	0
	Total Score Formula	$\sum_{criteria=1}^{n}(weighting\ of\ component)_{criteria} \times (material\ score)_{criteria}$									
	Total Score	Frame						7.8	5.4	5.5	3.6
		Manipulator						4.5	7.8	4.5	3.2
		Cable Glands' Plate						7.2	6.8	7.8	6
		Casings						6.7	6.6	5.6	2
		Brackets						8.4	6.6	7	3.4
		Guides Screws and Nuts						6.6	7	7.4	7.8

Table 1: Material Trade off matrix

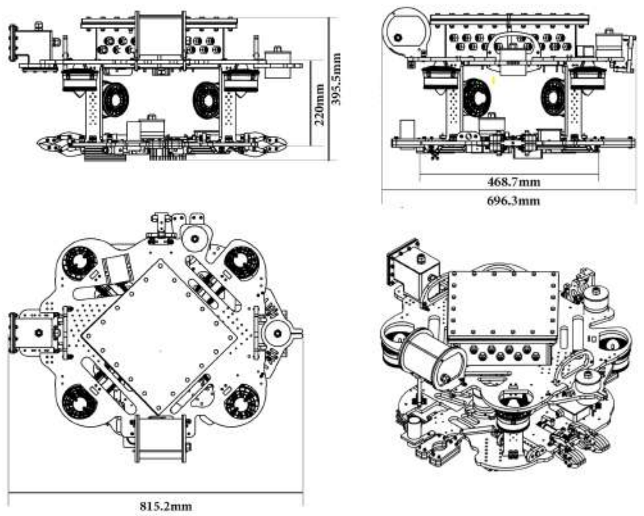


Figure 5: ***Nova***'s Drawing and Dimensions

2.2.2 Manufacturing Process

The manufacturing process guarantees dimensional accuracy and building integrity while being cost-effective. Cylindrical parts were manufactured using lathing, while acrylic, High-Density Polyethylene (HDPE), and aluminum plates were laser-cut and routed by a CNC machine. The aluminum plates were then welded together to be air-tight sealed. 2D CAD drawings were prepared for CNC cutting, taking into account optimizing the usage of the material sheets to reduce wasted material.

During this phase, the PCBs were delivered from the manufacturer and the assembly process started. Each section in every PCB was soldered and tested separately to narrow the possibilities of fault for easier debugging and troubleshooting.

2.3 Vehicle Core Systems

2.3.1 Mechanical

- **Frame**

HDPE was the selected material for this year's frame, as it is ductile, machinable, available, and cost-effective. Moreover, it allows ***Nova*** to be naturally buoyant as its density is approximately equal to fresh water's density. A more clear comparison between all material options is illustrated in the trade-off matrix in Table 1. The frame, shown in Figure 6, is designed to be light, weighing 10.82 kg, and measures at 815x395x695 mm.

Figure 6: ***Nova***'s Frame

It is mainly composed of 3 sections: the upper plate, the lower plate, and the vertical plates. There are four vertical plates in total that connect the upper plate to the lower plate and they are mounted at a 45° angle to comply with the thrusters' configuration.

The upper plate consists of a singular main plate that has numerous holes for cable routing. It holds the square canister, four camera cases, strain relief fixation, and one small buck converter.

The lower plate consists of the main fixed plate and two Variable Plate Fixations (VPF) that are connected using small custom-made aluminum links. It holds two fixed manipulators along with two variable manipulators, four buck converters, the water pump, and two camera cases: the stereo camera case and a manipulators camera case. This year, double V-slots were used to enhance the distribution of stresses, resulting from the upper plate and the canister, on the lower plate.

VPF is a modular feature of ***Nova***'s frame that allows some plates to be detached from the frame without affecting any other part of it. This gives us the ability to switch out plates and mount new/modified manipulators or payloads without needing to fully disassemble the frame and waste precious time.

All frame connections are made using mortise and tenon joints that increase the contact area between parts, and are further secured using stainless steel L-fixations; thus keeping the frame fixed and intact. Static analysis was performed using SOLIDWORKS to test the strength of the materials under extreme operating conditions and the results confirmed that our material selection was ideal.

Propulsion

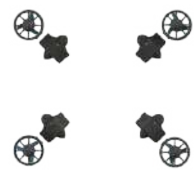
Nova is equipped with eight BlueRobotics thrusters; six of which were reused and two were newly purchased this year. A rigorous evaluation test was conducted on each thruster in order to evaluate its performance and decide whether it was fit for redeployment or not. This test verified that all the selected reused thrusters are still as adequate and reliable as they were when used in the previous year, allowing our design to be as cost-efficient as possible.

A major setback in last year's ROV was the lack of roll motion that would have aided in many missions. Thanks to this year's thrusters' configuration, ***Nova*** has all six degrees of freedom, shown in Figure 7a, that allowed it to perform numerous missions with greater flexibility and optimized performance. The roll motion aids in the 3D reconstruction, seagrass recovery, and fry release missions while the pitch motion aids in the UV light source and eDNA identification missions.

This configuration, shown in Figure 7b, was chosen to maintain symmetry in the frame while providing the best stability during motion. Four T100 thrusters are mounted horizontally at 45° in an X-shaped configuration producing 65.43 N of thrust in the forward direction, as each thruster has a maximum forward thrust of 23.15 N. For the vertical motion, four T200 thrusters are used, providing a combined thrust force of 145.58 N with each individual thruster having a thrust force of 36.4 N.

Despite the T200's higher cost and power consumption, it offers us a multitude of advantages. They range from its added lift capabilities, which were especially needed in the 12kg container mission, its higher force generation, which provides faster motion for ***Nova*** , as well as allowing for more degrees of freedom, all of which made its usage an imperative choice in our design.

(a) Degrees of Freedom



(b) Thrusters Configuration

Figure 7: Propulsion

Several flow simulations were made to validate that ***Nova*** can withstand the drag force and to calculate its maximum speed. The maximum coefficient of drag at surge speed was determined to be 0.75078 from the simulation shown in Figure 8, where 63.381 N drag at 1 $m\,s^{-1}$ speed and 0.16884 m^2 projected area were calculated according to equation 1.

$$F_D = C_D * A * \rho * V^2/2 \tag{1}$$

where F_D: drag force, C_D: coefficient of drag, A: projected area, ρ: density of the fluid, and V: flow velocity relative to the object.

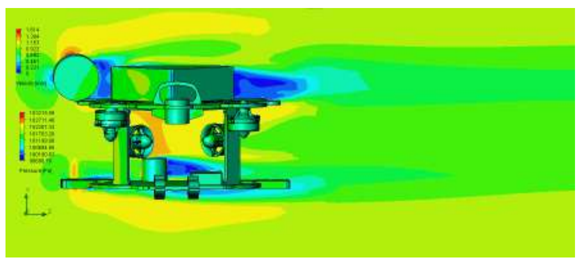


Figure 8: ***Nova***'s Flow Simulation in SOLIDWORKS

Buoyancy and Stability

During the design phase, simulations were made to determine the shift of the center of buoyancy (C_b) relative to the center of gravity (C_g). It was concluded to be 23 mm to ***Nova***'s left and 29 mm to ***Nova***'s back. Two new camera cases were aligned with the center of buoyancy and counter lead weights were added to ensure that the C_b lies above the C_g and that both centers lie on the same vertical axis, providing maximum stability.

Taking the center of the lower plate's back end as a reference, ***Nova***'s C_g coordinates are (227.15, 263.16, 438.57), and its C_b is located at (222.18, 286.16, 408.64). While both centers lie on the same vertical axis, to achieve stability, the C_b needs to be above the C_g in order to create a proper restoring moment. This is achieved by the addition of lead weights, which also contribute to achieving neutral buoyancy.

Nova's weight is 178.36 N, and the displaced volume is 19301.7311 cm^3. Archimedes' principle was then applied to calculate ***Nova***'s buoyancy, as shown in equation 2.

$$F_b = \rho * V * g \tag{2}$$

where ρ: fluid density, V: fluid volume, g: acceleration due to gravity, and F_b: buoyancy force. F_b equals 189.14 N which is greater than ***Nova***'s weight. Accordingly, 1.1 kg lead weights were added in order to reach a neutrally buoyant state.

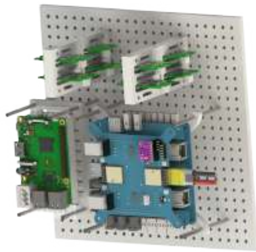
• Main Canister

The main canister, shown in Figure 9a, is used to encase and protect the electrical system. The design differs significantly from all previous generations as it has replaced the acrylic cylinder with a squared aluminum enclosure with a volume of 250x250x120 mm and a top cover acrylic lens that is 10 mm thick.

Just like last year's canister, acrylic was chosen for the lens mainly for its transparency which provides a clear view of our electrical system, allowing easier debugging and monitoring of the electrical system while also checking for any sealing faults. Moreover, the buck converters were again placed outside the main canister, as this technique proved throughout to reduce excess heat within the canister and allowed for a wide area of free space.

Adapting to this year's canister's unique shape, the drawer-like mechanism used to inspect the electrical system has been abandoned and a new custom mechanism was developed instead. This mechanism, inspired by the classical breadboard's

(a) Assembled View



(b) Breadboard Mechanism

Figure 9: Main Canister

shape, is composed of a variable plate shown in Figure 9b that provides the system brackets with multiple fixations and the ability to change the orientation of the system freely. Moreover, it allows for better and easier access to the components inside as the components remain completely in place, unlike the system that had to get dragged out in the previous year's design.

HDPE was the selected material for the brackets due to its strength and ductility needed to carry all our electrical components. The brackets are connected to the main variable plate using sliding stainless steel rods that have high rigidity and strength.

• Sealing

▶ Main Canister Sealing

The main canister's cover sealing is composed of a squared aluminum flange with a maximum area of 280x280 mm welded to the main body. This flange seals using a custom-shaped gasket compressed to the 10 mm acrylic lens using bolts, as shown in Figure 10.

The 3mm-thick aluminum sheet was chosen after conducting tests and proving its ability to maintain its strength even at small thicknesses without posing any leakage risks on ***Nova*** . Thirty-two AGRO glands are held on the sheet, each mounted on a groove 15mm in diameter.

▶ Main Camera Case

The main camera case, shown in Figure 11, is utilized and mounted above the end effector on the upper plate of ***Nova*** to hold the main front camera that overlooks one of the two clipper manipulators. Since it is connected to the shaft of a servo motor using a PLA part, the camera inside can rotate

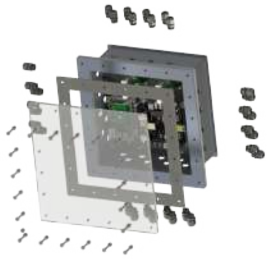


Figure 10: Main Canister - Exploded

180 degrees and provide ***Nova*** with an even wider, unobstructed view compared to a normal fixed setting. This camera case was utilized from last year as it proved to be reliable in sealing and in providing the pilot with a better view.

(a) Assembled View (b) Exploded View

Figure 11: Main Camera Case

The sealing is done via two flanges that seal using two radial O-rings. Together, they hold an acrylic cylinder that is 4 inches in diameter and 120 mm in length. Another pair of stainless steel guides are also used to keep it intact.

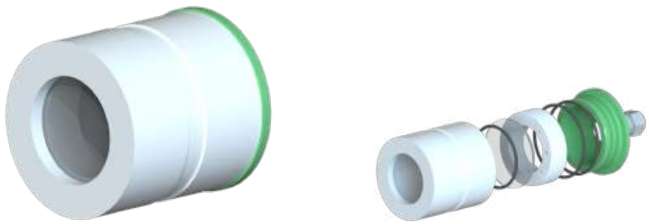
The back flange is mainly responsible for sealing the camera's cable using an AGRO gland, while the front flange is specially designed to mount a servo motor on it.

► Manipulators Camera Case

The manipulator's camera case, shown in Figure 12, is mounted twice on the upper plate and once on the lower plate to view a clipper manipulator, a crab manipulator, and one of ***Nova***'s sides.

The main idea behind this case is that the threaded part of the casing was adapted to be used as the source of compression on the O-ring. This sealing technique provided us with a more compact and lighter design, as it was sealed without using a single bolt.

It consists of three parts: the outer front case, the camera fixation part, and the back end cap. The outer front case comprises a face O-ring along with an internal thread, while the camera fixation part contains the camera along with an external thread. These two are then fixed together, compressing an acrylic lens between them using the O-ring. The back end cap holds the AGRO gland that seals the camera's power cable.



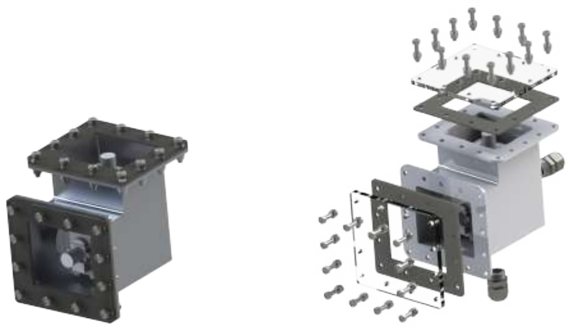
(a) Assembled View (b) Exploded View

Figure 12: Manipulators Camera Case

► Double-faced Camera Case

Designed with goals of compactness, efficiency, and expanding ***Nova***'s field of view, this case, shown in Figure 13, is able to hold two cameras within itself. Its unique L-shape allows the cameras to be placed within a 90-degree shift between each other to view both the crab manipulator and one of ***Nova***'s sides.

The case is built by welding two bent parts with an aluminum base and two aluminum flanges to each of its faces. Two custom-shaped gaskets are compressed to the flanges using 5 mm-thick acrylic lenses. Moreover, the cameras are fixed using rectangular HDPE parts and the main body contains two AGRO glands that are used for sealing the cameras' cables.



(a) Assembled View (b) Exploded View

Figure 13: Double-faced Camera Case

▶ Stereo Camera Case

This camera case, shown in Figure 14, is composed of a rectangular aluminum container with an area of 10x60 mm and a height of 40 mm. A rectangular flange with an area of 140x90 mm is welded to it. The case is covered by a rectangular 5mm thick acrylic lens to provide a clear view and it is sealed by a custom-made rectangular gasket that is bolted to the flange by the acrylic lens. The camera itself is fixed by a PLA 3D-printed part and its cables are sealed by an AGRO gland added to the side of the case.

(a) Assembled View (b) Exploded View

Figure 14: Stereo Camera Case

▶ LED Case

Inspired by the manipulator's camera case, the LED case, shown in Figure 15, is the smaller counterpart of it and is sealed in a similar fashion.

Having a diameter of 1.26 inches and a height of 85 mm, this mini case has a conical shape to concentrate the light of the LED. It is sealed by a back flange using two radial O-rings' threading and its acrylic lens is sealed with marine epoxy. Finally, an AGRO gland was added to the case to seal the 12V LED's cable.

(a) Assembled View (b) Exploded View

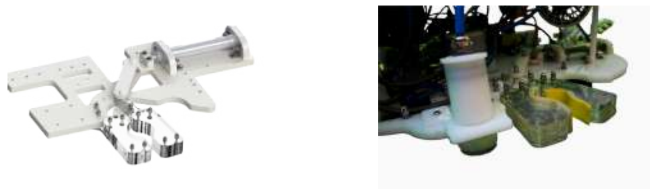
Figure 15: LED Case

● Manipulators

▶ Clipper Manipulator

The clipper manipulator, shown in Figure 16, can hold objects with a gripping force of 45.5 N. In addition, it was carefully placed to ensure the thrusters' flow won't interrupt the camera view. In order to amplify the piston's stroke, a scissors mechanism proved to be the most suitable for the design of this manipulator, as it doubled the 50 mm piston's stroke. Since we now only need to use one pneumatic cylinder, the size is significantly more compact.

It is utilized twice on both sides of ***Nova*** and was used in carrying the vertical profiling float, installing the long-term camera into a designated area, removing biofouling from floating wind turbines, and placing the tent over a diseased area.



(a) Render (b) Real Life

Figure 16: Clipper Manipulator

▶ Crab Manipulator

This manipulator, shown in Figure 17, imitates a crab holding an object between its claws. Its mechanism uses a pneumatic cylinder and HDPE links that double its stroke. The double grip allows ***Nova*** to hold long objects properly with a force of 20.1 N on each side and avoid any inclination in them, such as the half-inch PVC connectors.

The crab manipulator is installed twice on opposite sides of ***Nova*** to grab as many connectors as it can and complete the task in optimal time. It is used to carry both the fry container and the syringe needed for injecting a probiotic fluid into the tent and aids in installing the Eco-Mooring system. Moreover, the end effector was carefully designed to hold the PVC tightly in order to control it easily while attaching the carbineers to the desired place in the solar panel array mission.

(a) Render (b) Real Life

Figure 17: Crab Manipulator

2.3.2 Electrical

Nova's underwater electrical system, shown in Figure 18, is composed of a total of three PCBs: the control unit, the tether signal unit, and the power unit. Each was designed with Surface Mount Device (SMD) Technology to reduce size and cost. In contrast to last year, ESP32 microcontrollers were used instead of STM32 microcontrollers to incorporate the novel ROS2 into ***Nova***'s system. Furthermore, the number of four-layer boards has been increased due to the large number of signals present in the new system.

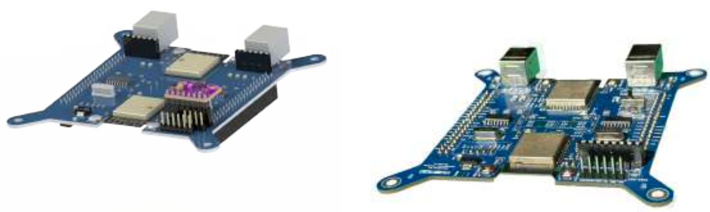
(a) Render (b) Real Life

Figure 18: ***Nova***'s Underwater System

- **Control Unit**

Sitting atop the boards in the multi-board fixation, the Control Unit is a 4-layer PCB that is mainly responsible for handling all control and communication signals of ***Nova*** .

The board, shown in Figure 19, hosts two ESP32s, one is in charge of the motion system and the other is in charge of the auxiliary system. While it proved difficult to implement, merging last year's communication and feedback boards into a single PCB offered a multitude of advantages, such as better routing, intuitive troubleshooting, and most importantly, a compact, space-efficient system.



(a) Render (b) Real Life

Figure 19: Control Unit PCB

Not only does the motion system node map all motion commands to each of ***Nova***'s thrusters and move it as desired, but it also incorporates the Proportional, Integral, Derivative (PID) control system, which mainly improves the maneuverability and stability of ***Nova*** . This system provides ***Nova*** with sufficient sturdiness and resistance against turbulent or calm changes in the water flow. The necessary readings of depth and orientation are continuously collected from the pressure and IMU sensors present on the board.

The PID system deploys a feedback loop principle that takes a desired orientation and a measured orientation to calculate an error value. The correction is based on proportional, integral, and derivative terms of the error each multiplied by a coefficient. The resultant terms from all the degrees of freedom are applied to the kinematic mapping algorithm that outputs all the thruster values.

The auxiliary system is connected to all Directional Control Valves (DCVs), servo, motor driver, and the pump present in ***Nova*** and relays all commands related to them.

- **Power Unit**

The middle of the multi-board fixation is the Power Unit board, shown in Figure 20, and is responsible for regulating, distributing, and maintaining stable power to all of ***Nova***'s electrical system. The buck converter used in this year's system has a much higher power efficiency than the previous one and was tested under a high load to monitor its noise and ripple voltages. Multiple regulators and buck converters are utilized to ensure the following components are supplied with adequate voltage and power:

- Cameras, DCVs, motor drivers, and thrusters - **12V** supply.
- Servo motors - **6V** Supply.
- Raspberry Pi and the Control Unit - **5V** Supply.
- ESP32 microcontrollers - **3.3V** Supply.

(a) Render (b) Real Life

Figure 20: Power Unit PCB

(a) Render (b) Real Life

Figure 21: Signal Unit PCB

As shown in Table 2, the maximum power consumed by ***Nova*** is approximately 909.476 W, which draws nearly 18.947 A of current from the 48 V power supply. The peak current is then multiplied by a 1.5 factor of safety, resulting in a maximum current of 28.421 A, therefore a 30 A fuse is placed. Note that the thrusters are not used at full power to remain within our power budget.

Component	Input Voltage (V)	Max. Current (A)	Quantity	Consumed Power (W)
Thrusters (T100)	12V	7.24A	4	347.52W
Thrusters (T200)	12V	10.5A	4	504W
Analog Cameras	12V	0.2A	4	9.6W
IP Cameras	12V	0.25A	2	6W
DCV	12V	0.33A	4	15.84W
Servo Motor	5V	0.9A	1	4.5W
Ethernet Switch	5V	0.8A	1	4W
Raspberry Pi	5V	2A	1	10W
ESP32	3.3V	260mA	2	1.716W
LED	12V	0.125A	1	1.5W
Pump	12V	0.4A	1	4.8W
Total	________	__________	____	909.476W

Table 2: Power Calculations

Tether Signal Unit

At the base of the underwater electrical system is the Tether Signal Unit, shown in Figure 21. It acts as the main hub of all signals going to and coming from ***Nova*** through its tether, which includes four analog cameras, two IP cameras, the Raspberry Pi, and CAN Bus signals. Additionally, it transports all control signals from the Control Unit to the ESCs, DCVs, and servo motors connected to ***Nova*** .

We use a combination of analog and IP cameras to draw the most benefits from each; the high resolution of IP cameras is useful in autonomous and image processing missions and the low latency of analog cameras is optimal for maneuvering the ROV. A total of four analog cameras are mounted on ***Nova*** and extra attention was given to the choice of their mounting positions in the frame to ensure the best field of view with minimum cost. Two IP cameras are mounted on either side of the ROV to be used in the docking mission and the 3D reconstruction mission.

A more detailed illustration of ***Nova***'s vision system can be seen in Figure 22 and Figure 23.

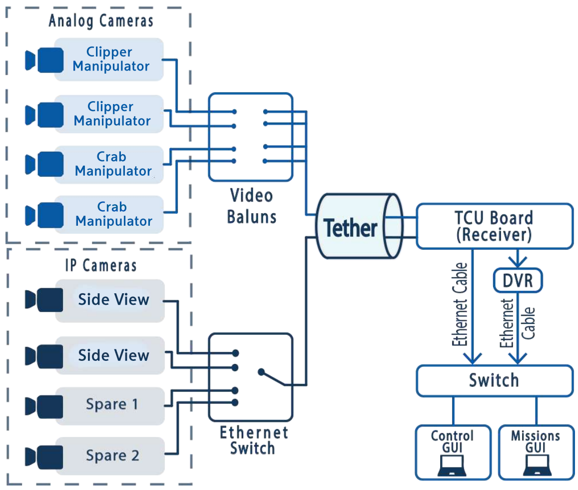


Figure 22: Vision Diagram

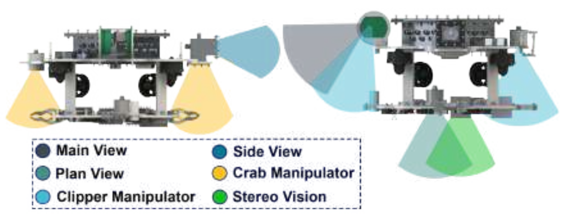
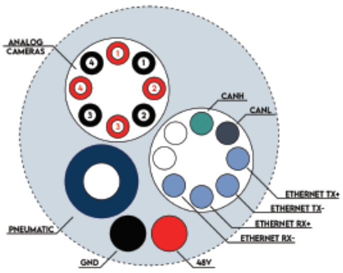


Figure 23: Fields of View

Tether

Nova's tether, shown in Figure 24a, is composed of a power cable, a pneumatic hose, and two Ethernet cables: one transports all analog camera signals and the other transports the digital communication signals. They are deliberately separated to reduce their noise interference with each other.

The tether was made neutrally buoyant by periodically adding short rubber sheaths along it; an important feature that prevents it from accidentally cutting off ***Nova***'s path during motion. Measuring at 20 m, the tether is wrapped with a protective sheath that makes it more sturdy and durable. The tether connectors on both ends feature strain relief, shown in Figure 24b, which is needed to protect the tether from excessive tension and accidental strong tugs.



(a) Cross Section View

(b) Strain Relief

Figure 24: Tether

High-quality copper wires were used to minimize power losses and withstand ***Nova***'s power consumption. Moreover, shielded twisted pairs were used in transmitting video signals to neutralize external noise and ensure the best image quality.

A tether management protocol is implemented to ensure the safety of the ROV as well as the employees, in which a tether-man is responsible for the proper deployment and handling of the tether during operation. The protocol is achieved as follows:

1. Before deployment, the tether-man, who is the only one near the poolside, unrolls the tether and lays it on deck.
2. The tether is carefully connected to the topside control station and the strain relief is secured to it to prevent accidental tugging damage.
3. After deployment, the tether-man holds the tether carefully at all times to ensure it doesn't block or hinder ***Nova***'s movement.
4. The tether-man disconnects it from the topside control station after the ROV is retrieved from the water and powered down.
5. The tether is rolled up again to eliminate any tripping hazards and/or damage to it.

Thanks to the careful following of this protocol, along with the added protection from the strain relief, we were able to reuse the tether from last year which helped us greatly reduce cost and minimize the time of the pre-deployment phase.

• Topside Control Station

Aquaphoton's control box, shown in Figure 25, is custom-made, by our team, from wood. It comprises a 400x540 mm case containing our Topside Control Station's PCBs, shown in Figure 26, wires, cables, and connectors, as well as a specific place for the joystick. Furthermore, it is designed with a 300x450 mm sliding part that acts as a holder for the co-pilot's laptop. It is equipped with a 21-inch LCD screen that provides the cameras' view for the pilot. This control box was reused from last year as its design is sturdy, portable, and very convenient for our station. Moreover, precious resources, such as time and funds, were reserved from this decision with little to no drawbacks.

Figure 25: Control Box

► Topside Power Unit

The Topside Power Unit (TPU) is responsible for distributing power within the control box to the Topside Control Unit (TCU), network switch, and DVR. For added security and safety, it is equipped with a relay, a Hall effect current sensor, fuses, and varistors.

The relay is installed to control the flow of electrical current in ***Nova*** by opening and closing it. It can be operated either manually, using an external switch, or automatically through the microcontroller on the TCU that detects any water leakage within the ROV using the sensor message sent from below.

The Hall effect current sensor is utilized to measure the total current drawn from the power supply and initiate a predetermined safety protocol in case of any malfunctions identified while monitoring it.

The onboard fuses and varistors are equipped for overcurrent and overvoltage protection, respectively. Since they are crucial to protecting ***Nova***'s electrical components from these hazards, they were used in both the TPU and TCU.

▶ **Topside Control Unit**

The TCU is also a main hub for signals, similar to the Signal Unit, at the other end of the tether. Not only is it the receiving end of all camera signals and a primary CAN node, but it also has the added functionality of autonomously initiating safety protocols in case any electrical hazards are detected.

All analog cameras pass through the TCU before they are transmitted to the DVR while the IP cameras' signals are routed through the PCB and directed towards a switch. In case of any failures in the ROS2, the CAN Bus is continuously working in parallel to it for improved communication stability. The TCU plays a part in this by being the main CAN node that transmits and receives data from ***Nova*** and can operate completely independently from the ROS2 system.

(a) Topside Power Unit

(b) Topside Control Unit

Figure 26: Topside Control Station Boards

2.3.3 Software

• Communication System

The communication system, shown in Figure 27, is composed of ROS2 communication and a CAN Bus that work interchangeably in parallel.

Nova's main method of communication is ROS2. A Raspberry Pi acts as the bridge between the topside control station and the underwater system, connecting to the underwater system via micro-ros. All joystick commands are neatly organized into multiple topics that the station publishes, which the underwater system subscribes to and then executes the commands accordingly.

Starting from the top, the topside control station initializes the ROS2 control node that begins publishing all commands to their corresponding topics, e.g., motion topic, servo control topic, etc...

Then, the Raspberry Pi initiates and acts as a server for all the ROS2 nodes, at the topside control station and at the underwater control unit, allowing communication among them.

The motion system node subscribes to all motion and speed change topics to both directly move ***Nova*** and to pass it along to the PID system that in turn performs calculations and calibrations needed for maintaining smooth and stable motion. Moreover, it also publishes temperature, pressure, current and voltage readings to the topside control station, giving the co-pilots a complete status report of ***Nova*** that is invaluable for both safety and mission completion tasks.

Meanwhile, the auxiliary system node subscribes to all commands in regard to the DCVs change of state, servo movement, and pump. Since the two nodes are separated, swift execution of the commands is guaranteed and wouldn't be affected by the PID calculations.

To ensure stability and maintain a foolproof safety net for ***Nova*** , the CAN communication protocol is still incorporated and fully functional in case of any error or reboot in the ROS2 system. An error-checking protocol is always active and will automatically switch back and forth between the two systems seamlessly, providing the pilot with uninterrupted and constant communication with the ROV.

• Graphical User Interface

Designing an intuitive, easy-to-use, and configurable Graphical User Interface (GUI) is one of, if not the most, important aspect of any ROV, as it is what allows the pilot to maneuver and monitor it in the final stage of deployment. With that in mind, ***Nova***'s split GUIs architecture was created to ensure maximum optimization and the best capabilities for both the pilot and the co-pilots. All GUIs are developed in Python and the Qt application framework.

In total, we have two main GUIs, shown in Figure 28: the Control GUI and the Missions

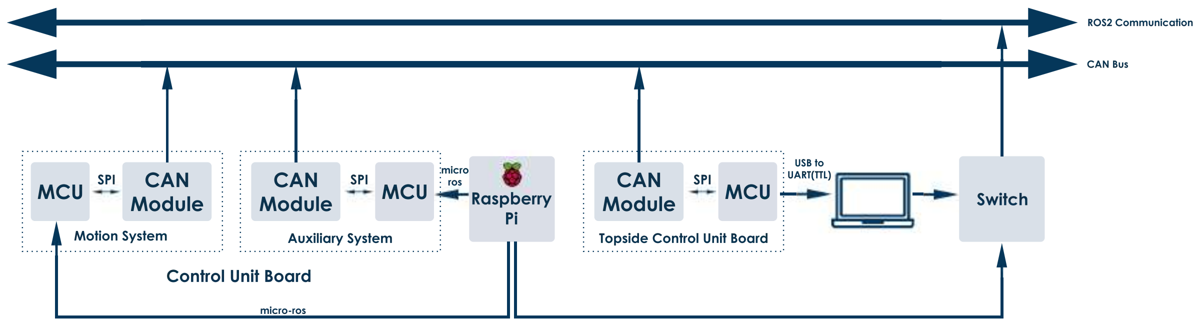
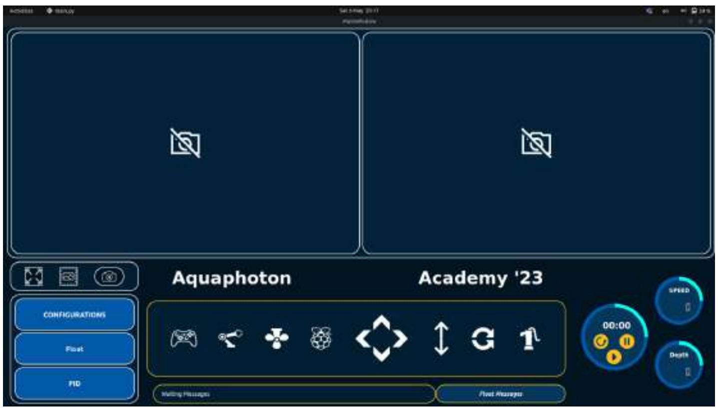
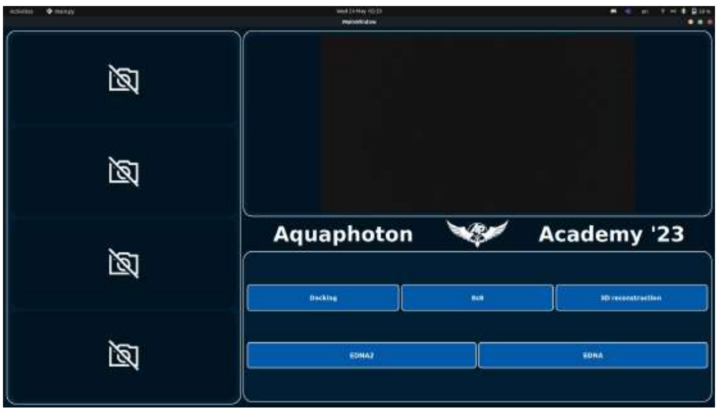


Figure 27: Communication System Diagram

GUI. The Control GUI is made primarily to be used by ***Nova***'s pilot while the Missions GUI aids both copilots and the pilot in performing image processing missions, autonomous missions, and missions that rely on manual calculations.



(a) Control GUI



(b) Mission's GUI

Figure 28: GUIs

▶ Control GUI

The Control GUI has more debugging and configuration options than it would usually provide to make any changes as easily and fast as possible. It is divided into three main sections:

1. A setup window, that can dynamically configure the thrusters' orientation (clockwise or anticlockwise). It also allows us to send new PID coefficients during the initial calibration phase. This setup is usually conducted and finalized before the deployment of the ROV and may have minor adjustments later on.
2. A control window, shown in Figure 28a that displays the video feed of all cameras in parallel and synchronized real-time, as well as various sensors' readings that indicate ***Nova***'s current state. Moreover, this window features connectivity indicators for the Raspberry Pi, motion node, auxiliary node, and pump for easier and swifter monitoring.
3. A configuration window that allows the pilot to quickly remap the joystick's buttons and change the cameras' IP addresses in case of any change. In addition, it automatically detects the serial port connected to the laptop and connects to it to begin the backup CAN bus communication with the ROV.

▶ Missions GUI

The Missions GUI, shown in Figure 28b, allows the copilots to switch between certain camera feeds specific to each mission, along with any relevant sensor readings needed. Each mission has a special interface and customized widgets that aid in successfully performing it. Since there are two separate GUIs, the pilot can monitor and maneuver ***Nova*** in parallel with the co-pilots who oversee autonomous missions and complete any calculations needed.

2.4 Mission Specific Auxiliary Tools

2.4.1 LED

One of the methods of restoring a diseased area of a coral reef is to expose it to artificial UV light and thus ***Nova*** is equipped with a 12V LED that can shine a focused beam on a specific area. For more details about the LED's sealing techniques, please refer to section 2.3.1.

2.4.2 Water Pump

The first step in preserving the health of a coral reef is identifying the organisms in it for better and more detailed analysis. A water sample is therefore collected from inside a container using a sealed water pump fixed on the upper plate. A syringe acts as a tank that stores the collected sample in it. Two pneumatic cables are connected to this pump, one in the tank and another passes through a hole in the clipper manipulator for easier control and routing.

2.4.3 Fry Container

As per the need of preserving and relocating the endangered Northern Redbelly Dace fry, a container, shown in Figure 29, was designed and manufactured.

For more details about the design, please refer to the Non-ROV Devices Design document.

Figure 29: Fry Container Render

2.4.4 Vertical Profiling Float

Aquaphoton believes in the importance of collaborating to overcome the climate change challenges and thus, we decided to support the National Science Foundation (NSF)-funded GO-BGC project's goal. A vertical profiling float was designed as a prototype that can be used in real life for ocean monitoring and inspections.

The float's mechanism is composed of three parts: firmware, electrical and mechanical designs. The firmware is responsible for controlling the DC motor that toggles the directions of rotation when a limit switch is pressed. It also sends the real-time from the RTC module integrated in the system to our GUI. This is achieved using a web server that is initiated on the ESP32. The web server is accessed by connecting to the ESP32 IP address through a wireless Local Area Network(LAN) from our GUI.

For more details about the electrical and mechanical design, please refer to the Non-ROV Devices Design document.

2.4.5 Lift Bag

Our implementation of the lift bag depends on a ready-made tire tube that is 8 inch in diameter. The tire tube, that is attached to ***Nova*** to increase the lift capability, is air-filled using a 5/2 DCV, a throttle valve to control air flow and prevent flow back, and pneumatic cables. The use of a ready-made tire tube makes its replacement easier in case of any punctures or defects in it. The lift bag has a volume of 64150 mm^3 and a buoyancy force of 62.8 N, which represents its capability of lifting 6.41 kg. Given that ***Nova***'s thrusters at full force can lift up to 9 kg, the total combined lifting force will be 151.018N, indicative of ***Nova***'s ability to pick up weights of 15.41 kg.

2.4.6 Software Algorithms

- **Piloting into Resident ROV Docking Station**

Resident ROVs are crucial for the future of marine renewable energy and the offshore aquaculture industry, as they can perform periodic maintenance with no human aid. This mission simulates the need for ROVs to autonomously stay in their dedicated docking stations after completing their tasks.

An algorithm was developed using the OpenCV Python library. The process begins by manually selecting a region of interest around the docking station and then autonomously tracking it. Next, the coordinates of the center of the tracked region are compared to the coordinates of the camera frame's center, and then the deviation vector is calculated.

Depending on the magnitude and direction of the calculated deviation, the ROV moves to minimize it. This process is continuously repeated while ***Nova*** is moving forward and the PID system aids in stabilizing and correcting the motion until the ROV is docked completely inside the station and the button is pushed.

- **Coral Head 3D Reconstruction**

To start analyzing and working out the restoration methods of a coral reef, the diseased areas must be first identified. ROVs prove to be very useful for this task as they can autonomously maneuver through dangerous and vast areas and then report back with all the diseased areas for further research. This mission is simulated by a coloured plastic bowl with markings on it to indicate disease.

To construct the 3D model of the coral head autonomously, ***Nova*** rotates around the plastic bowl and captures sequential frames with a rate of 5 FPS using the left IP camera. The captured frames are aligned to get the tie points between the images, the tie points are then used to build a mesh showing the 3D model of the coral head as shown in Figure 30, the diseased tissues are simulated by black squares of areas 400 mm^2, 1600 mm^2 and 3600 mm^2.

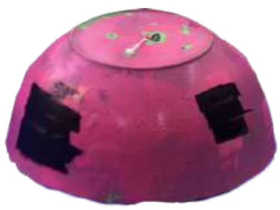


Figure 30: Coral Head 3D Model

To get the required dimensions, the bowl is centered under ***Nova*** , and the diameter is measured by the stereo camera. The image of the front XZ plane is built from the 3D model, as shown in Figure 31a to get the height of the bowl using the diameter as a reference. The 3D model is then flattened about the Z-axis to represent the side of the bowl on a 2D image, as shown in Figure 31b, where the width of the image is equal to the circumference of the bowl. Using the diameter of the bowl as a reference, the area of the diseased tissues is calculated.

The bowl shown in Figure 30 has a diameter of 240 mm, a height of 110 mm, and diseased tissues of a total area of 5600 mm^2. Using the

(a) XZ Front View (b) Cylindrical View

Figure 31: 2D Orthomosaics

previously discussed approach, a diameter of 237 mm, a height of 105.6 mm, and a total area of 5600 mm^2 are estimated.

3 Safety

Aquaphoton believes that all injuries are preventable by implementing strict safety measures. This drives the company to provide a safe working space and the training necessary to handle all equipment safely, as shown in Figure 32.

Figure 32: Safety Practices in Action

3.1 Workshop Safety

Aquaphoton is well aware of the dangers and hazards that might arise while assembling the ROV, whether they are mechanical or electrical. This led us to implement multiple strict safety protocols that ensure the safety of all our employees. Moreover, the workshop is equipped with various safety equipment, like a face guard, protective gloves and a soldering fume extractor. A dedicated safety director is always present during any operation and ensures the complete safety checklist, that can be found in Appendix B, is thoroughly followed.

3.2 Safety Training

Along with the technical training, novice employees are trained by our experienced employees on all safety measures and protocols that must be followed. Through intensive safety training and hands-on experience gained from tasks completed in a controlled environment, everyone becomes well-familiarized with the procedures that ensure safety at all times.

3.3 ROV Safety Features

Safety is Aquaphoton's top priority and thus it is always kept at the forefront during the design and manufacturing phase. The frame is carefully sanded down to remove all sharp edges and all bolts are thoroughly covered. The thrusters' propellers are all covered with shrouds that ensure the safety of our employees and anyone handling ***Nova*** .

In addition, extra safety measures were implemented for ***Nova***'s mission auxiliary tools and manipulators. A 12V LED was carefully selected to not cause any overheating and be compatible with our power system and a special enclosure was designed for it that minimizes, and nearly negates any leakage risks. The water pump is completely enclosed with no external rotating or moving parts that could hook into playground elements and cause damage. It is also equipped with a filter to avoid pulling in any loose debris.

All the manipulators are covered in boro to ensure a soft grip that doesn't pose any risk on the vertical profiling float, the fry container, and any playground elements while transporting them. Finally, along with the tightly sealed enclosure of the float, (please refer to the safety review document for more details) a pressure release valve is placed on the battery container to ensure that the internal pressure never exceeds the external pressure. All these measures combined ensure that ***Nova*** is not a hazard to its surroundings by any means and is compliant with MATE's safety requirements.

3.4 Safety Checklist

Aquaphoton takes safety very seriously and follows a strict protocol for all company members before, during, and after ***Nova*** is deployed. Inspections are conducted regularly and a complete list of operational safety guidelines can be found in Appendix C. While it is the duty of employees to thoroughly follow the safety checklist, a safety director ensures that it is followed rigorously.

4 Testing and Troubleshooting

4.1 Full System Testing

Full-system testing procedures, shown in Figure 33, are carried out on ***Nova*** before any operations.

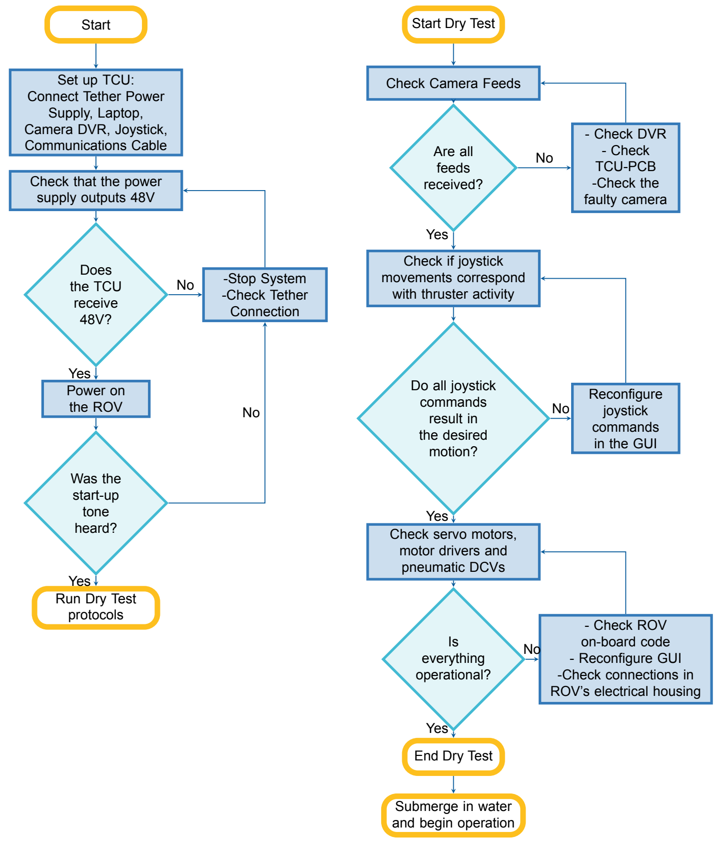


Figure 33: Full System Test Flowchart

4.2 Mechanical Testing

Through rigorous mechanical testing, ***Nova***'s mechanical system was optimized to ensure its reliability, efficiency, and durability. Not only does that minimizes the potential of failures and negates safety hazards in ***Nova*** , but it also ensures its successful operation in the challenging and harsh underwater environments.

All components of the mechanical system were prototyped first to conduct safety tests and ensure the design is effective and efficient. Each prototype was thoroughly refined and tested before reaching the final design and assembly phase to avoid any complications while integrating it into ***Nova*** . The stability of the frame was validated by loading and subjecting it to high vibrations which ensured that all fixations are secure. Moreover, the pneumatic manipulators and their DCVs underwent testing to guarantee the full mobility of the end effectors. Finally, the sealing mechanisms also underwent a validation process according to the procedure shown in Figure 34 to ensure their effectiveness.

4.3 Electrical Testing

Before assembling the electrical system of ***Nova*** , every PCB is tested individually before being integrated into the system. This approach significantly reduces the time and effort required for troubleshooting. An electrical testing and troubleshooting plan was implemented, as shown in Figure 35, to provide a structured approach to identifying and resolving any issues encountered during the testing process.

Furthermore, a comprehensive functional testing plan was performed to validate the performance of the electrical system. This involved conducting a series of tests to assess the system's ability to regulate voltage, transmit data, and control the ROV's various components.

To test and validate the stability of the newly used ESP32 microcontroller, multiple iterations of a prototype PCB were developed. Through rigorous testing, a better and more reliable design was reached with every iteration until the most optimal one was realized and integrated into our main system.

5 Logistics

5.1 Company History

Aquaphoton Academy is a student-run company from Alexandria University that has been taking part in the MATE ROV Competition for the past 11 years. We placed 1st in Egypt's Regional Competition in 2014 and 6th in the International MATE ROV competition held in Michigan, USA. In 2021, we ranked 2nd in Egypt's Regional Competition, 5th in the International MATE ROV Telepresence category competition and have placed 1st in the 2023 MATE ROV regional competition. Every year, Aquaphoton adds a new innovative ROV to its collection, with the latest one shown in Figure 36.

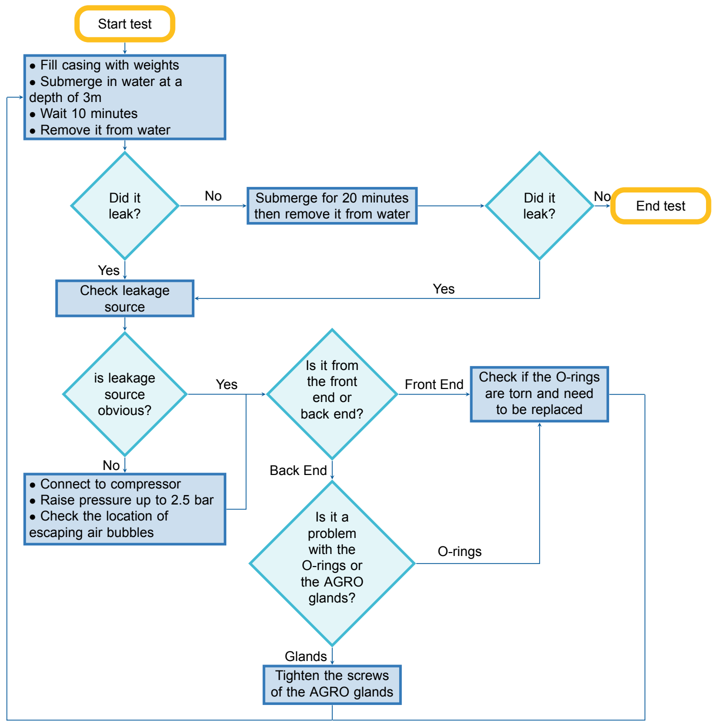


Figure 34: Sealing Test Flowchart

Figure 36: Aquaphoton Academy's ROVs

5.2 Company Structure

Aquaphoton Academy consists of 27 members that are split into two technical teams (Mechanical and Electrical) and four non-technical teams (Media, Documentation, Public Relations (PR), and Social Media). These teams are further broken down into project groups that take care of specific aspects of the vehicle's systems. The leader of the organization is the CEO, with two CTOs who oversee the technical teams. For more details, you can check out Appendix D for the company structure chart and job descriptions.

5.3 Project Management

5.3.1 Project Scheduling

Creating an accurate project timeline, shown in Figure 38, with realistic deadlines is crucial for the success of any project. Aquaphoton adopted a

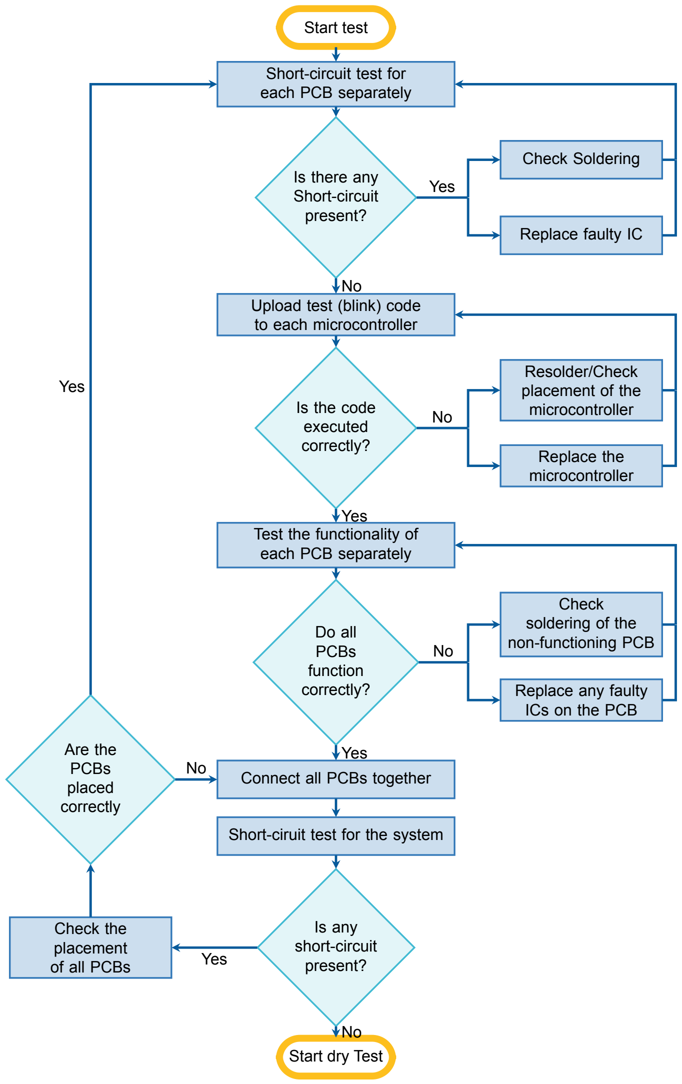


Figure 35: Electrical System Testing Flowchart

digital project management process using a Trello board, shown in Figure 37, to oversee all project groups and tasks while keeping an eye on the bigger picture. The CEO and CTOs determine the exact time periods for each phase of the project and arrange meetings with non-technical department heads to ensure they are one step ahead of schedule.

Weekly meetings are held for each sub-team to assign tasks, discuss progress, and brainstorm new ideas. Company-wide meetings inform all members of progress, upcoming events, and decisions that need to be voted upon.

Board meetings are periodically held to make sure that the whole project timeline is being well followed. The CFO is also present to keep track of the company's budget on a monthly basis and to take note of any additional resources needed.

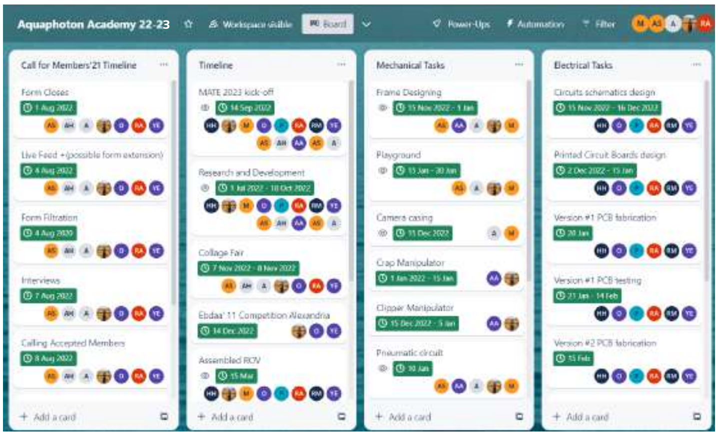


Figure 37: Aquaphoton's Trello Board

5.3.2 Workspace Management

Aquaphoton's headquarters is divided into several designated areas, including a PCB soldering station, a water testing area with a pressurized tank, a machining area, and a storage room. It's important to prepare the work area by cleaning it and ensuring that all necessary tools are available before starting any task. A workshop director is appointed to ensure that everything remains clean and organized, and he performs any repairs or improvements to maintain the workspace.

5.3.3 Shared Files and Libraries

Aquaphoton leverages cloud storage to promote collaboration among team members. By utilizing cloud storage, design files can be easily shared, tasks can be submitted, and corporate knowledge can be accessed from anywhere, making it easier for team members to work remotely. Overleaf is also used to streamline documentation tasks, enabling all members to read and add comments as needed. Similarly, GitHub serves as an effective platform for parallel code development, keeping all team members up-to-date with the most recent version of the code and its edit history. Additionally, shared Altium models of ***Nova***'s PCBs are available to ensure everyone has current and accurate 3D designs of the system boards.

5.4 Budget and Accounting

Aquaphoton's self-funded budget is limited and must be used carefully to avoid unnecessary expenses. Therefore, a CFO manages all of Aquaphoton's finances, including setting

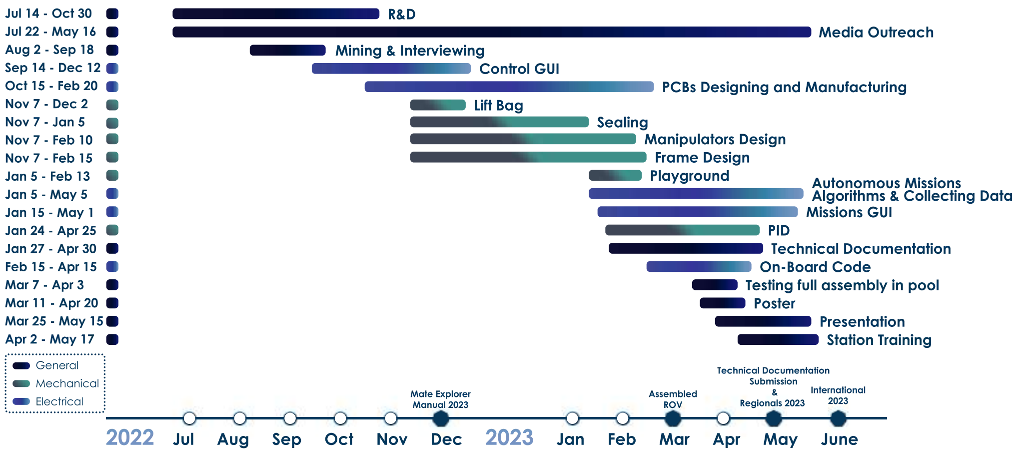


Figure 38: Project Gantt Chart

budgets and ensuring that the company's financial resources are utilized efficiently. A more detailed breakthrough of the budget can be found in Appendix E and Appendix F.

6 Conclusion

6.1 Future Improvements

Aquaphoton strives to achieve success by consistently improving and evolving its designs to keep up with modern technologies. The company believes in the importance of innovation, and as such, is exploring new ways to enhance its ROV designs.

Our next major goal is implementing a localization system into our ROV that will allow us to take a step closer towards creating a completely autonomous ROV that doesn't even need a pilot.

Moreover, several custom modules were designed, manufactured, and tested in parallel to the deployment of ***Nova*** and will be integrated into next year's system. This includes our own independent design of a buck converter and an Ethernet switch. This custom buck converter has a higher current than that of commercially available ones, which gives the thrusters more torque. It is also compact and has more safety features.

6.2 Acknowledgments

Aquaphoton would like to extend a special thank you to:

- Dr. Mostafa Elhadary for his guidance.
- Eng. Sara Safwat for her advisement.
- Parents and friends for their moral support.
- MATE for making this experience a reality.
- AAST for organizing the regional competition.
- JLCPCB for sponsoring our PCBs.
- Fathalla Market for sponsoring our team.
- Makers Electronics for offering discounts.
- SolidWorks, Fusion 360, and Altium Designer for providing us with student licenses.

Figure 39: Acknowledgements

6.3 References

- MATE ROV Competition Manual 2023
- BlueRobotics' T100. and T200 Thrusters Documentation.
- ROS2 Humble Documentation
- micro-ROS for Arduino
- Texas Instrument TPS54561 buck converter
- MPU6050 IMU
- Arduino-PID-Library-V2
- JLCPCB Capabilities
- OpenCV Documentation
- HDPE material specifications
- Acrylic material specifications
- Espressif Systems ESP32 Datasheet.
- BOSCH CAN Specification v2.0 .
- PID controller.
- Distance to objects using single vision camera.

7 Appendices

A SIDs

• Electrical SID

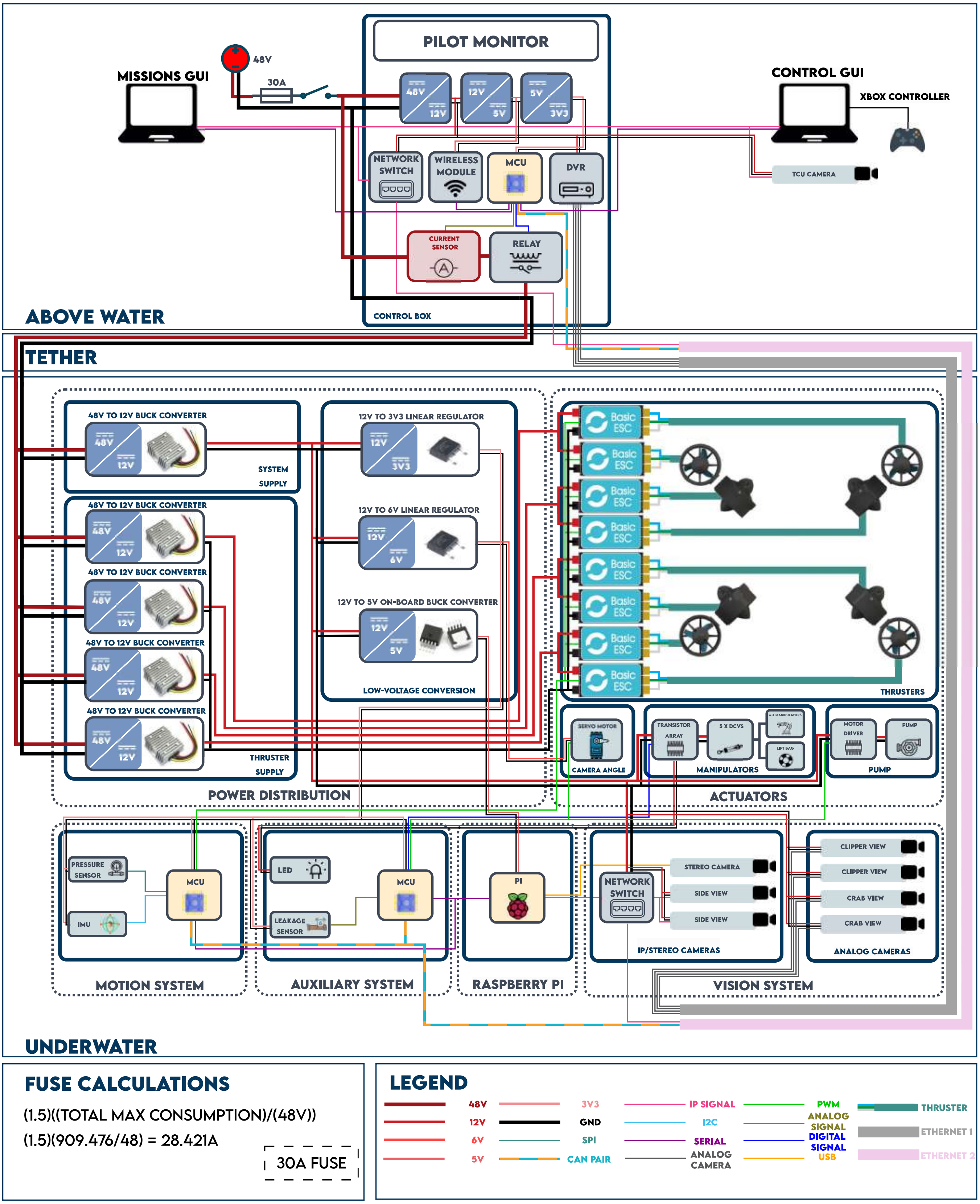


Figure 40: Electrical SID

- **Pneumatic SID**

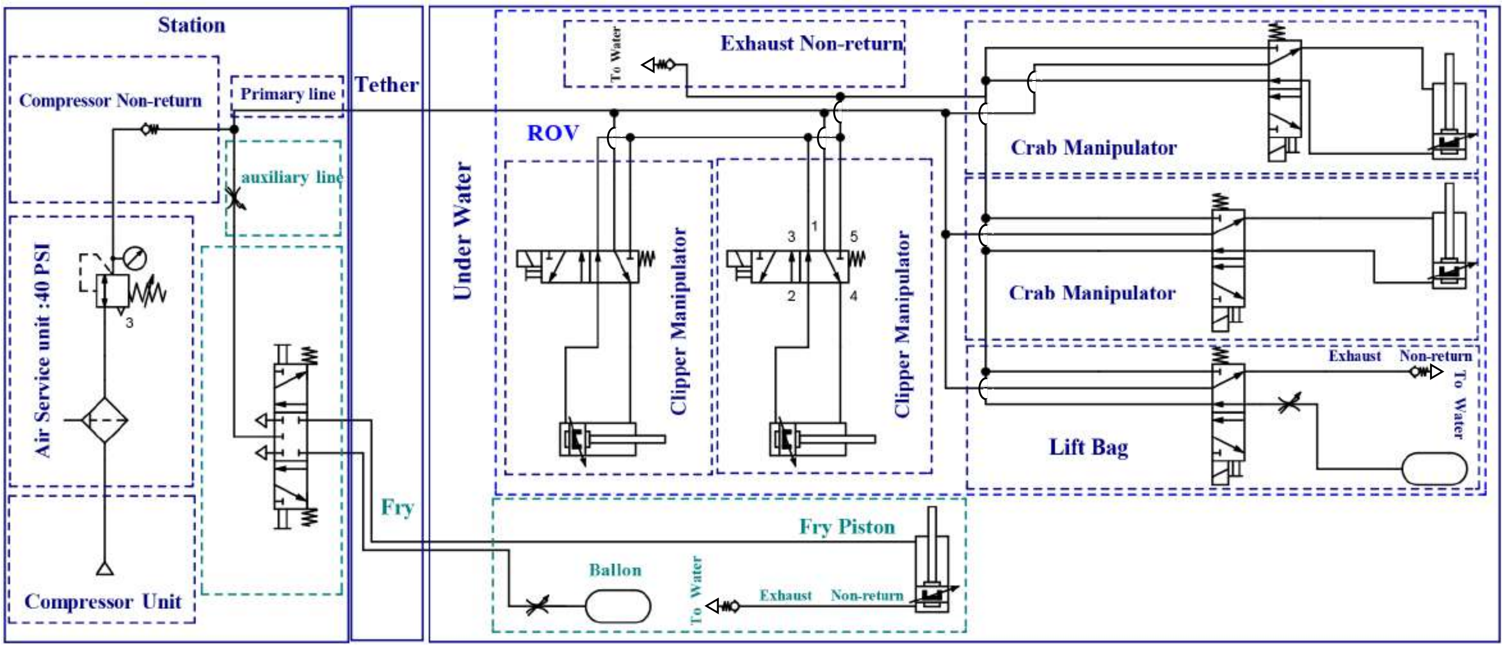


Figure 41: Pneumatic SID

B Construction Checklist

- ☐ Sanitized proper personal protective equipment (PPE) (e.g. gloves, goggles, and earmuffs) are worn when performing any task.
- ☐ Maintenance and repairs are performed proactively.
- ☐ Emergency kits (including fire extinguishers and first-aid kits) are checked regularly to make sure they're stocked and functional.
- ☐ Hazardous materials are clearly marked and stored separately to ensure they're handled carefully.
- ☐ Sharp tools are handled carefully, when not in use, they are stored in racks and boxes, and their sharp edges are covered with a cap -if available.
- ☐ Any in-water tests are performed far away from the Electrical Team's work area.
- ☐ The work area is well-ventilated, and additional fume extractors are used– to avoid the inhalation of harmful fumes when working with epoxy, glass fiber, etc... or soldering.

C Operational Safety Checklist

▶ Before Deployment

- ☐ Only designated crew members on deck.
- ☐ On-deck crew wearing proper safety attire.
- ☐ Power is OFF.
- ☐ Poolside is clear of obstructions.
- ☐ Tether is untangled and connected to ROV through the strain relief.
- ☐ Tether is connected to Control Unit.
- ☐ No exposed wires or loose connections.
- ☐ Electronics housing is sealed.
- ☐ Control computer is running.

▶ Powering Up

- ☐ Control Unit receives 48V.
- ☐ Dry test of thrusters, manipulators, and payloads.
- ☐ Check all video feeds.

▶ Launching and In Water

- ☐ Two members are handling the ROV.
- ☐ Tether-man has hold of the tether.
- ☐ Visually inspect for leakage and check for air bubbles.
- ☐ Test thrusters, manipulators, and payloads.

▶ **Loss of communication**

- ☐ Reboot ROV
- ☐ Resend test package.
  If no communication:
- ☐ Power down ROV.
- ☐ Retrieve ROV via tether.
- ☐ Check ROV is free from damage or leakage.

▶ **Retrieval**

- ☐ Pilot surfaces the ROV and then turns off the thrusters.
- ☐ Designated on-deck crew members grab hold of the ROV by its handles.
- ☐ ROV is secured on deck.
- ☐ ROV and Control Unit are powered down.

D Company Structure and Job Description

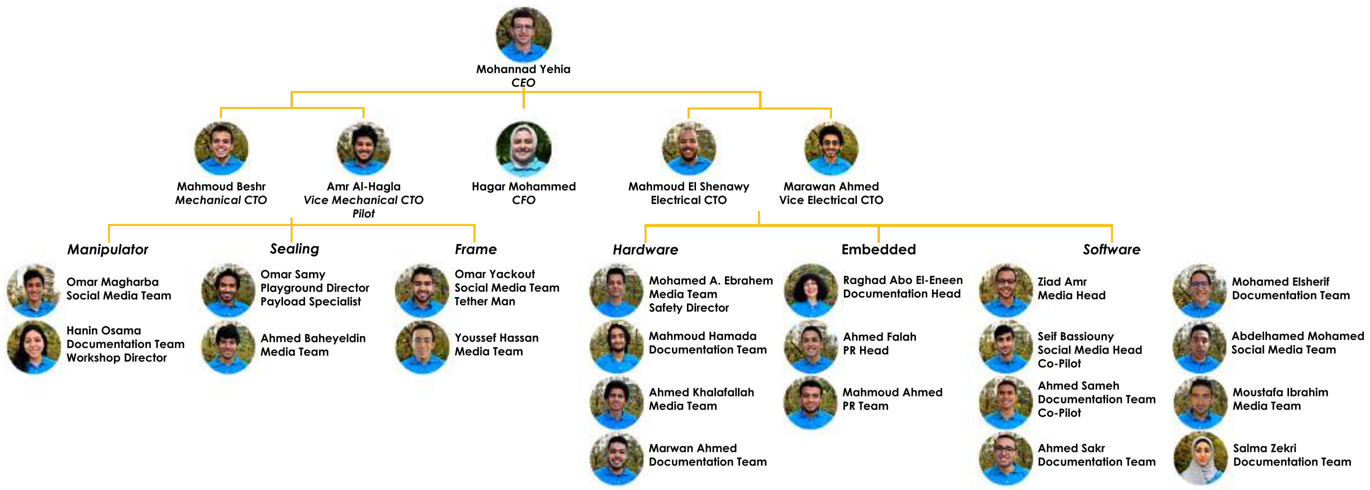


Figure 42: Company Structure

CEO The official representative of the company, interdepartmental coordinator.
CTO Manages project groups and day-to-day operations.
Vice CTO Helps the CTO in distributing the technical tasks and managing them.
CFO Bookkeeper, handles the company finances and sets the budget.
Documentation team Led by a head, responsible for documents submission.
Media team Led by a head, responsible for all graphic designs and media displays.
PR team Led by a head, and is responsible for all the public relations affairs.
Social Media team Led by a head, manages all social media accounts and creates a seasonal plan.
Workshop Director Maintains working order of the workspace, and performs routine maintenance.
Playground Director Simulates the ROV's operating conditions, and coordinates the in-water testing.
Safety Director Ensures all safety protocols and procedures are followed.
Pilot Controls the movement of the vehicle from a cabin or other indoor location on the surface.
Co-Pilot Assists the pilot during mission tasks.
Tether-man Responsible for handling the tether while the ROV is underwater.
Payload Specialist Handles all payloads, unloading samples, and plastic debris gathered by the ROV.

E Project Budget

	Category	Source	Amount (USD)
Income	Self-Fund	Employee Dues	2,624.60
	Cash Donated	Fathallah Fund	323.62
	Parts Donated	JLC PCB	100.00
	Other	Fund from last season	906.15
	Total		3,954.37

(a) Income

	Category	Project Cost (USD)
Expenses	Product Cost	2,808.29
	R&D Costs	140.45
	Running Costs	1,529.45
	Equipment	190.96
	Total	4,669.16

(b) Product/Operations

Figure 43: Projected Budget in United States Dollar (USD)

	Category	Project Cost (USD)
Travelling Expenses	Team transportations in Colorado	500.00
	Rov Shipping	600.00
	Residency in Colorado per member	450.00
	Tickets expenses per member	1,800.00
	Visa Fees per member	160.00
	Travelling expenses per member * X	2410 * X
NOTE: X is Number of members Travelling to USA. Depending on the number of members who have visas, we will be able to determine the total cost of the traveling expenses. In either case, we are actively seeking sponsorship opportunities to potentially offset some or all of the costs. We expect to have a clear understanding of the aforementioned details by June 12, 2023.		

(a) Travelling Expenses

Category	Amount (USD)
Total Income	3,954.37
Total Expenses	4,669.16
Total Expenses-Re-Used/Donation	3,495.16
Fund for next season	459.21
Tickets expenses per member	1,800.00
Residency in Colorado per member	450.00
ROV Shipping	600.00
NOTE: The travelling expenses to the USA depend on the status of our members' visas.	

(b) Total Cost

Figure 44: Travelling and Total Cost

F Cost Breakdown

School Name:		Aquaphoton Academy Faculty of engineering Alexandria University		From: 9/9/2022 To: 5/22/2023	
The exchange rate between the U.S. dollor (USD) and Egyptian pound (EGP) is 30.9 EGP per dollar in Mon, 22 may 09:00.					
Detailed Project Expenses					
	Category	Description	Type	Projected cost (USD)	Budgeted Value (USD)
Product Costs	Thrusters T100	4*T100, 4 *ESCs	Re-used	744.00	-
	Thrusters T200	4*T200, 4 *ESCs	Purchased	507.00	507.00
	Material	HDPE (Sheet + Cylinder), Aluminum Sheet, Acrylic (Sheet, Cylinder,Dome)	Purchased	254.37	254.37
	Fabrication	CNC Routing, Laser Cutting, 3D printing,Lathing	Purchased	165.05	165.05
	Pneumatic System	Pistons, Valves, Fittings, tubes, DCVs	Purchased	62.46	62.46
	Fasteners	Screws (Stainless), Counter Nuts, L-Fixations (Nickel-Chrome), Caps (Stainless Steel)	Purchased	49.03	49.03
	Sealing	O-Rings, AGRO Glands, Marine Epoxy	Purchased	15.44	15.44
	Elecrtical System	PCBs, Electronic Components, 5*DC Converter	Purchased	582.52	582.52
	Vision System	2 IP Camera, 4 Analogue Camera, 1 stereo camera ,Ethernet Switch	Purchased	184.47	184.47
	Actuators	Micro Servo Motor, Dc Motor	Purchased	14.24	14.24
	Tether	Sheath, Power Cable, Ethernet Cable, Pneumatic Cable	Re-used	81.00	-
	Control Unit	Control Box, Monitor, Buttons, Joystick, AWG-6 Wires	Re-used	115.00	-
	Miscellaneous	Zipties, Heatshrink, Velcro, V-Slots, Weights, Buoyancy Foam	Purchased	18.45	18.45
	Vehicle Safety Equipment	Shrouds, Caps, Stickers, Fuses	Purchased	15.28	15.28
		Total		2,808.29	1868.29
R&D Costs	Mechanical	Square Canister	Purchased	40.45	40.45
	Electrical	Jetson Board, Test Board PCB	Parts donated	100.00	-
		Total		140.45	40.45
Running Costs	Playground	PVC Pipes, PVC Connectors, Spray Colors, Ropes, Plastic Fish, Corregated Sheets	Purchased	45.95	45.95
	Workshop	Workshop Fees	Purchased	64.72	64.72
	Competition Registeration	Mate, Mate Egypt, Fluid Power Quiz	Purchased	600.00	600.00
	Marketing	Posts Boosting	Purchased	17.80	17.80
	Printables	Brochures, Business Cards, Poster, Banners, Documentation Reports, Flyers	Purchased	58.25	58.25
	T-shirts	Company Staff T-Shirts	Purchased	80.91	80.91
	Training & Testing	Pool, Transportation	Purchased	606.80	606.80
	Travel Expenses(Regional)	Transportation, ROV Shipping	Purchased	55.02	55.02
		Total		1,529.45	1529.45
Equipment Costs	Compressor	25 Litre Compressor Unit + FLR unit	Re-used	85.00	-
	Power Supply	2 * 24V-20A	Re-used	49.00	-
	Mechanical Tools	Driller, Screw Drivers, Sand Paper, Piller, silicon	Purchased	38.83	38.83
	Electrical Tools	Soldering Iron Station, Flux, Solder, Avo Meter	Purchased	18.12	18.12
		Total		190.96	56.96
Total Cost				4,669.16	3495.16

Figure 45: Expenses

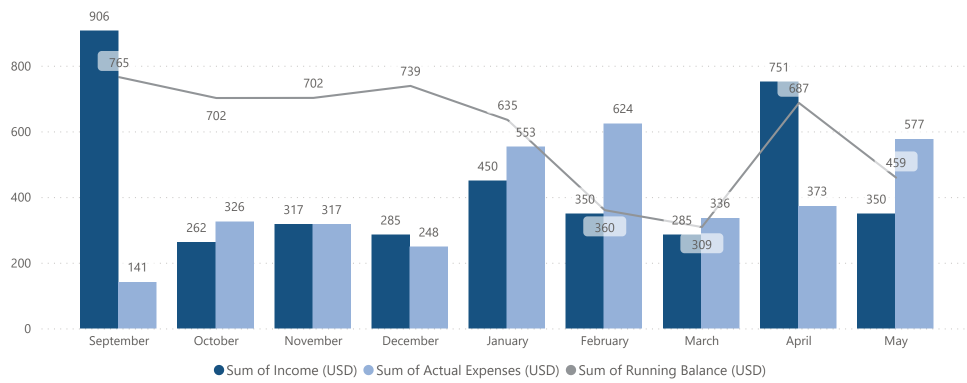


Figure 46: Cost Breakdown