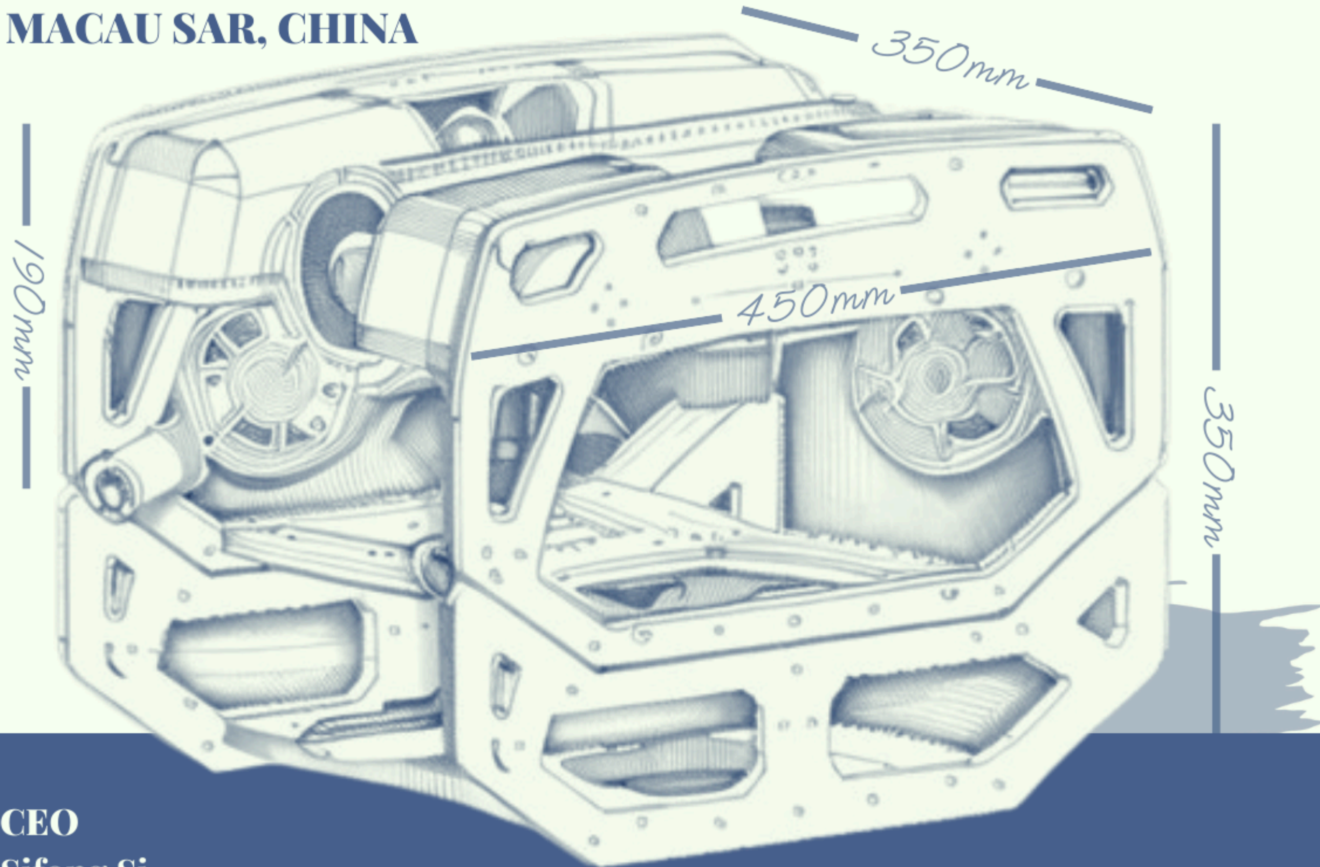
Achelous

Technical Documentation

Pui Ching Middle School

MACAU SAR, CHINA



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Introduction

Abstract

Fig.1 The Nessie

Achelous is a team specializing in making underwater robots, and it approaches the design and construction of Remotely Operated Vehicles (ROVs) creatively designed to carry out duties in the marine environment. Our crew comprises eleven high school pupils who enjoy creating stuff, recognizing issues, and discovering solutions.

Achelous' latest and highest-performance product is the Nessie, tested and improved by students over 150 days. We carry out the specific mission precisely with a full operation to determine the Nessie's passageways; this includes planning, investigating and analyzing, testing and experimenting, comparing materials, debating the findings, formulating conclusions, and deciding how to implement. We kept the design from last year to increase task operation efficiency and smoothness and concentrated on the Payload upgrade this year. The Nessie is equipped with various mission-specific tools and payloads, meticulously crafted to tackle a wide range of MATE 2024 missions. The payloads incorporated into the ROV include a manipulator for goods relocation and SMART cable deployment, a treble hook for coastal array establishment, a shovel for sediment sampling, and a servo motor for irrigation system activation.

Nessie is a very dependable and effective submersible robot. It comes fully furnished with various gadgets that were created especially for it. With its broad capabilities, individualization, and accuracy, Nessie is a great tool for accomplishing the 2024 MATE ROV Competition goals. It is made to satisfy a variety of mission requirements with high possibilities.

Fig.2 Achelous Team Photo

I. Project Management

A. Company Description

Achelous, a team based in Macau, is dedicated to addressing the challenges faced by the marine ecosystem and combating global warming. Our innovative solutions involve the development of underwater robots, which aim to assist and empower humans in their efforts to tackle these pressing issues.

Achelous' internal staffing structure is composed of four departments: Mechanical, Electrical, Software, and Public Relations & Safety. The company's CEO is dual-hatted with Electrical Lead, where he manages the cooperation between departments and ensures the viability of the hardware.

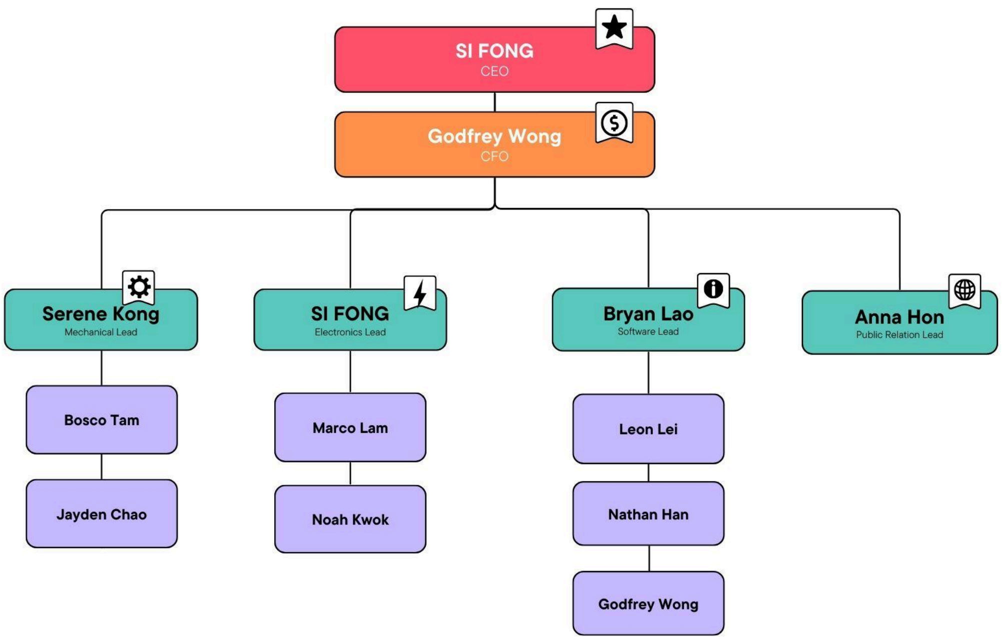

Fig.3 Achelous corporation organization chart

B. Schedule, Team Organization, and Assignments

Compared to last year, Achelous has strengthened the project management and promotion of things, programming to realize a more complete operation process, including the allocation of manpower, time mastery, practice process, and the use of funds.

We chose to use a Gantt chart to record and show the timeline of individual departments of the work they had put into Nessie throughout the year, and in the months leading up to the competition, different departments worked together to make adequate preparations for any task mission.

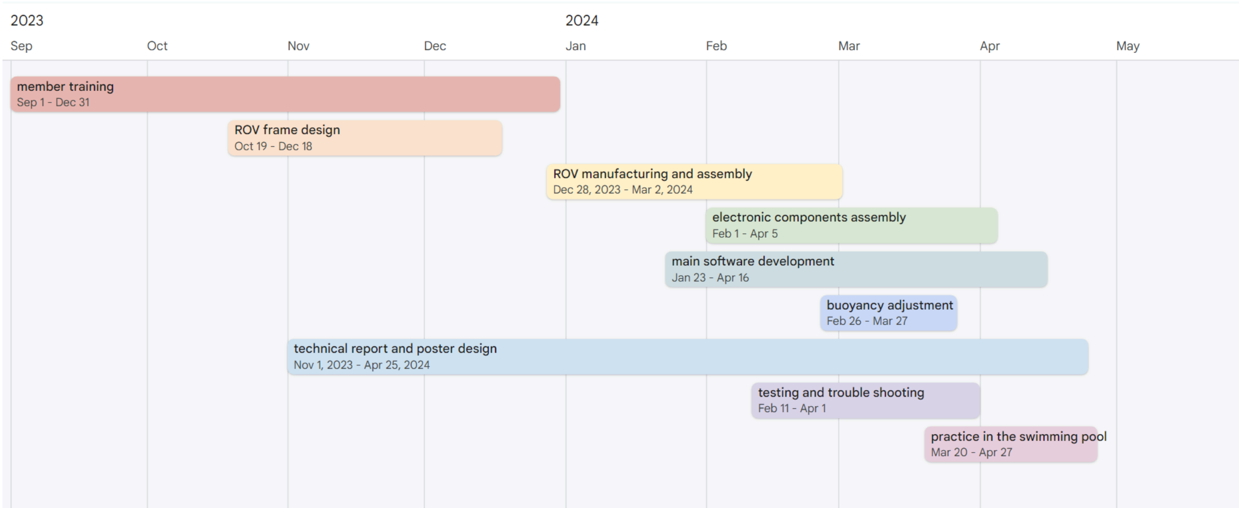

Fig.4 Gantt chart

Achelous employs a pool log to meticulously track the time required for testing tools and remotely operated vehicles (ROVs) in the pool to boost productivity. Additionally, a practice log is maintained to record practice sessions and the duration spent on specific tasks. This valuable data is leveraged to enhance overall work performance by optimizing the movement code of the ROVs and improving tool efficiency. Regular stand-up meetings are held by Achelous' team members to further enhance output. These meetings facilitate the establishment of goals, progress evaluation, and teamwork improvement. The adoption of these techniques has effectively addressed operational issues arising from incompetence and inadequate pool procedures, resulting in notable improvements in manufacturing processes.

Through these resource management strategies, well-defined procedures, and standardized protocols, Achelous successfully meets mission objectives and effectively resolves day-to-day operational problems. The diligent allocation of resources, adherence to established protocols, and continuous evaluation of procedures have contributed to the achievement of project goals while fostering seamless collaboration within the team. By effectively managing resources and implementing robust procedures and protocols, Achelous has been able to enhance operational efficiency and overcome challenges in its daily activities.

II. Design Rationale

A. Key Design Objective

Based on the MATE ROV 2024 competition charter, Achelous has extended the design concept and implementation of the previous year's design, and added different small designs to the base, especially in the design and production of the tools. Nessie is built upon the fundamental ROV architecture, upon which we have been making changes. Owing to its hydrodynamic design, the robot experiences low resistance and disturbance from the water flow. Furthermore, by manually modifying Nessie's weight, this design may swiftly resolve the buoyancy adjustment issue. This allows Nessie to maintain its stability in the water and maintain its capacity to remain balanced. When designing, we first consider practicality, safety, and reliability. Meanwhile, when choosing materials, Achelous tries to make the best use of available resources by first selecting the right accessories and materials from the affordable ones, before considering more expensive ones.

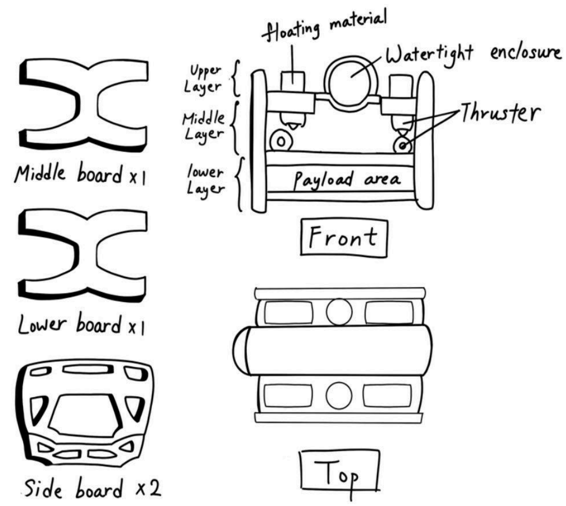

Fig.5 first concept design

B. Design Methodology and Process

The design methodology employed by Achelous prioritizes iteration, lean principles, and collaborative teamwork to ensure continuous improvement and success throughout the process of building the ROV. By embracing an iterative approach, the team strives to learn from existing problems and mistakes, using them as valuable lessons to drive further enhancements. This commitment to constant refinement is complemented by the application of lean principles, which emphasize efficiency, waste reduction, and value creation at every stage of the ROV's development.

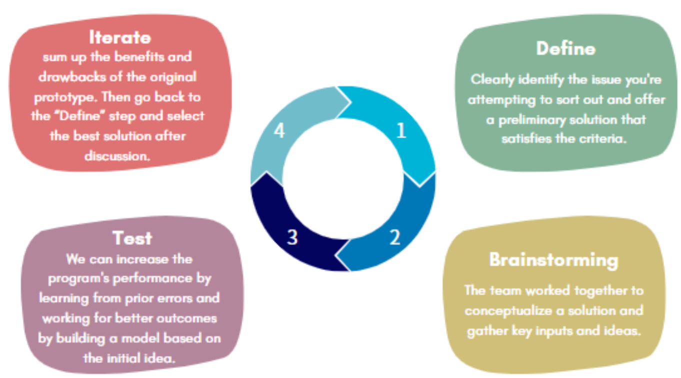

Fig. 6 Achelous Design Methodology

During the design phase, the team observed that ROV designs featuring two sideboards had been particularly successful among past contestants. Taking this into consideration, the team incorporated refinements and improvements to the ROV's structure. Sacrificing the portability of the ROV, the performance of the ROV underwater is maximized. Through experiments, such as speed-power performance testing, the ROV's maneuverability is optimized, maximizing its potential. Continuous experimentation has demonstrated the ROV's capability to perform complex missions and tasks, including those required in this year's MATE ROV competition. Furthermore, in alignment with the theme of ocean conservation and environmental protection, the team conducted a review of the ROV's eco-friendliness, ensuring the minimal use of polluting materials.

To ensure the effectiveness of their design decisions, Achelous employs a comprehensive evaluation process. They gather data from various sources, including online information, computer simulations, and real-life experiments. This multi-faceted approach enables them to assess the effects and results of their design choices, validating assumptions and making informed adjustments as needed.

Recognizing the diverse mission requirements that the ROV encounters, the Achelous team places great importance on offering distinct design options. This approach allows them to tailor the ROV's features and capabilities to specific needs, ensuring optimal performance in various scenarios. Whether it's the frame structure or the choice of payloads, each aspect is carefully designed to adapt and accommodate the varying demands of different missions.

C. Mechanical System

Frame

The ROV's outer frame measures 450 x 350 x 350 mm mm and is constructed using polyformaldehyde as the main material. In comparison to other products available on the market, our frame demonstrates exceptional resilience to impact and creep. Its adaptability is further enhanced by the channels on the frame that enable the attachment of tools, cameras, and thrusters.

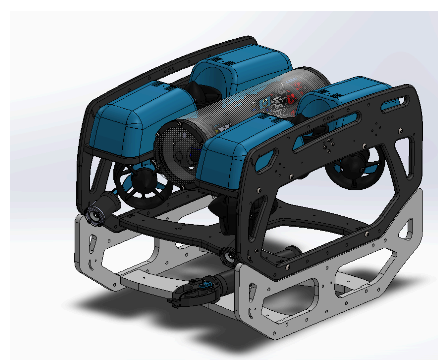

Fig.7 Nessie frame

We achieved optimal balance in our robot by making significant refinements based on insights from our previous design. A notable improvement was achieved through the restructuring and redesigning of the center boards, enhancing the capabilities of our ROV. In our new design, careful attention has been given to repositioning the thrusters to facilitate a more organized and systematic operation of our ROV. By strategically relocating the thrusters, we have achieved improved maneuverability and control, resulting in smoother piloting and precise movements in various underwater environments.

These enhancements of ROV design offer significant advantages in terms of enhanced stability, maneuverability, efficiency, precise control, and versatility.

Electronic Housing

The 4-inch, 100-meter-rated Blue Robotics waterproof acrylic tube, which has an outer diameter of 114 mm and a length of 300 mm, contains Nessie's bottom-side electronics. The electronic components inside the housing can be quickly and effectively inspected visually owing to this clear acrylic tube. Navigating Nessie underwater is made simpler by a wide field of view provided by a transparent frontal cap. Additionally, each end of the O-ring has precisely machined interfaces that provide stable and constant contact with the sealing flange. O-ring and epoxy are used for the protection of the circuit boards and components.

The acrylic tube houses a Raspberry Pi 3B, which serves as the receiver for command and control instructions from the surface-based control unit. Acting as the companion computer, it efficiently manages the hardware components essential for the ROV's operations, including thruster control and the transmission of sensor and telemetry data. To precisely regulate the thrusters, the Raspberry Pi is connected to a Pixhawk, which generates PWM signals to effectively govern the six electronic speed controllers inside the tube connecting to each thruster respectively.

Propulsion

We have chosen to use T200 thrusters from Blue Robotics as they offer the most thrust for the size.

Via the increased power consumption of using six thrusters, the strong propulsion provided by the thrusters allows our pilot to do complex movements such as rotation. By utilizing these thrusters, we can finish the tasks quickly and efficiently.

The Nessie utilizes six thrusters in a vector configuration to make the ROV stable and maneuverable, thrusters one to four are dedicated to horizontal movements, while thrusters five and six are responsible for vertical movements. The horizontal thrusters are strategically positioned at a 45-degree angle to maximize thrust efficiency. This configuration enables the Nessie to smoothly pan and maneuver in any desired direction, except pitch. As a result, this design significantly enhances the convenience and efficiency of our task processes.

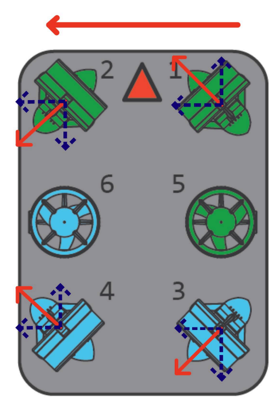

Fig.8 Diagram of Propulsion force

Buoyancy

After conducting extensive material experiments, we have determined that a high-density fiberboard is the optimal choice for constructing the floating boards. In comparison to regular pool noodles or alternative materials, high-density fiberboard demonstrates superior performance by maintaining its shape and stability even under high pressure. This exceptional characteristic ensures maximum safety and stability for the ROV, particularly in challenging and harsh environments. To achieve balance while the ROV is in motion, four of these floating boards are securely attached to the main body of the frame.

Attached to the tether, buoyant polyethylene (Float noodles) maintains the tether's neutral buoyancy. In addition, they stabilize the ROV's body because the float noodles remain separate from the body and do not interfere with the robot's movement.

D. Electrical Systems

Remote Piloting System (Control Box)

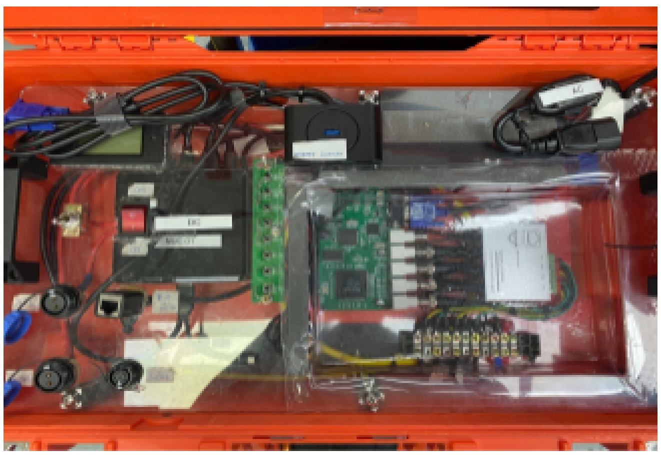

Fig.9 Interior of the topside control unit

Our control unit comprises three primary components: the topside computer, the video processing system, and two monitors. The topside computer plays a crucial role in managing data received from various sources, including the camera hub and other equipment. Working in tandem with QGroundControl and the ArduSub underwater robot operating system, it allows the pilot to have precise control over the essential maneuverability of the Nessie ROV.

The video processing system is responsible for processing signals from the four fisheye cameras, which are all connected to the camera hub on the ROV. These cameras capture visuals from four different directions, providing comprehensive coverage of the ROV's surroundings. The received footage is then transmitted to two monitors located within the control box.

The first monitor displays visuals captured by the front camera, offering a forward-facing perspective to the pilot. This provides crucial real-time feedback on the ROV's immediate environment. The second monitor showcases the visuals from the four fisheye cameras, enabling the pilot to have a panoramic view of the surroundings from multiple angles. This comprehensive visual feedback greatly enhances situational awareness and enables more precise navigation and maneuvering of the ROV.

By integrating these three components into a cohesive control unit, we have created an efficient and effective system that allows for seamless control and monitoring of the Nessie ROV. The combined functionalities of the topside computer, video processing system, and monitors provide the pilot with the necessary tools to navigate and operate the ROV with precision, ensuring successful mission outcomes.

Tether

The Nessie is connected by four tethers, consisting of two 20-meter-long power cords and two 20-meter-long ethernet cables. The purpose of the power cords, which have a gauge of 10 AWG, is to ensure that the remotely operated vehicle (ROV) receives a steady current of 25A.

The ethernet cables serve different functions in facilitating communication between the underwater control system and the onshore computer. One of the ethernet cables enables the transmission of data and video signals, allowing for the exchange of information between the control system's Raspberry Pi and the onshore computer. The second ethernet connection serves as a signal path connecting the onshore operating system with the underwater control system.

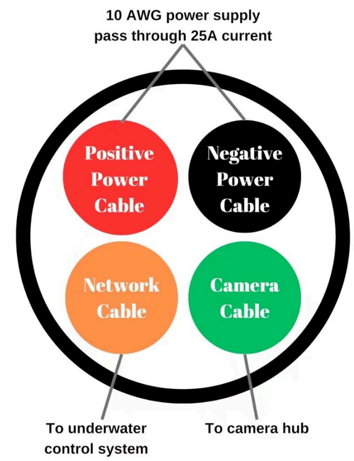

Fig.10 Nessie endplate

To improve camera connection reliability during operations, we replaced the original ethernet wire with a BlueRobotics Fathom tether. This upgraded tether provides better quality and faster transmission speed, ensuring a reliable connection. Its durability withstands stress, twisting, and bending, reducing the need for frequent replacements or repairs. The cable's elasticity allows for easy movement in various directions, enhancing the ROV's agility.

SID

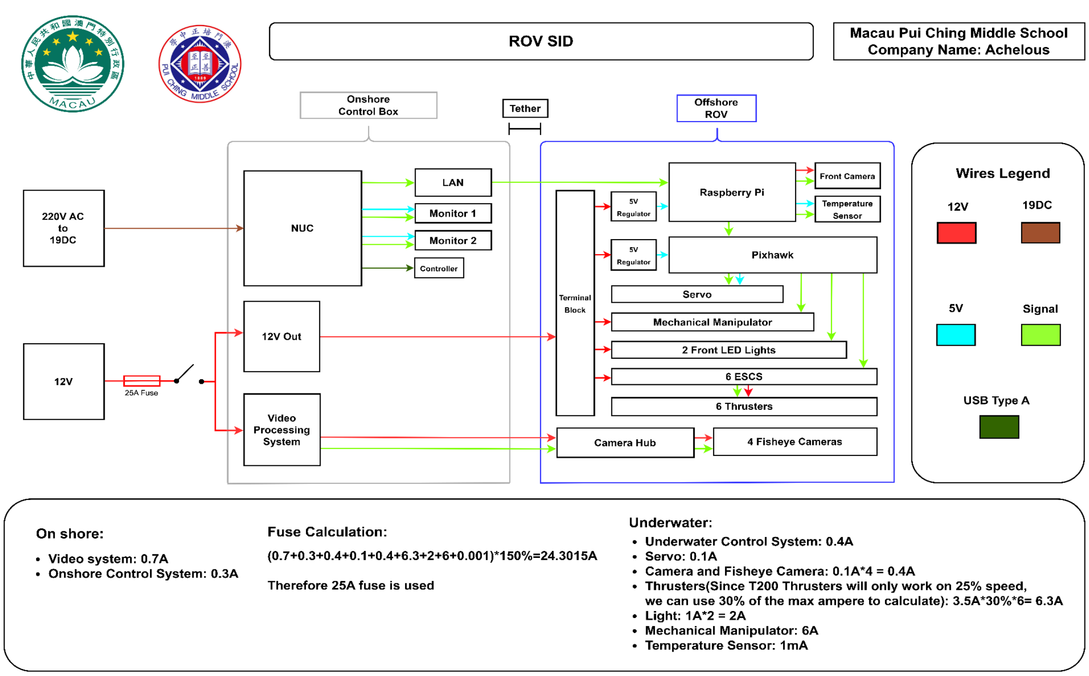

Fig.11 SID

E. Top Side and Bottom Side Software

Nessie's software system is designed to integrate various components, including command and control, ROV telemetry, digital imaging, and joystick inputs. The software is divided into two parts: topside and companion.

The topside software component provides a user interface and controls for the pilot. It consists of a control box containing an Intel NUC, which communicates with the companion computer. The control box is equipped with peripherals such as a keyboard, mouse, and monitor. Our primary software for missions is QGroundControl, which enables basic maneuvering of the ROV. Certain software missions will be assigned to other programs like PyCharm, particularly for autonomous activities.

On the other hand, the companion software component runs on a Raspberry Pi 3B. It receives command and control instructions from the topside control unit. The companion computer manages the hardware required for ROV functions, such as thruster control and the transmission of sensor and telemetry data. Thruster control is achieved by connecting the Raspberry Pi to a Pixhawk, which generates PWM signals to control six electronic speed controllers. The Pixhawk was selected for its reliability and compact size, which allows for adequate space for other components, including wiring for mission-specific features.

By splitting the software system into topside and companion components, Nessie achieves effective command and control capabilities, seamless communication between the control unit and the ROV, and efficient management of hardware functions, resulting in enhanced operational performance.

F. Digital Camera System

Camera Waterproof Head Durability Test

A fish eye camera's waterproof head must undergo a durability test to confirm its water resistance, evaluate its dependability, and guarantee product quality. Furthermore, this experiment can also be used to test whether the old lenses can function properly and smoothly. It boosts user confidence and lifespan by confirming the camera's resistance to water exposure in demanding conditions.

We conducted many tests on three distinct types of cameras to evaluate the robustness of our equipment. We can determine how to best safeguard the solder joint of the camera so that it breaks less readily by twisting the cameras until the connection is lost.

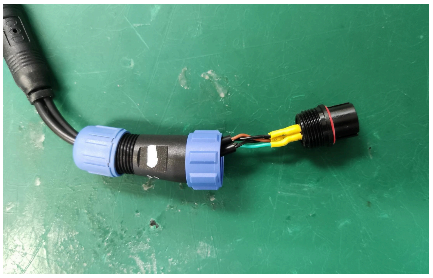

Fig 12. Camera soldering joint without any extra protection

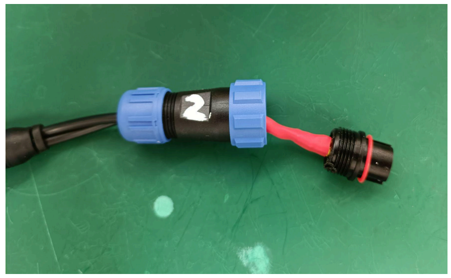

Fig.13 Camera soldering joint with large heat shrink tube

Fig.14 Camera soldering joint with large heat shrink tube and hot glue

After disassembling and examining a previous fisheye camera, we concluded that since it is completely watertight, it is highly improbable that water leaking is the root of the issue causing the disconnections.

Video System

The camera system comprises one low-light USB camera and 4 fisheye cameras. The USB camera is at the front of Nessie. It is attached with a servo placed in the watertight enclosure. With the help of the servo, the USB camera can adjust its position and enable a view of a tilted angle, which is ideal for the mission of image recognition.

Additionally, 4 waterproofed fisheye cameras are used for monitoring the environment around Nessie. All 4 cameras are connected to the external camera connection hub located at the back of Nessie, where all camera signals are gathered and transmitted through the ethernet cable to the control box. Finally, the captured video will be shown on the monitor on the control box onshore.

Fig.15 Camera Hub

G. Mission Tasks

Task 1

We made a claw to tackle mission 1.1. We have to design a tool for pulling out "the Trigger". To achieve this goal, we have designed the Claw. The Claw was printed with PLA plastics, which maintains it in a light and rugged condition. Besides that, the claw is also designed without sharp edges, as you can see, it is designed with many rounded corners and chamfered angles. Therefore, safety measures are also considered so as to make sure no one will get hurt because of that .

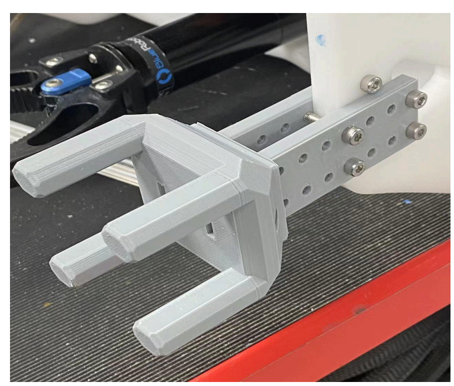

Fig.16 Claw

How to use the Claw is very simple, with the four extruded columns(Fig.15), the pilot can use it to hold "the Trigger", then our pilot will control the Nessie to move forward and backward, then "the Trigger" will be pulled out from the multi-function node easily.

Besides the tool of task 1.1, we also created another tool(Fig.16) for recovering the multi-function node. The most significant feature of this multi-function node is its #310 U-bolt. In order to recover it, we have designed the Rapid Buckle. It's 3D printed and attached with two rubber bands and has hooks on the side. The gadget is designed similarly to a buckle used for mountain climbing, as you can see in the picture, with elastic material used to bind on both ends. The device's resilience and ability to revert to its previous shape are made possible by the elastic material. Because of its unique design, there is less chance of the U-bolt falling out because the device will hold it in place unidirectionally. This tool's ingenious design increases user safety by guaranteeing that the gadget is securely connected to the U-bolt.

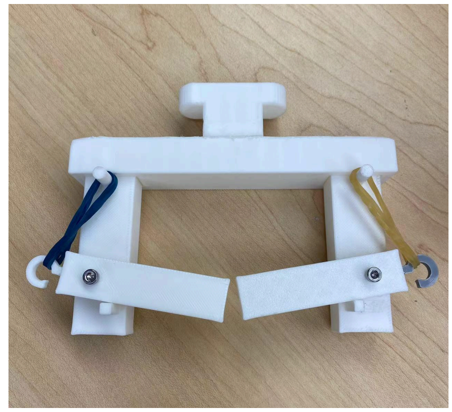

Fig.17 Rapid Buckle

In practical terms, when the pilot maneuvers the ROV, the gravitational force causes the exposed part of the pin to naturally orient downward, assuming no unforeseen circumstances arise. Therefore, successfully engaging one of the hooks with the pin is all that is needed to effortlessly retrieve and complete the assigned objective.

Task 2

To ensure a smooth deployment of smart cables along the designated waypoints, a protocol was devised to prevent any confusion between different tethers and cables. Pool noodles were strategically positioned near the ROV's tether to keep it separate from the sinking smart cable.

To streamline the completion of tasks, a specialized shovel was designed to facilitate easy object pickup. The temperature sensor was carefully placed on the bottom of the ROV frame to guarantee the highest level of precision and accuracy. This positioning protected the sensor from disturbances caused by the flow of the thruster, enabling reliable data collection. Furthermore, the ROV frame underwent modifications that included the addition of multiple holes, making it easier to retrieve and install the power connector. This alteration significantly improved the system's maneuverability in water.

By implementing these measures, the deployment of smart cables through the specified waypoints was successfully accomplished, eliminating entanglement issues and maximizing operational efficiency.

Task 3

In order to autonomously transplant the brain coral to the restoration area, a process similar to last year's docking system is used, in which PWM signals combined with OpenCV detection were used to successfully automatically dock the ROV.

We chose to use a 360-degree waterproof servo to assist us in completing task 3.1, which is to activate the irrigation system. To facilitate the tool's attachment to the water pipe and produce the spinning effect, we fitted a rectangular frame to the front of the servo. Conversely, a portion of the servo is attached to the fuselage, allowing it to be kept on the middle layer during the workweek and removed for use when needed. Additionally, the servo's top has a component that facilitates the robot's clamping motion and reduces shaking.

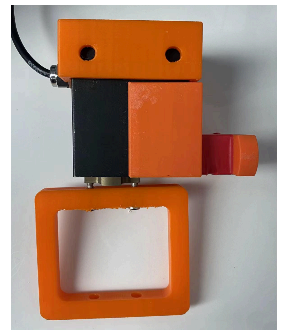
Fig.18 Rotary Servo

The pilot initializes the autonomous transplant by manually picking up the brain coral from the coral nursery, ensuring that the ROV is as perpendicular to the restoration area as possible. This is to reduce the possibility of error when the autonomous transplant process is initiated. The ROV moves into position by first adjusting its position in accordance with the restoration area. Then, it gradually moves up until the camera can clearly view the red velcro area, and the ROV then releases the brain coral on the red velcro area.

For the 3.3 3D Coral Modeling step, the approach involves autonomously performing 3D coral modeling using Python libraries such as OpenCV, YOLOv8, and CadQuery. The process is divided into three parts: target acquisition, size calculation, and 3D model generation.

To acquire the target, our ROV is utilized to capture an image of the coral restoration area. The image is then transferred to a computer onshore. A trained YOLOv8 model is employed to identify key reference points in the image, such as the endpoints of a fixed-length pipe, endpoints in the length direction, and endpoints in the height direction.

Next, in the size calculation phase, the coordinates of these reference points are inputted to calculate a crucial ratio: pixels/cm. This ratio enables the calculation of actual distances between any two points in the image. Using the Python-CadQuery library, a 3D model of the coral restoration area is generated. The area is divided into three cuboids, and by adjusting the length and height of each cuboid, an accurate 3D model of the coral restoration area is created.

Task 4

We have successfully designed and built a vertical profiling float that adheres to MATE's specifications. After conducting several rigorous tests, we have determined a simple solution by using a buoyancy engine. This innovative system consists of various components, including an

ESP32 microcontroller, an L298N motor driver, two limit switches, a Bar30 depth sensor, a 5-volt regulator, a piston, a 12-volt battery pack, and six 10-milliliter syringes.

The ESP32 microcontroller serves as the control center of our vertical profiling float. It is responsible for establishing a connection with a computer and executing precise commands to control the piston's movement. By pushing or pulling the syringe, the piston enables us to draw water into the float or drain it out. This mechanism can provide a 0.6 Newton difference to the vertical profiling float to influence the float's buoyancy, allowing it to ascend or descend in the pool as needed.

During the sinking process, our vertical profiling float actively collects and records valuable depth data, which is then utilized to calculate the corresponding pressure data, using the Bar30 depth sensor. These pressure measurements serve as crucial information for generating comprehensive graphs and charts that provide insights into the water column's characteristics and properties.

III. Testing and Troubleshooting

While testing and troubleshooting our ROV, we focused on three key criteria to ensure its optimal performance. These criteria encompassed the examination of the anti-water leakage capability of our cameras, as well as the evaluation of the functionality of connectors, particularly those designed for underwater use, using a multimeter. Additionally, we employed air pressure measurement equipment to verify the proper sealing of electronic enclosures and floats.

Firstly, we conducted testing to verify the effectiveness of the anti-water leakage mechanisms of our cameras, with specific attention given to the fisheye cameras. By subjecting the cameras to simulated underwater conditions, we assessed their ability to withstand water intrusion. This involved immersing the cameras in controlled environments and monitoring their performance to ensure they remained fully sealed, thus protecting the internal components from water damage.

Secondly, we utilized a multimeter to assess the functionality of connectors, paying particular attention to the connectors intended for underwater use. Through careful inspection and electrical testing, we determined whether the connectors were properly transmitting signals and maintaining a secure and reliable connection. This step was crucial to verify the integrity of the connectors, ensuring seamless communication between various ROV components, even in challenging underwater environments.

Lastly, we employed air pressure measurement equipment to evaluate the effectiveness of the sealing mechanisms of electronic enclosures and floats. By subjecting these components to controlled air pressure, we could identify any potential leaks or weak points in their construction. This meticulous testing process allowed us to ensure that the enclosures and floats were adequately zipped, maintaining the necessary pressure differentials and safeguarding the internal electronic components from water ingress.

IV. Safety

A. Safety Philosophy

At Achelous, safety comes first. Since accidents may happen at any time and are frequently unanticipated, we enforce stringent safety procedures and rules to make sure that every team member is aware of the risks and how important safety is. We take the appropriate safety precautions, such as donning protective gear and closely following the safety checklist and Job Safety Analysis (JSA), before doing any underwater testing. Accepting these preventative steps will help us lower the likelihood of errors and guarantee the security and welfare of our team members.

B. Safety Protocols

To meet the requirements of the International Standard for Laboratories (ISL), we prioritize the safety of our technicians and staff. All personnel are equipped with Personal Protective Equipment (PPE) as mandated by the standard. Our goal is to ensure that no one is harmed during experiments or other activities.

We place great emphasis on training and briefing our staff. To ensure their preparedness, all students and staff members undergo a comprehensive 72-hour tutorial and safety course. This equips them with the necessary knowledge and awareness of safety protocols. Before using specific machinery, such as laser cutting machines and CNCs, users are required to thoroughly review the provided user guidelines and evacuation leaflets.

In the event of a fire, we conduct annual drills to familiarize all laboratory personnel with evacuation routes and procedures. This ensures that everyone is well-prepared to respond in emergencies.

To guarantee the safety of our technicians, we regularly monitor air quality within the laboratory environment. This proactive approach allows us to identify and address any potential risks promptly.

C. Vehicle Safety Feature

Our strong commitment to safety is evident in the design of the Nessie physical machine, which incorporates multiple security measures and reminders. To address any potential emergencies during ROV operations, we have included an emergency switch button in the control box. This allows for immediate power-off of the ROV when necessary.

To safeguard against collision damage while performing tasks, we have installed 3D-printed thruster guards with mesh sizes smaller than 12.5 mm. Additionally, warning labels are prominently displayed on the Nessie to alert users to potential hazards. Spiral protection sleeves are used to secure exposed wires at the end of the electronics housing, minimizing the risk of tangling during ROV operation.

In order to prevent short circuits, we have implemented various fuses, including 25 amp fuses. These fuses serve as protective measures to maintain the integrity of the electrical system.

As for securing the tether, we have employed the Strain Relief method, fixing it at the rear of the main body of the ROV. This ensures that even if the tether is mishandled, it remains intact and undamaged. Ultimately, this safeguards both pedestrians on shore and the ROV itself.

D. Operations and Safety Checklists

Whenever we come up with a new idea, apart from practicality, safety is also a very important indicator. To better protect the safety of team members and bystanders during the operation of underwater robots, we have developed an operation and safety checklist, which is included in the Appendix page.

V. Accounting

A. Budget

Based on the build costs from the prior year and taking into account the requirements of the 2024 MATE competition, Achelous creates a budget for the development of ROVs. The Macau Pui Ching Middle School provides funding to meet operating and material costs. Donations and team dues are also recognized as revenue sources. Every department drafts and submits a project proposal at the beginning of the year that details the expected costs for developing new tools and improving ROV designs.

The CFO oversees orders and inventory management, and mentor permission is required for all purchases. Throughout the manufacturing phase, the budget is consulted to make sure the project stays within its allocated budget. Employees of Achelous are in charge of covering their own travel and meal expenses, which are allocated differently in the competition budget. Refer to Appendix B.

B. Project Costing

In the years 2023-2024, the majority of Achelous' expenses were allocated to the acquisition of electronics and cameras. To ensure accurate tracking of project costs, a Google Sheet was used and regularly updated. For a detailed breakdown of costs, please refer to

Appendix C. Achelous effectively managed its budget by employing efficient cost management techniques, such as securing donations and carefully evaluating the necessity of purchasing, manufacturing, or reusing materials by comparing the advantages and disadvantages of each side. By implementing these strategies, as well as constructing custom components and procuring reliable materials, Achelous successfully adhered to its budget.

C. Build vs. Buy, New vs. Reused

This year, we prioritized our financial situation and opted to reuse functional parts whenever possible. We carefully assessed our tasks for the year and adapted by refining and recreating tools using existing materials or components. For example, we needed a manipulator and decided to use the BlueROV gripper, which we had purchased and utilized last year. This choice not only delivered optimal performance during missions but also helped us save money. Additionally, we replaced outdated electronic components, including cameras and connectors, in the electronic enclosure since they were no longer available.

In order to evaluate the values of our reused parts, we considered the fluctuations of prices negligible and calculated the total value with the original price when we brought them. In Appendix C, a detailed table of the expenditures can be seen.

VI. Challenges

Our team has encountered and diligently addressed several challenges during the development of our ROVs. These challenges include water leakage, mechanical breakdown, and maintenance issues.

To overcome water leakage, we have implemented robust and watertight enclosures for our electronic systems and connectors. Seals, gaskets, and pressure compensators are used to prevent water from entering critical areas and equalize pressure differentials.

To address mechanical breakdown, we focus on enhancing component durability and resilience. We use corrosion-resistant materials, and advanced lubrication systems, and conduct regular inspections and maintenance to minimize wear and tear and prevent failures.

Maintenance challenges are tackled by designing modular and easily serviceable ROVs. Quick-replace components, remote diagnostic systems, and automation help streamline repairs and reduce the need for human intervention in remote and inaccessible locations.

VII. Lesson Learned and Future Improvement

Building and participating in the MATE ROV competition was a valuable learning experience for our team. We faced challenges, including water leakage due to insufficiently sealed connectors. To address this, we learned to use epoxy on connectors, which improved water resistance and performance. Another lesson was the importance of double-checking before each dive to avoid avoidable problems. However, the most valuable lesson was the significance of team cooperation and learning from our mistakes. We fostered open communication, supported each other, and implemented improvements, resulting in a stronger team and a more capable ROV.

VIII. Conclusion

Our team gained valuable experience and learned important lessons while preparing for the competition. One key takeaway was the importance of effective teamwork and communication. By allocating time and working efficiently, we realized that communication is essential for coordinating each other's progress and ensuring the smooth construction of the ROV. We came to appreciate that effective communication is the key to achieving team goals, and this experience will inspire us in future learning and work.

In addition, we recognized the importance of designing programs for robot making. To this end, all team members learned to use software such as Solidworks and CorelDraw. This not only improved our productivity but also enriched our knowledge. We also gained practical skills such as laser cutting and soldering by making components such as tethers and cameras. By acquiring these skills, we could design ROV structures and components more efficiently and better understand physical principles such as mechanics and fluid mechanics. These skills and knowledge will be valuable assets as we pursue future learning and career development, enabling us to approach challenges and opportunities confidently.

A. Acknowledgements

Achelous would like to express our most sincere gratitude to our contributors and supporters for their help and assistance in the making of the Nessie:

Macau Pui Ching Middle School - for providing us with laboratories, tools, and persistent help

Solidworks - for providing us with the software we used to produce the Nessie.

Mr. Lao Kun Wa Thomas - our instructor, supervisor, and mentor

Mr. Lou Weng Keong Marco - our instructor, supervisor, and mentor

Education and Youth Education Bureau- for permitting us to test in a swimming pool

MATE Center- for organizing the international ROV competition, allowing the public to learn more about marine technology.

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IX. Appendix

A. Construction and Operating checklist

General

- Communication is loud and clear enough
- Only crew members are working on the Nessie
- safety equipment, including safety glasses and protective gloves must be put on while using power tools and sharp tools
- Clear work area to prevent hazards (knocking things over, tripping hazards, etc.)
- Tools and equipment are properly stored
- Regular sanitizing of work and personal space
- Tether is connected to the strain relief
- Verify electronics housing is sealed

Pre-mission

- All connections are secured and correctly connected
- Shrouds are added to thrusters
- The tether is straightened
- No electronic components are exposed
- No wires are damaged or loosed
- Cameras and lights are not blocked

During mission run

- Communication between pilots and deck team members.
- Area with no tripping hazards.
- Tools are all installed in the correct position.

After mission run

- Power switch is OFF before detaching the tether
- Electronic parts remain dry during disconnection
- Controller is disconnected
- Tether is kept tidily and neatly

B. Budget

Budget			Reporting Period	
School Name	Macau Pui Ching Middle School		From	09/2023
Instructor	Thomas Lao, Marco Lou		To	05/2024
Income	Type	Description	Amount(USD)	
Private Donation	Donation	Donations from private donors		$30,287.29
Team Dues	Cash	Membership Dues $62.18 @11 Team Members		$683.98
Expenses				
Category	Type	Description	Projected Cost (USD)	Budget Value (USD)
Electrical	Purchased	Waterproof Cameras, Small four pole male plugs,Small four pole female socket, Nine pole female socket, Nine-pole male plug	$105.13	$105.13
Travel	Employee Paid Expense	Competition Transportation, Competition Accommodation, Meals	$30,287.29	$30,287.29
Training	Employee Paid Expense	Venue, Lifeguard Fee	$1,573.24	$1,573.24
Total Income				$30,971.27
Total Expenses				$31,965.66
Total Expenses - Reuse/Donations				$31,965.66

C. Project Cost

Category	Type	Date	Expense	Notes	Budget (USD)
Electronics components	Purchased	10/2023	Camera(20 pcs)	Used for camera system, spares included	$55.95
	Purchased	11/2023	Small four pole male plug(20 pcs)	Waterproof cable connector for cameras, spares included	$22.12
	Purchased	11/2023	Small four pole female socket(10 pcs)	Waterproof cable connector for cameras, spares included	$11.06
	Purchased	11/2023	Nine pole female socket (5 pcs)	Waterproof cable connector for camera hub, spares included	$8.00
	Purchased	11/2023	Nine-pole male plug(5 pcs)	Waterproof cable connector for camera hub, spares included	$8.00
	Reused	09/2019	Pixhawk Flight Controller	Controlling unit for the ROV	$189.99
	Reused	11/2022	Waterproof servo	N\A	$108.89
	Reused	11/2022	Lumen Subsea Light	N\A	$320.00
	Reused	12/2022	4-CH Passive Video Balun HD Transceiver	Used for camera system	$10.88
	Reused	09/2019	Hatch fixing ring	N\A	$121.74
	Reused	09/2019	Raspberry Pi 3B	N\A	$50.12
	Reused	10/2022	Thrusters(6 pcs)	N\A	$1,200.00
	Reused	09/2019	Fathom ROV Tether(18 m)	N\A	$52.50
	Reused	09/2019	Fathom Spool	N\A	$680.00
	Reused	09/2019	BlueROV2 Fairing(4 pcs)	N\A	$48.00
	Reused	10/2022	Newton Subsea Gripper	N\A	$590.00
Total Budget(Electronic components)					$3,477.25
Control box components	Reused	12/2022	14 inch Monitor	N\A	$41.24
	Reused	09/2022	Control box case	N\A	$24.00
	Reused	10/2022	Camera box	N\A	$52.90
	Reused	10/2022	NUC	N\A	$98.99
	Reused	10/2022	Monitors(DELL)	N\A	$84.99

	Reused	11/2022	Console	N\A	$28.79
Total Budget(control box components)					$330.91
Mechanical Components	Reused	09/2019	Cast Acrylic Tube	N\A	$216.00
	Reused	09/2019	End-cap with Holes	N\A	$32.00
	Reused	09/2019	O-ring Flange	N\A	$86.00
	Reused	09/2019	Acrylic End-cap	N\A	$40.00
Total Budget(Mechanical Components)					$374.00
Total Budget					$4,182.16
Total Budget(Purchased)					$105.13