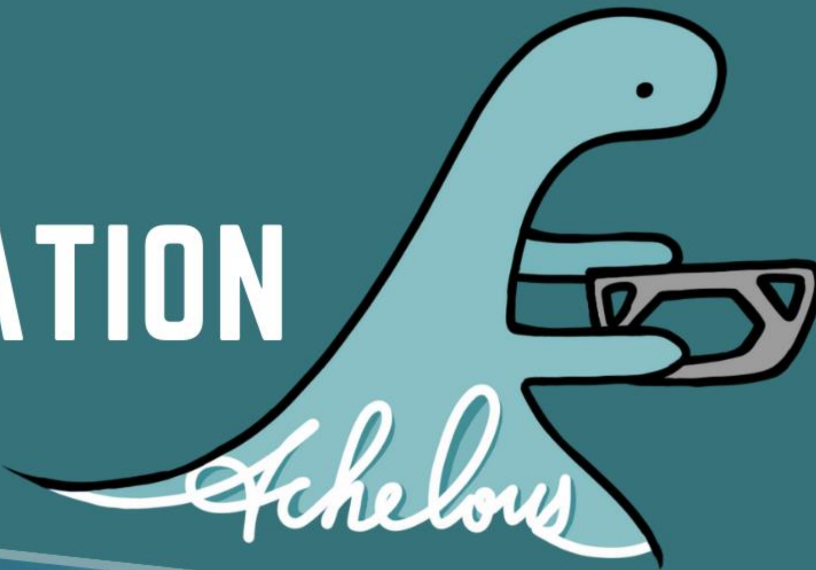
ACHELOUS

PUI CHING MIDDLE SCHOOL
MACAU SAR, CHINA

TECHNICAL DOCUMENTATION



Team members:

CEO
SIFONG SI

CFO
GODFREY WONG

CTO
BRYAN LAO

MECHANICAL ENGINEERS
SERENE KONG (LEAD)
BOSCO TAM
JAYDEN CHAO
MATTHEW LAO

SOFTWARE ENGINEERS
BRYAN LAO (LEAD)
GODFREY WONG
LEON LEI
NATHAN HAN

ELECTRONIC ENGINEERS
SIFONG SI (LEAD)
MARCO LAM
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PUBLIC RELATIONS & SAFETY
ANNA HON (LEAD)
VIVIAN LEI
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MENTORS
THOMAS LAO
MARCO LOU

Content

Introduction

Abstract (Nessie)

The Achelous comprises fourteen students from Grades 8 to 10 who are passionate about marine ecosystems and underwater robotics. Working for more than 313 hours throughout the project, cooperation between the mechanical, electrical, and software departments, employees of Achelous have perfected our latest ROV, the Nessie. It has been developed to maintain healthy environments from the land to the seas and to improve quality of life.

It comprises months of designing, manufacturing, and testing under a strict safety protocol. We referenced the basic and default design and customized it with our unique features. These include detachable tools, a high-definition lighting system, and a safety protection design.

As a novice team, we are thrilled to participate in the recent competition organized by MATE ROV. Our collective enthusiasm and drive were palpable as we prepared for this exciting new challenge. With a strong desire to improve our team spirit and coordination, we seized the opportunity to learn and grow together, pushing ourselves beyond our limits and striving for success.

Fig. 1 Our team members

Project management

Schedule, Team Organization and Assignments

Our company assigns work tasks every Wednesday. The CEO organizes routine meetings to monitor the program's progress and ensure its comprehensiveness. During meetings, we discuss the project's scope, outline specific tasks and deadlines, and clarify what we expect from each team member. This helps us to establish a shared understanding and vision for our work.

Throughout the project, we supported the team members as needed. This included access to specialized tools and equipment, training and development opportunities, and assistance with problem-solving and decision-making. Moreover, we encourage team members to share their suggestions and current results in their respective areas of responsibility, fostering a culture of collaboration, learning, and continuous improvement.

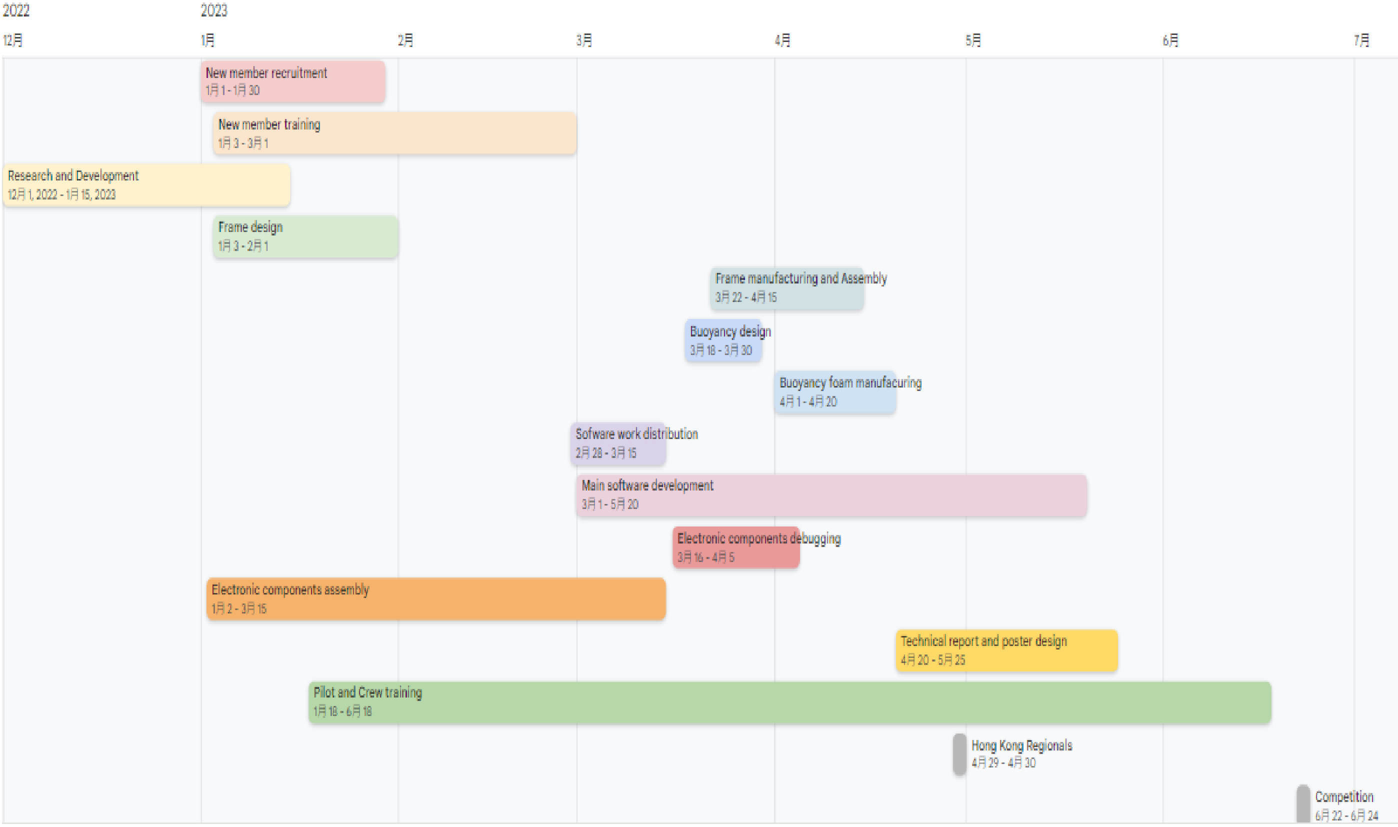


Fig. 2 Gantt chart of Nessie's developmen

More members have joined the Achelous since January. As the team expanded, the new members were trained to cooperate throughout this year. Meanwhile, the staff is offered the chance to enjoy the process of making the robot, also fulfilling their imaginations and enthusiasm.

In the early stages of our program, the team mainly focused on training members and designing the robot, especially the frame. Even with the above, the electronic enclosure was quickly made within 3 months, from January to March.

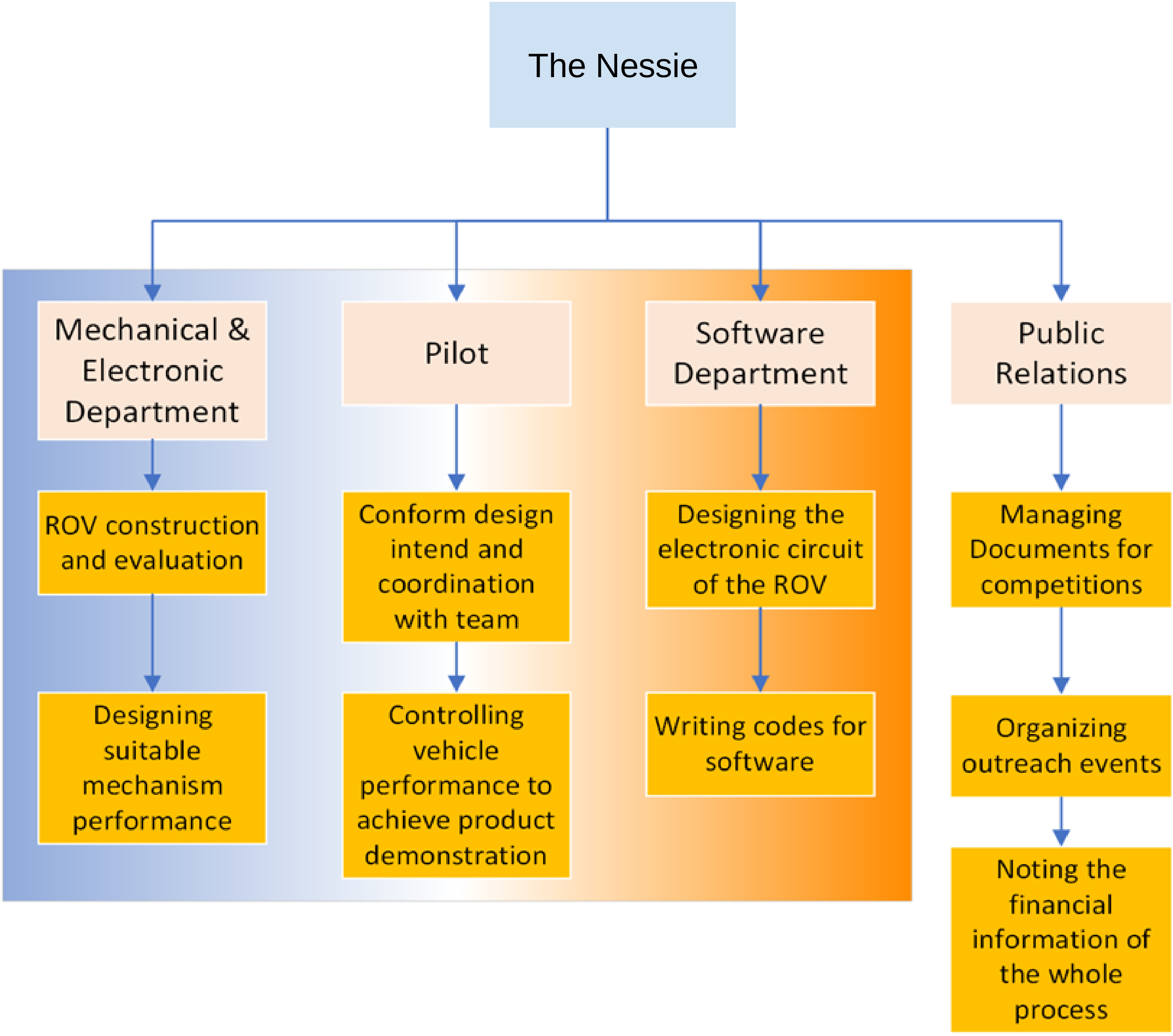


Fig. 3 Organizational chart

Members of Achelous were working on the debugging and engineering of the Nessie between March and April. In particular, the frame and the electronic system were finished and tested. Meanwhile, software engineers have worked hard to finish the software and control system within the scheduled time.

Taking on heavy responsibilities, pilots and tether managers have begun their training throughout the entire year. Thus, they often stayed at the laboratory and worked overtime.

The graph above depicts the brief schedule of the team.

Design Rationale

Overview

Nessie is based on the most basic structure of ROVs. We are using ArduSub for the primary control system. And using QGroundControl for manual control. Except for the center camera view provided by the ArduSub system, Nessis also has 4 extra cameras mounted on the body for more angle views. That helps Nessie to complete complex missions quickly and firmly. Lastly, the interchangeable feature of our payload attachments allows Nessie to achieve a broad range of tasks in different scenarios.

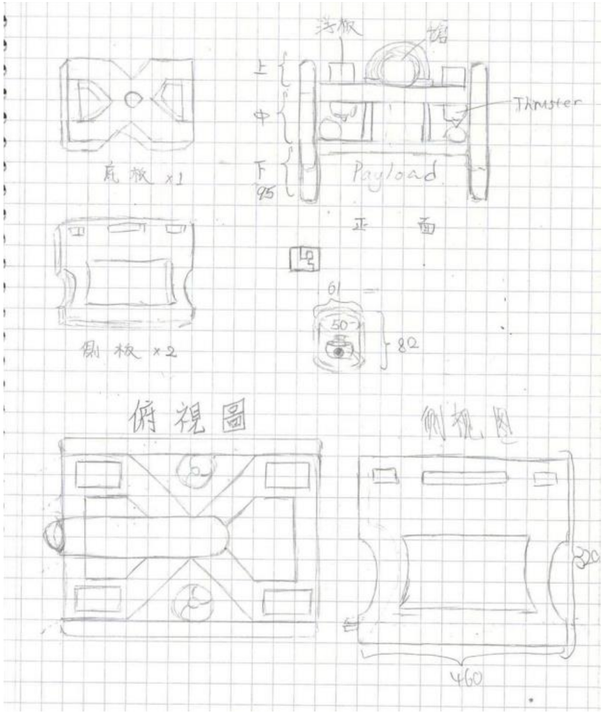


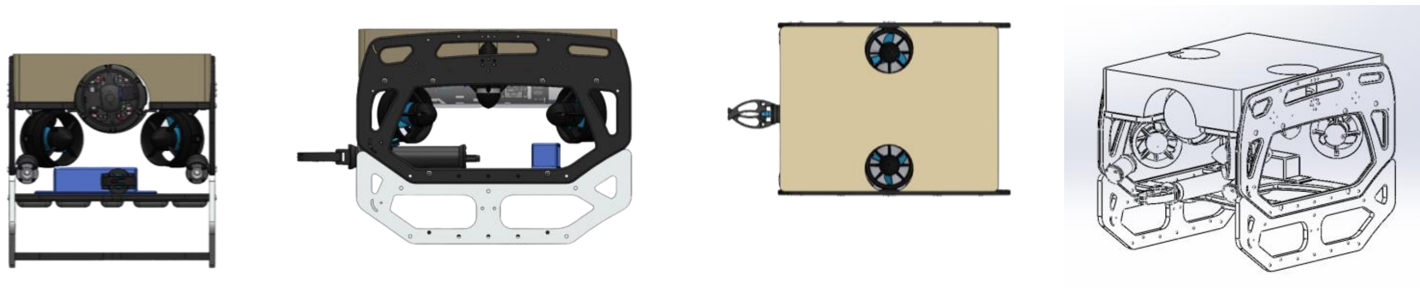
Fig. 4 First concept design

Design Process

We designed the first version of the frame based on the basic structure of ROV. To fix the stability and buoyancy, we redesigned our frame.

One of the primary considerations when designing the Nessie is to allow it to be as hydrodynamic as possible; therefore, we have developed the frame to be round, which reduces the drag forces. We have built on the inadequacies of Nessie's predecessor by adding designs, such as an additional frame at the bottom of the ROV. Thereby we can have more room for tools and payloads.

Our initial choice of manufacturing technique was 3D printing. Instead of ABS, which was used in our prototype ROVs, PLA is chosen as it is more environmentally friendly, in addition to its low cost and ease of use. However, using just 3D printed components is too fragile, and lightweight and hard material is considered. Stainless steel was used in our prototype ROVs, yet it is heavy and hard to be managed in our workshop. The research was done, and we concluded that 6061 aluminum plates are ideal for building a stable and hard frame. The aluminum plate can be easily managed and handled in the CNC machine in our workshop as it is malleable.



front side top isometric

Fig. 5 Orthographic projection of the ROV

Frame

Due to time constraints, we had to use the unfinished base plate and side panels from the prototype version of our design to create the current version. To improve its performance underwater, we opted to round the side panels, which reduced drag and enhanced mobility. We strategically arranged multiple large and small holes in the side panels to improve mobility while ensuring optimal weight distribution.

To accommodate new payloads, we divided the base plate into two layers. The top layer houses the electronic enclosure and thrusters, while the bottom layer remains free to install payloads. This design allows for greater flexibility and versatility in using the ROV. Despite the limitations imposed by time constraints, we have taken great care to ensure that our design is functional and efficient. We are confident that this approach will result in a successful outcome for Nessie.

Watertight Enclosure

The Nessie employs various waterproofing methods, such as epoxy and O-rings. This is for the protection of the circuit boards and components. During the troubleshooting process, several factors are considered. For example, we ensured an exact fit of materials to prevent leaks. Moreover, we chose materials that can withstand underwater pressure for a longer lifespan than usual ones. Furthermore, epoxy and O-rings are added to the entire electronic enclosure so that no short circuit will occur underwater.

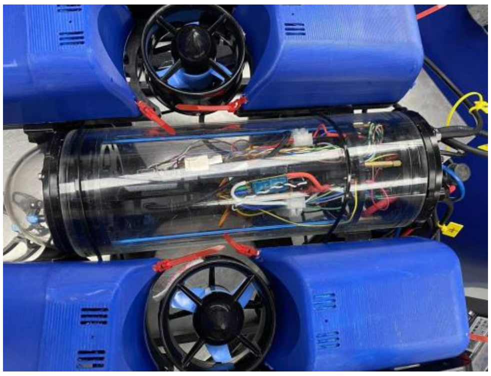


Fig. 6 electronic enclosure

Electronic design and cabling

The Nessie is connected to four tethers: two power cables and two ethernet cables, which are approximately 20 meters long. 10 AWG power cables are chosen to ensure that a current of 25A can convey to the ROV, as an insufficient amount of current will lead to constant reset which severely affects the Nessie's performance. One of the Ethernet cables is the communication bridge between the on-shore computer and the Raspberry Pi of the underwater control system. In contrast, the other ethernet cable is a signal channel between the underwater control system and the onshore operating system.

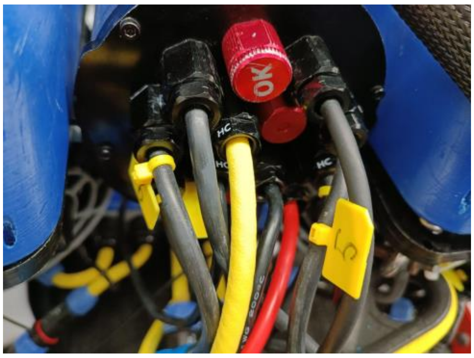


Fig. 7 tether

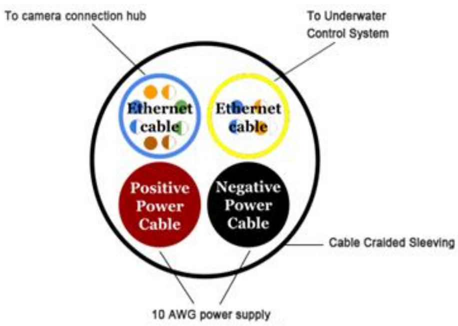


Fig. 8 Inside view of tether

They are used for data and video signal transferring. An unstable camera connection was spotted during the operation. Hence the original ethernet cable connecting the underwater control system and the onshore operating system was replaced by a BlueRobotics Fathom tether with better quality and transmission speed. The cable can withstand bending, twisting, and tension using a Fathom ROV tether. This enhances the reliability and longevity of the line, reducing the need for frequent replacements or repairs. Moreover, the cable's flexibility enables it to move freely in different directions, allowing excellent maneuverability for our ROV.

All the connectors between the tether and the onshore control box are detachable so that the tether can be detached from the control box. The detached tether is then managed with a movable wire spool for easy transportation. Strain relief is added for extra protection. Eventual tension will be transferred to the mainframe. The power cables are connected to a terminal block inside the electronic enclosure, providing power for the entire ROV and equipment. Thruster control is done by connecting a Raspberry Pi to a Pixhawk that generates PWM signals which control six 30-amp electronic speed controllers. Other equipment, such as the front camera, the LED lights, and the manipulator, are also connected to the Pixhawk.

The electronic department and the tether manager are jointly responsible for the tether. The tether manager should not only understand the basic structure of the tether but also pay attention to the followings:

1. Never forcibly pull the tether
2. Always pay attention to the position and direction of the ROV to make relative adjustments.
3. Avoid tangling the tether
4. Coordinate with the pilot effectively (e.g., using hand movements)
5. Ensure the tether has enough slack

Control System

Our control unit consists of three main components: the topside computer, the video processing system, and the monitors. The topside computer manages data received from the camera hub and other equipment. Together with QGroundControl and the ArduSub underwater robot operating system, it allows the pilot to control the essential maneuverability of the Nessie. The video processing system receives signals from the four fisheye cameras, which are connected to the camera hub on the ROV, providing visuals from four different directions. Footages taken from the cameras are transmitted to two monitors inside the control box, displaying visuals captured by the front camera and the four fisheye cameras, respectively.

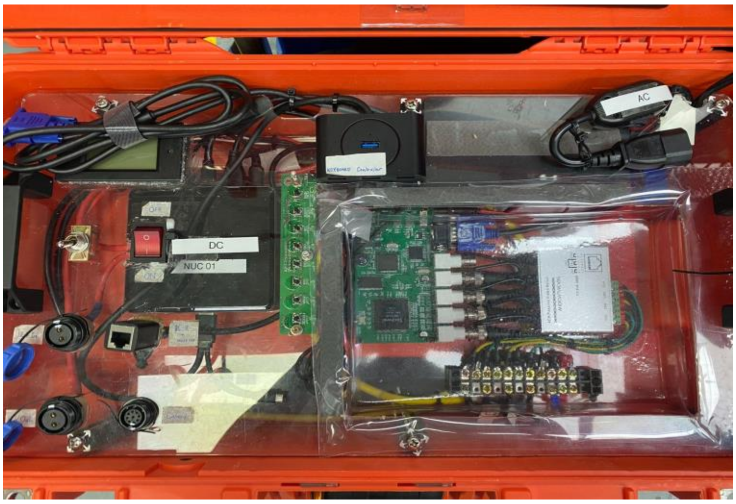


Fig. 9 Interior of the topside control unit

System Interconnection Diagram (SID)

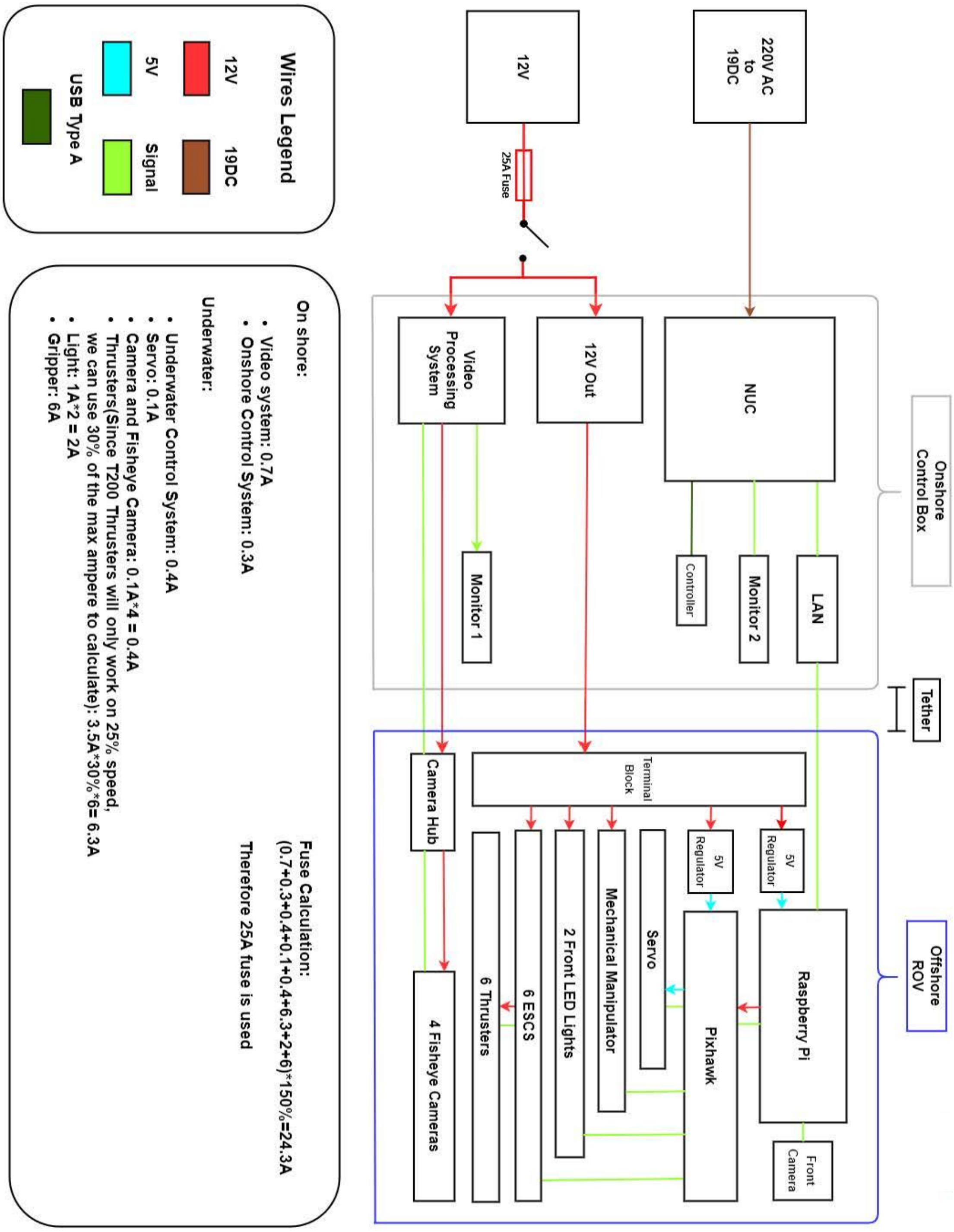


Fig. 10 System Interconnection Diagram

Propulsion

We have chosen to use the T200 thruster as it offers the most thrust for the size. The Nessie utilizes six thrusters in a vector configuration to make the ROV stable and maneuverable. This allows the ROV to have navigational control over three movements: lateral, horizontal, and vertical, and two axes: roll and yaw. This configuration leaves pitch out of the picture but can be omitted due to the lack of need for such a movement underwater. Additionally, this configuration offers the advantage that the thrusters do not require much adjustment before operation.

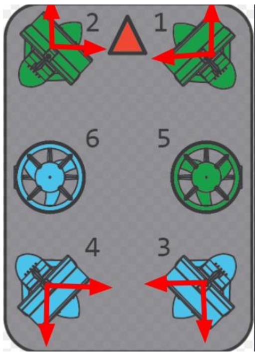


Fig. 11 thrusters configuration

Buoyancy

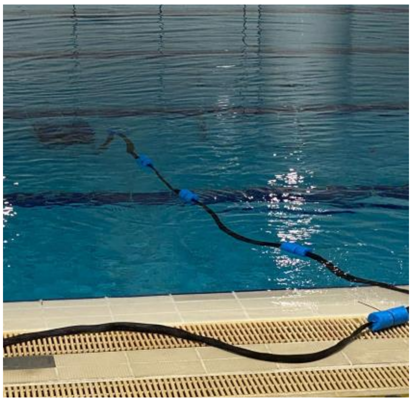


Fig. 12 Tether tied with floating pool noodle

After testing, floating boards made of high-density fiberboard were added to optimize the buoyancy of the ROV. Moreover, it minimizes the workload which the robot withstands. The floating boards provide the body with a condition of suspension, offsetting the gravitational and buoyant forces of the Nessie.

Buoyant polyethylene (Float noodles) is attached to the tether and keeps it in neutral buoyancy. Meanwhile, the float noodles stabilize the body of the ROV since it stays independent from the body and thus not affecting the robot when it moves.

An integrated design is used for the floating plate because it is easy to install and can secure the electronic enclosure. Additionally, it eliminates the need for the original two iron bars and allows for direct counterweight integration into the frame without requiring extra steps. Further, the integrated design enhances the overall aesthetic of the device.

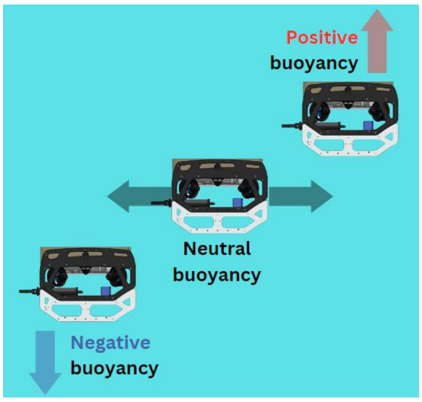


Fig. 13 Status of Buoyancy

Tools

Illumination LED

Mechanical engineers of Achelous have chosen the Lumen Subsea Light from Blue Robotics since it offers a light output of 1500 lumens. It is installed on both sides of the middle layer, which allows the camera to have a concentrated beam of light with a 135-degree angle range so that the light from the two lights can converge in front of the main lens and provide a wide range of light coverage. This gives the pilot a clear view and gives our algorithms better coverage of the colors shown.


Fig. 14 LED lights mounted on the middle layer

Multi-functional manipulator

Due to the assortment of tasks that the ROV has to handle, we first attempted to design our manipulator, but due to the design being unreliable and having inadequate strength, coupled with the high investment of time needed to make such a design viable, a pre-built manipulator from Blue Robotics was chosen as its replacement. This greatly diminishes the inconveniences the pilot has to endure and ensures that the manipulator's core function is unfettered.

Fig. 15 Manipulator

System Architecture

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 enables a view of a tilted angle, which is ideal for the mission of image recognition.

On the other hand, 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 ar e gathered and transmitted through the ethernet cable to the control box. Finally, captured video will be shown on the monitor on the control box onshore.

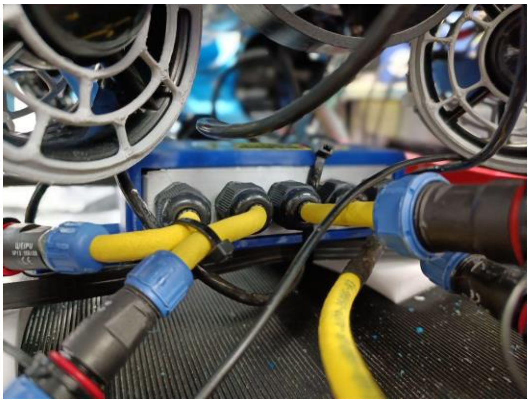


Fig. 16 Camera Hub

Software

Nessie’s software system integrates command and control, ROV telemetry, digital imaging, and joystick inputs. The software is split into two parts: topside and companion. The topside provides a user interface and controls for the pilot, while the companion receives the command and control data for the thrusters and tools and sends sensor information and camera footage back to the topside.

Topside

The topside control unit is the control box consisting of an Intel NUC, which communicates with the companion computer, and its peripherals, such as the keyboard, mouse, and monitor. Most of our software missions are done via QGroundControl, which allows basic ROV maneuvering. Due to the limited time this year, there needed to be more time to design a proper GUI and operating system for the ROV. As such, some software missions will have to be allocated to other programs, such as PyCharm, for autonomous activities.

Companion Computer

The companion computer is a Raspberry Pi 3B which receives command and control from the topside control unit. It manages the hardware for ROV functions, for example, thruster control and communication of sensor and telemetry data. Thruster control is done by connecting the Raspberry Pi to a Pixhawk that generates PWM signals which control six electronic speed controllers. The Pixhawk was chosen due to its reliability and compact size, which ensures enough space for other parts, such as wiring for mission-specific features.

Mission Specific Features

Task 1: Marine Renewable Energy

Automatic docking system

Achelous's software engineers have developed software to track the entry of the ROV into the docking station. This software utilizes Pymavlink, a python module, to control the ROV's thrusters, and OpenCV, to find the position of the red button underwater. The ROV first inspects the docking station to find the button it has to push and centralizes the ROV (and the camera feed) around it. This ensures the ROV does not drift around when automatically piloting into the docking station. Once locked on, it automatically drives forward while accounting for the drift by using a PID controller. The software will quit once the ROV presses the button.

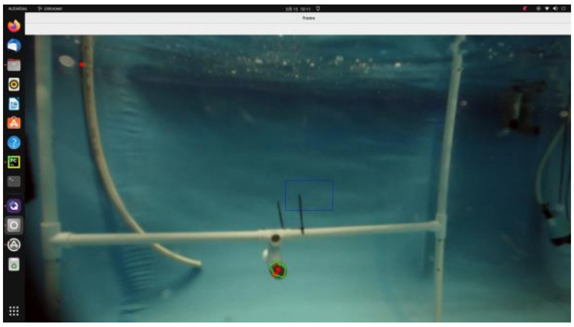


Fig. 17 Algorithm detects the red button

Task 2: Healthy environments from the mountains to the sea

3D modelling algorithm

Nessie's 3D modeling algorithm allows it to quickly and accurately measure the size of the coral head. The program uses OpenCV, an open-source computer vision library, to process the image, first by adjusting the lighting and removing noise from the input and then using the contour function to identify the location of the coral head in the camera feed. It then references an object to calculate the pixel per centimeter, which is then used to calculate the height and radius of the coral head, therefore finishing the 3D model.

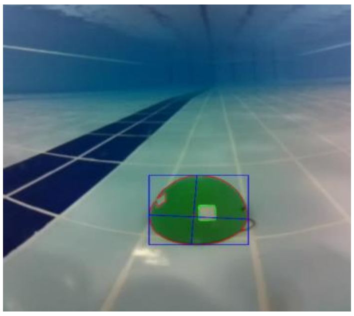


Fig. 19 Coral head

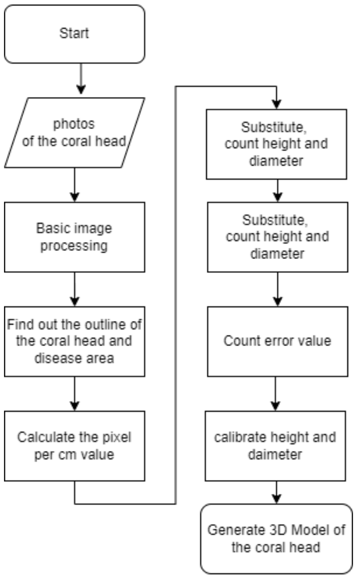


Fig. 18flowchart

Syringe holder

Fig. 20 Syringe holder

The tool consists of a 3D-printed stand with a C-shaped position for the syringe, a wheel that acts as a steering wheel, and a position for the servo immediately next to it. The pilot can achieve the mission objective by mounting the servo in the fuselage and turning it to pump water from the bucket when they reach the desired position.

Grout and Trout Container

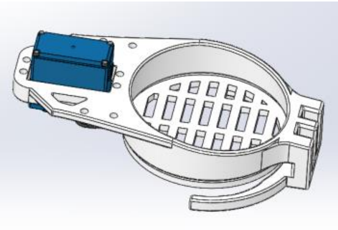


Fig. 21 Grout and Trout Container

Composed of a cup, a 3D printed holder, and an acrylic lid with a servo, the container is the perfect tool to transfer grouts and trouts from onshore to underwater. The container is attached to our ROV through the holder, and the servo enables the pilot to control the water drain lid. When our ROV approaches the destination, the pilot switches on the servo to open the lid and accurately release the grouts and trouts into the target area.

Task 3: Design and construct an operational vertical profiling float

General Construction:

Fig 23 Internal structure of the vertical profiling float

The Achelous Vertical Profiling Float contains an integrated buoyancy engine. The float housing comprises a 4" acrylic tube and two o-ring flanges. One end is connected to a power switch, and the other has six 10-milliliter syringes connected with adhesive. The float contains an ESP32, L298N, a 5V voltage regulator, a piston, and a 12V battery box. The vertical profiling float is 33.9cm in size and 11.5cm in diameter, which is within MATE's specifications. To safeguard the float's internal circuitry, keep the float's total weight from rising, and simplify debugging to a suspended position, we add o-rings to cover off any openings where water may enter the float easily. Since it is not possible to utilize rechargeable lithium batteries, we included a 7.5A fuse to the power supply circuit to guard against over-current and an imbalanced power supply. We used an AA battery pack to power the ESP32 board and linear actuator. This battery pack can hold eight AA batteries at 12 volts.

Fig. 22 Buoyancy engine inside the acrylic tube

Buoyancy Engine Powered Vertical Profiling Float:

We have created a vertical profiling float according to MATE's specifications. After several test and design iterations, we have chosen a simple solution. The Bluetooth connection to the ESP32 controls the pushing of the piston to control the amount of water in the syringe and achieve the purpose of floating or sinking. In addition, the ESP32 can receive local time to complete the task accurately.

Safety

Safety Philosophy

Accidents are often unpredictable and can occur unexpectedly. We implement strict safety protocols and guidelines to ensure each team member is aware of the potential hazards and the importance of safety. Before any testing underwater, we take the necessary precautionary measures by putting on protective gear and then carefully following the safety checklist and Job Safety Analysis (JSA). By accepting these proactive measures, we can significantly reduce the risk of accidents and ensure the safety and well-being of our team members.

Lab protocol

Fig. 24 soldering in the workshop

Since many people go in and out of the studio daily, the staff ensures that the paths are unobstructed, used tools are returned to their proper places, and the various small and large facilities are marked.

Some protective gear, such as goggles and ear protection, is essential for personal safety while soldering and drilling holes. In addition, after making a new solid design tool, we cleaned up the garbage left behind and organized the lab equipment to maintain a good working environment. Before all employees use the machines, we let relatively experienced employees demonstrate the procedures and precautions before they use the machines independently.

Vehicle Safety feature

i. Mechanical

To minimize the risk of harm or injury to the body, our team takes great care in designing our robots. We eliminate sharp objects or corners to ensure that protruding corners are ground off during the final assembly process. Additionally, we've placed shrouds on the thrusters with mesh sizes less than 12.5 mm to prevent collision damage during missions and installed protective guards on the four small cameras. All bolts and connectors are appropriately covered to ensure the electronics remain unaffected underwater. We also ensure that the tether has proper strain relief at the ROV and affix precautionary labels to any potentially dangerous objects. Our team prioritizes both feasibility and safety in the robot's design to create a successful design that meets competition requirements while safeguarding users and the environment.

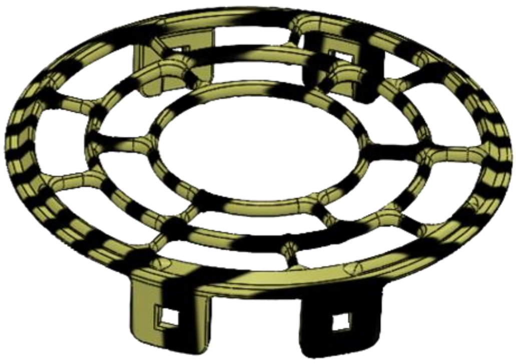


Fig. 25 protective casing for the thrusters

ii. Electronic

To ensure safety in the electronic department, a 25A fuse was added to prevent short circuits from occurring when the current exceeds the circuit's capacity. A short circuit can be hazardous and potentially cause damage or injury. The fuse serves as a protective mechanism to break the circuit if the current exceeds the fuse's rating. This ensures the safety of the electronic devices and the users, and the electrical system's integrity. The addition of the fuse is a reliable measure taken to guarantee the safety and reliability of the electronics department.

Fig. 26 25A fuse

Finance

New Reused Components

Nessie's body was 70% reused, accounting for 82% of the total cost. Hardware-wise, the camera, searchlight, and thrusters are brand-new. The other parts were used components. For the control box, only the container was purchased.

In general, most of the parts were reused. Nearly 2,800 USD have been saved as a result. In addition, Achelous could reuse or reference prototype designs by utilizing used parts, which brought the company efficiency during the design. Approximately 60% of the parts used in the Nessie were reused, accounting for around 82% of the budget. Regarding the above mentioned factors, we innovated some parts' shapes and assembly methods based on the original design.

At the same time, by reducing the amount of waste generated, the company has also achieved the goal of protecting the environment.

In-House Built vs. Commercial Components

Due to the loss of funding from the Educational Bureau of Macau, we have lowered our budget from 4000 USD to 2500 USD and below. Also, we were forced to rely more on in-house-built parts and reused ones. As a result, members of Achelous have learned to create essential components for Nessie. Our company uses 3D printing technology to make protective shrouds, camera hubs, and camera mounts. And we are using a CNC machine to manufacture Nessie's side panels, saving around 200 USD.

Only a few parts were purchased when making the topside control unit, while the rest were designed, soldered, and assembled by our electronics department, saving 250 USD. For the parts that are harder to make, we purchased ready-made products to ensure quality and save time.

Travel and training expenses

Total travel expenses are 49,840 USD, with 37,800 USD being airline tickets, 2400 USD for hotel reservations, 630 USD for car rentals, 2240 USD for visa appointments, and 7730 USD for insurance and catering.

Due to our training venue not being located in our school, we have to spend 112 USD every time to rent out a pool, costing 560 USD altogether. In addition, 50 USD has to be spent on hiring a lifeguard each time a pool is rented, costing 250 USD.

Budget

Budget			Reporting Period	
School Name:	Macau Pui Ching Middle School		From: 09/2022	
Instructor:	Thomas Lao, Marco Lou		To: 06/2023	
Income			Amount(USD)	
Macau Pui Ching Middle School Grant			$2500.00	
Parents			$49840.00	
Expenses				
Category	Type	Description	Projected Cost (USD)	Budget Value (USD)
Electronics	Reused	Blue Robotics T200 Thrusters, Control box, Cameras, Monitor	$ 1700.00	$ 42.00
Travel fee	Purchased	Transportation, Hotel Booking fee, Fly tickets	$ 49840.00	$ 49840.00
Training fee	Purchased	Venue, Lifeguard fee	$ 810.00	$ 810.00
Total Income:			$52340.00	
Total Expenses:			$52350.00	
Total Expenses-Reuse/Donations:			$50692.00	
Total Fundraising Needed			$1648.00	

Fig. 27 Budget

Project costing

Category	Type	Description	Amount(USD)
Electronics components	Purchased	Pixhawk Flight Controller	$ 189.99
	Purchased	Servo	$ 108.89
	Purchased	LED light	$ 300.00
	Purchased	Passive hd transceiver(4 pcs)	$ 10.88
	Purchased	Hatch fixing ring	$ 121.74
	Reused	Camera	$ 64.00
	Reused	Fisheye Camera	$ 19.20
	Reused	Raspberry Pi 3B	$ 50.12
	Reused	BlueOS Raspbian microSD Card	$ 18.00
	Reused	Thrusters(6 pcs)	$ 1,416.00
	Reused	Fathom ROV Tether(18 m)	$ 63.00
	Reused	BlueROV2 Fairing	$ 16.32
	Reused	Newton Subsea Gripper	$ 590.00
	Reused	Electronics Tray	$ 100.00
Total Raised(Electronic components)			$ 3,868.14
Topside Control Unit components	Purchased	14 inch Monitor	$ 41.24
	Reused	Control box case	$ 24.00
	Reused	Camera box	$ 52.90
	Reused	NUC	$ 98.99
	Reused	Monitors(DELL)	$ 84.99
	Reused	Console	$ 28.79
Total Raised(control box components)			$ 41.24
Mechanical components	Reused	Cast Acrylic Tube	$ 216.00
	Reused	End-cap with Holes	$ 32.00
	Reused	O-ring Flange(2 pcs)	$ 86.00
	Reused	Acrylic End-cap	$ 40.00
Total Raised(Mechanical components)			$ 500.00
Total Raised(Without control units)			$ 3568.14
Total Budget(Purchased)			$ 772.74

Fig. 28 Project costing

Critical Analysis

Testing and Troubleshooting

During our first test at the swimming pool, our team faced several issues due to our lack of experience. These issues included insufficient equipment, our team members needing to understand the equipment's placement fully, and the testing venue's delicate nature. After returning to school, we discussed and concluded that a comprehensive checklist must be prepared well before the next test.

To avoid similar issues in the future, the team member responsible for the venue will communicate with the divers to ensure that each venue is in the appropriate location. This will prevent the operators from becoming too familiar with the venue and overlooking potential issues. Additionally, we will reinforce the venue during construction to prevent it from becoming unstable or falling apart during testing.

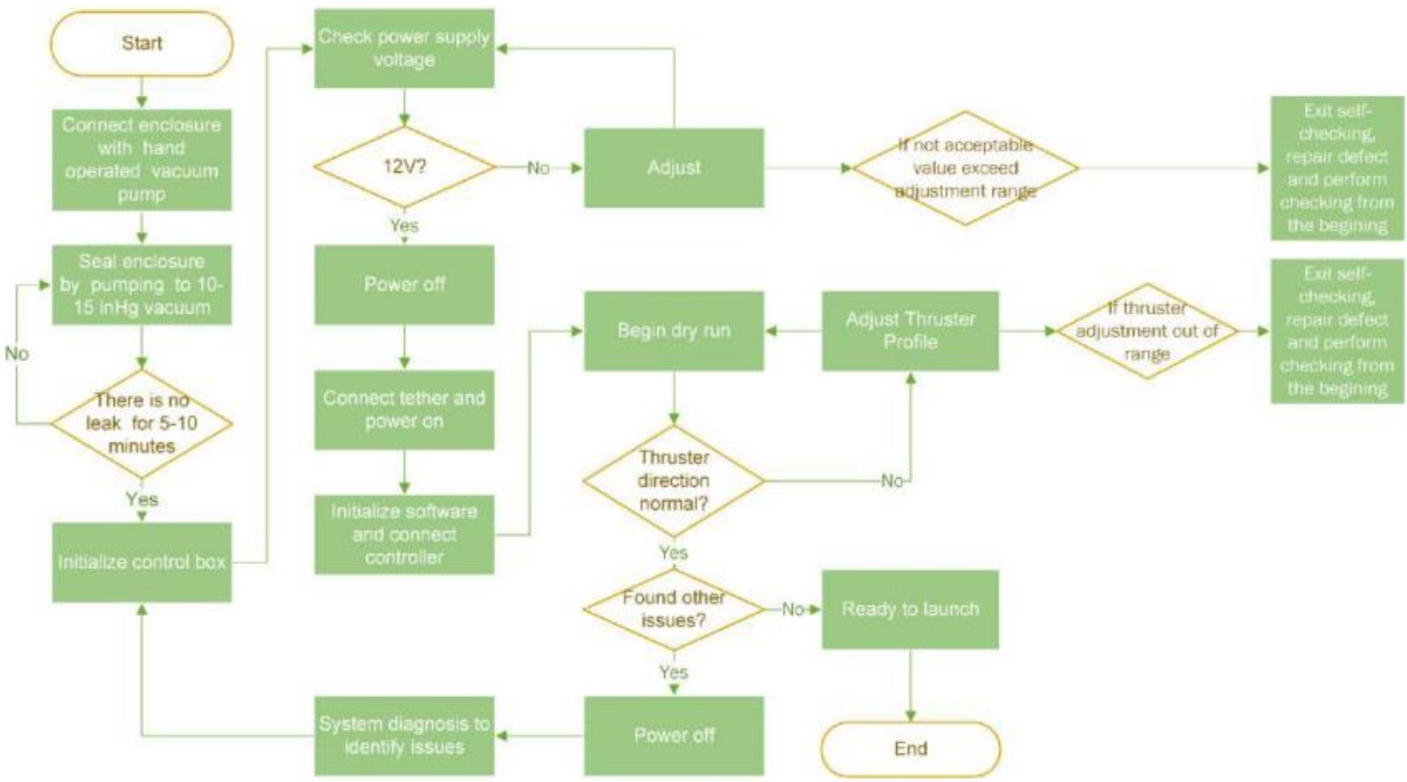


Fig. 29 troubleshotting flowchart

By taking these proactive measures and implementing a comprehensive checklist, we are confident that we can avoid issues during future tests and ensure the success of our project. Our team is committed to learning from our experiences and continuously improving our approach to testing to deliver the best outcomes possible.

Challenges

The team encountered several difficulties in the process of the making. Examples are shown below:

Mechanical

- Dysfunctional payloads: The time spent on the redesign is excessive since the ideal solution does not match the actual one.
- Failing 3D Prints: Miscalculated precision and tolerance contribute to size problems.

Electronical

- Old fisheye cameras often failed to run whenever soldering was done to them due to the age of the cameras and the long time spent stored away. This issue could not be solved, and new cameras were bought instead.
- The lenses of the cameras went foggy, often underwater. To combat this, an anti-fog wipe was applied to the cameras every time the ROV went under.

Software

- Water currents can drift the ROV, making it unstable during one-dimensional movement (e.g., diving automatically). This has been solved by activating a PID function whenever the ROV moves out of a predetermined position.
- Nested loops are often bugging, such as being stuck in perpetual loops. The solution is to use IF functions whenever necessary, as the main program already has a loop that runs along the entire process.

Non-technical

- Due to the epidemic, our school has not been sponsored by the Macau Education Bureau (DSEDJ) in the past two years, so we have had to lower our budget from 4000 USD to 2500 USD and below, slowing down our progress.
- Due to school and academic reasons, the time we can spend working on our robot is usually limited. As a result, team members often come to meetings late.

Lesson Learned

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.

Future Improvements

Following our participation in the Hong Kong competition, we have identified several areas for improvement in future endeavors. Firstly, there is room for enhancing team cooperation, which is essential for effectively achieving our goals. We also aim to encourage greater responsibility and accountability among team members, recognizing the importance of each individual's contribution to the team's success. In addition, the capabilities of Nessie, our ROV, can be further enhanced by attaching more sensors and tools. This will enable the ROV to undertake more complex missions and achieve even greater success in future competitions.

To sum up, we are committed to continuous improvement and learning from our experiences. By addressing these areas for improvement, we will be better equipped to achieve our goals and succeed in future competitions.

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

Appendices

1. 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

Soldering

- Safety goggles and mask must be worn
- Ventilation must be turned on
- The working area must be clear after processing

Pre-mission

- All connections are secured and correctly connected
- Shrouds are added to thrusters
- The tether is straightened
- No electronic components are exposed
- Cameras and lights are not blocked
- Watertight enclosure is secure

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

2. Non-ROV device SID

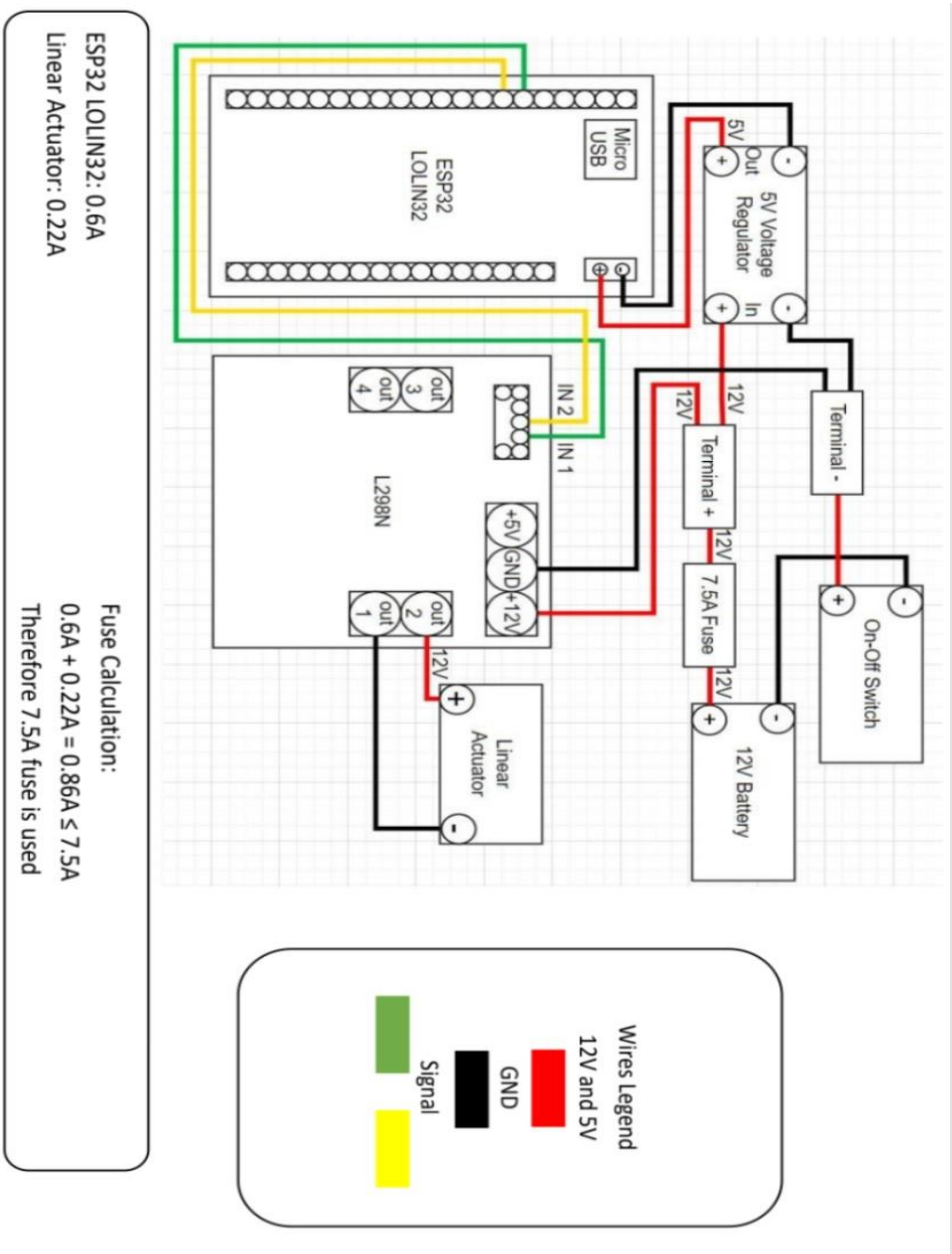

Fig. 30 Non-ROV device Vertical profiling float SID