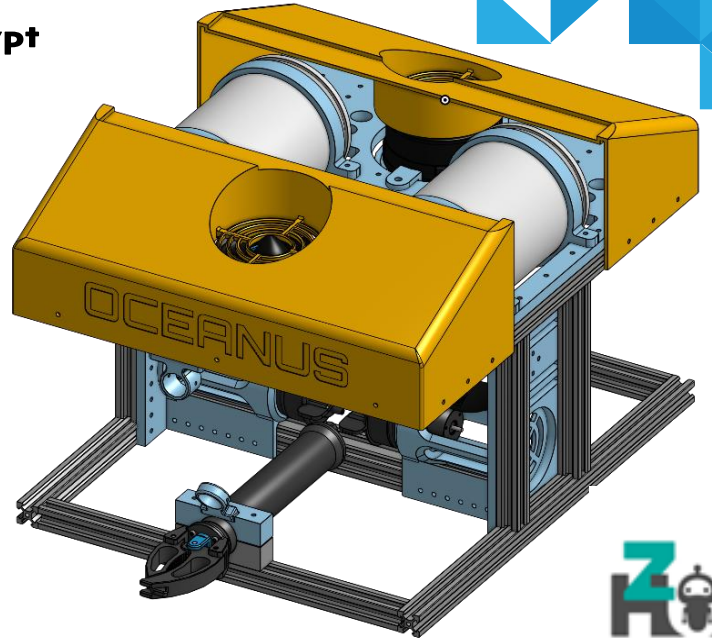




OCEANUS.CO

Team Technical Documentation Report (TDP)

Z-Hub Robotics Centre, Alexandria, Egypt



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1.Abstract:

Oceanus.co is an Egypt-based underwater robotics team that began competing in the MATE ROV Competition in 2013. The team developed a remotely operated vehicle (ROV) called ‘Nemo’ to complete mission tasks including coral sample recovery, subsea infrastructure interaction, environmental monitoring, and iceberg surveying.

The vehicle was designed using a systems-driven approach prioritizing efficiency, reliability, and mission-specific performance under the 25 A current constraint. Its propulsion system combines two high-thrust Blue Robotics T100 thrusters for primary motion, two vertical T100 thrusters for depth and pitch control, and two low-power bilge pump thrusters for lateral maneuvering. This hybrid configuration enables precise control while minimizing total current draw. More complex vectored propulsion systems were evaluated but not implemented, as they introduced additional electrical and mechanical complexity without significant performance benefit for the competition objectives.

The ROV integrates a Blue Robotics Newton gripper, a bilge pump rotating actuator for use in the observatory camera cleaning task, a modular foam buoyancy system, and custom waterproof tool-less penetrator connectors. A custom topside control station and Python-



based control interface using a CustomTkinter based GUI provide real-time operator control, data analysis, and system feedback.

2.Design rationale

The design of Nemo was guided by a systems-focused engineering approach that prioritized efficiency, reliability, and mission-specific performance within the constraints of the 2026 MATE ROV Competition. A primary constraint was the 25A current limit, which directly influenced decisions related to propulsion, power distribution, and system architecture. Rather than maximizing component and feature count, the design focused on maximizing performance per unit power, ensuring each subsystem contributed effectively without introducing unnecessary electrical or mechanical complexity.

To evaluate design options, a structured decision-making process was used. Multiple propulsion configurations were brainstormed and assessed comparing thrust output, current consumption, cost, and control complexity. Motor selection decisions were supported by experimental data, as shown in [Figure 31 \(Motor comparison table\)](#), which compares thrust output and current consumption across tested configurations.

A key design decision was the implementation of a hybrid propulsion system combining high-thrust and low-power actuation. Fully vectored thruster layouts and higher-thruster-count systems were considered, as they offered increased maneuverability. However, these options were abandoned due to their higher current consumption, increased cost, and added control complexity, which conflicted with both the electrical constraints and the goal of maintaining a compact, lightweight, and reliable vehicle. For detailed motor testing results, see Motor Comparison Table ([Fig.31, Appendix 13.5](#)). This table was used to compare the peak thrust outputs per current drawn in amps, to select an appropriate thruster combination that would provide the highest maneuverability with the least power draw. We gathered this data by placing each motor in a fish tank and attaching it to

a travel bag scale via a pivot, and recorded the data in the table for each thruster while also noting the electrical factors.

The final design utilized two Blue Robotics T100 thrusters for primary forward propulsion and two vertical thrusters for depth and pitch control. To enable lateral movement without exceeding current limits, low-cost bilge pump thrusters were integrated. This decision significantly reduced system cost and weight compared to using additional high-performance thrusters, while still providing sufficient maneuverability for mission tasks.

The resulting ROV has a size of 35x38x33.3cm (LxWxH) and a dry mass of approximately 14Kg.

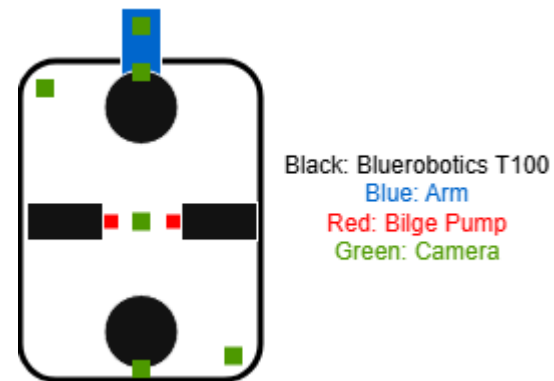


Figure 1 ROV Layout

This approach represents a deliberate trade-off between maximum maneuverability and overall system efficiency. While vectored systems offer greater control authority, the selected hybrid configuration achieves reliable and predictable motion within the available power budget, while also minimizing cost and maintaining a manageable vehicle size and weight.

The physical layout of Nemo was also influenced by these constraints. A compact dual-tube design was selected to balance buoyancy, weight distribution, and ease of maintenance. Separating components across two enclosures reduced wiring complexity, improved accessibility, and allowed better organization of electrical subsystems, contributing to overall system reliability.

The design process was iterative and informed by testing and analysis. Early prototypes exhibited voltage drop across the tether, resulting in reduced performance and occasional

system instability. This issue was investigated through testing and measurement, and was addressed by redesigning the tether cabling and improving power distribution. These changes reduced losses and improved voltage stability under load. The team invested approximately 500 hours of development time across design, fabrication, and testing phases.

Throughout development, design decisions were evaluated based on their impact on the overall system, ensuring strong integration between electrical, mechanical, and control subsystems. This systems-level approach resulted in a balanced and efficient vehicle capable of meeting mission requirements within the defined constraints.

3. Build vs. Buy, New vs. Used

A combination of in-house manufacturing and commercial components was used to balance performance, cost, and development time. Critical structural and system-integration components, including the frame, tether, pressure tubes, and custom PCBs, were designed and manufactured in-house. This allowed the team to optimize layout, reduce wiring complexity, and tailor the system specifically to mission requirements while maintaining full control over reliability and maintainability.

Commercial components were selected where performance and reliability were critical and difficult to replicate efficiently in-house. Blue Robotics T100 thrusters and R3 ESCs were used due to their proven performance, reliability under load, and compatibility with underwater applications. Cameras were also commercially sourced to ensure consistent video quality and reduce development time.

To improve cost efficiency, several components were reused from previous iterations of the vehicle, including the T100 thrusters and ESCs. These components were carefully evaluated and tested to ensure they met this year's performance and reliability requirements. Each thruster had a thrust and electrical draw test run on it to verify all the

components still met standards after sitting for many years. Reusing these high-cost components allowed resources to be allocated toward new system improvements without compromising functionality.

Manipulator systems followed a hybrid approach. A Blue Robotics Newton gripper was used for primary manipulation tasks due to its reliability and precision, while an additional rear rotating gripper was designed and built in house to expand functionality and allow interaction from multiple orientations. This combination provided flexibility while maintaining cost efficiency.

Overall, build vs. buy decisions were driven by a balance between customization, reliability, and cost-effectiveness, ensuring the vehicle met mission requirements without unnecessary complexity or expense.

4. Buoyancy and Ballast

The buoyancy system was designed to achieve slight positive buoyancy, ensuring that the vehicle would naturally ascend in the event of power loss, improving operational safety. This was accomplished through the use of sealed pressure tubes and foam-based buoyancy elements.

Air-filled chambers within the pressure tubes and external chambers provided baseline buoyancy, while foam was used to fine-tune the vehicle's buoyancy and achieve stable equilibrium in water. The distribution of buoyant materials was carefully adjusted to maintain a level orientation and prevent unwanted pitch or roll during operation.

To make the ROV stable underwater, the CB (center of buoyancy) has to be above the CG (center of gravity). We achieved this in Nemo by making the most buoyant components (eg. Foam) at the highest point, and the heavier ones (eg. T100 thrusters) as low as possible. This helped achieve a stable vehicle underwater that would drive predictably

The final system demonstrates application of buoyancy principles by balancing the weight of the vehicle against the displaced water volume, resulting in a slightly positively buoyant system that remains stable and controllable underwater.

5. Payload, Tools, and Sensors

Nemo is equipped with a combination of cameras, manipulators, and sensors designed to meet mission requirements while maximizing operator awareness and control.

A total of six cameras were integrated into the system, including two fisheye cameras equipped with IR blasters and four automotive backup cameras. This combination was selected to balance cost and performance, with fisheye cameras providing wide-angle situational awareness and backup cameras offering additional viewpoints at lower cost. Camera placement was carefully planned to provide full operational visibility. Forward-facing cameras assist with navigation and task alignment, while additional cameras are positioned to monitor manipulators and critical interaction zones. This multi-camera system allows the operator to maintain awareness of both the environment and tool operation simultaneously.

The vehicle includes multiple manipulation systems to increase task flexibility. A front-mounted gripper is used for primary object interaction, while a rear rotating gripper enables manipulation of the observatory camera.

Sensor integration includes an inertial measurement unit (IMU) for orientation feedback, current sensing for system monitoring, and a water pressure sensor for an altitude hold function. These sensors support stable control and provide feedback on system performance during operation.

Overall, payload and sensor selection was driven by mission tasks and required features for the pilot to be able to complete the missions efficiently and in a timely manner.

6.Safety

6.1. Electrical Safety

- Wire size calculated based on system current (see Figure 21 Tether Power Calculation)
- 25A fuse selected using full-load current (FLA)
- Power kill switch in main station
- No splices or terminations in submerged sections
- Separated power rails:
 - 5V rail → sensors only
 - 9V rail → microcontroller only
 - 12v rail → motors

6.2. Waterproofing and Sealing

- Custom-built chambers with dual O-ring end caps
- Cable penetrators with triple O-rings + epoxy potting
- No exposed electrical joints underwater
- Pre-deployment leak testing performed

6.3. Mechanical Safety

- Thrusters equipped with shrouds (<10 mm openings)
- All sharp edges filed and rounded
- All fasteners use nylock nuts or anti-loosening methods

6.4. Tether and Connection Safety

- Dedicated tether strain relief point on ROV
- Load distributed across wire bundle evenly at the ROV side
- Station-side connectors use threaded lockrings to prevent accidental disconnection

6.5. Software and Operational Safety

- All motors initialized to neutral before arming
- Motor self-test function before deployment
- Code automatically exits if no activity has been detected within a recent window of time

7.Float

Our float is designed as a space-efficient and innovative dual-chamber system. The lower chamber houses four piston syringes, while the upper chamber contains a linear actuator, forming a buoyancy engine. The upper chamber also houses a partial PCB stack of our ROV, with the main Arduino Nano control board and relay driver board installed, while the ESC board is omitted to save space. A DFRobot Gravity water pressure sensor is used to measure depth, and an HC-05 Bluetooth module enables communication with the ground station. The float is powered by ten 1.2 V, 3 Ah NiMH cells connected in series to form a 12 V battery pack. A 5 A fuse is installed to comply with MATE ROV regulations. The cells are spot-welded to ensure a secure and high-current-capable connection. During operation, the buoyancy engine draws water in until the desired altitude is within ± 20 cm, after which the system pauses to allow readings to stabilize. Once stabilized, water is expelled and the float surfaces. Upon reconnection to the computer via Bluetooth, the float begins transmitting data. The Python software on the laptop uses Matplotlib to generate a depth profile graph for evaluation, while a CustomTkinter-based GUI displays both the graph and the transmitted data packets for verification.

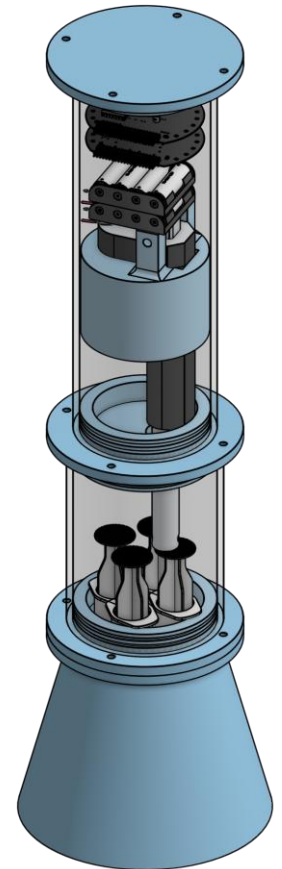


Figure 2 Vertical Profiling Float

8.Vehicle Systems

Description

The ROV was designed using a joint engineering approach that integrates mechanical, electrical, and control subsystems into a cohesive and reliable vehicle. Each subsystem

was developed with consideration of its interaction with the others, ensuring efficient operation and simplified maintenance.

8.1. Mechanical

The mechanical system consists of a custom-built 2020 extrusion frame and dual pressure tube enclosures, designed to provide flexibility while maintaining a compact and balanced form factor. The dual-tube design allows separation of components, improving weight distribution and reducing internal wiring congestion. This configuration also simplifies access for maintenance and minimizes interference between subsystems. Buoyancy is achieved through a combination of sealed air-filled tubes and strategically placed foam and air ballast containers, resulting in slight positive buoyancy and stable underwater behavior. All the pressure vessels in Nemo have been tested up to 8m depth.

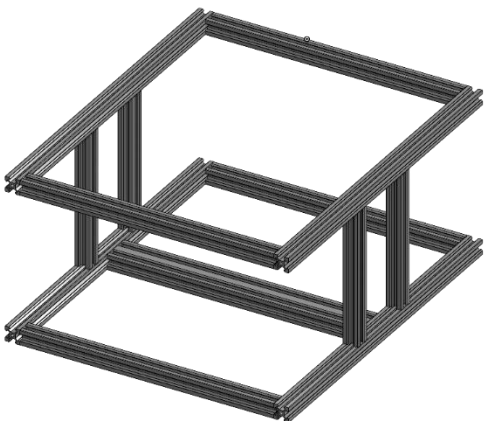


Figure 4 ROV Frame (Aluminum Extrusions)

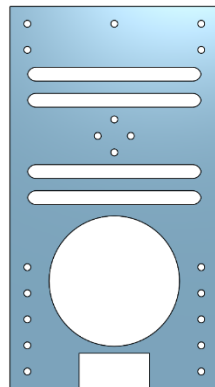


Figure 5 Side Sheet (Artillon)

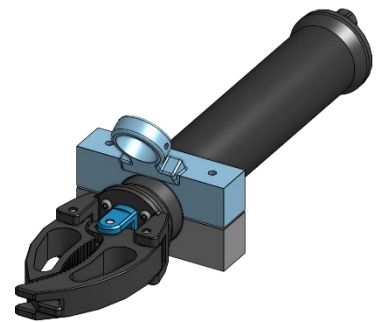


Figure 6 Gripper & 3d-printed Bracket

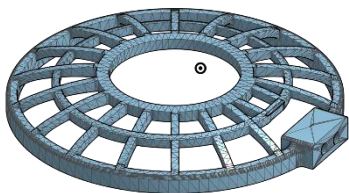


Figure 7 T100 3d printed Shroud (Part 1 of 2)

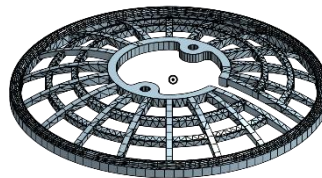
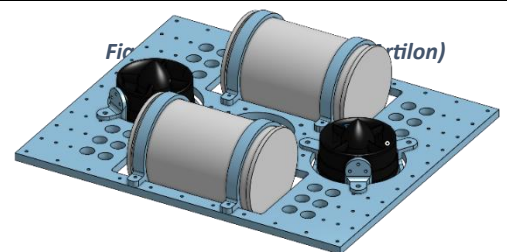


Figure 8 T100 3d printed Shroud (Part 2 of 2)



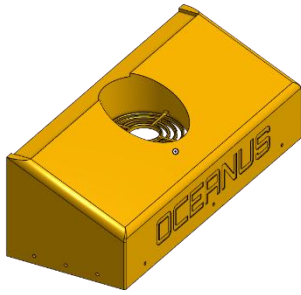


Figure 9 ROV Float (3d printed)



Figure 10 Fisheye Camera Bracket (3d printed)

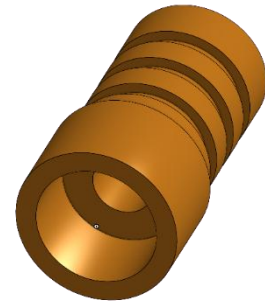


Figure 11 Custom penetrators (milled from copper)

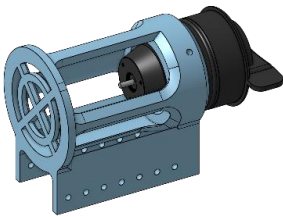


Figure 12 Bilge Pump and 3d printed bracket

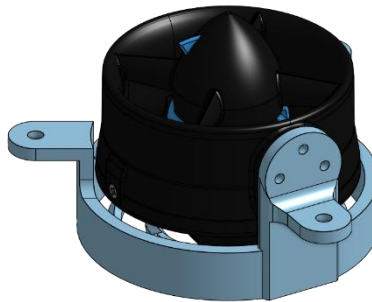


Figure 13 Vertical T100 and 3d printed bracket

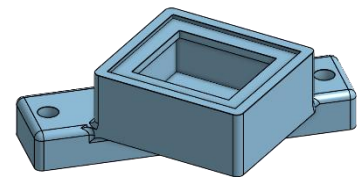


Figure 14 Car camera bracket (3d printed)

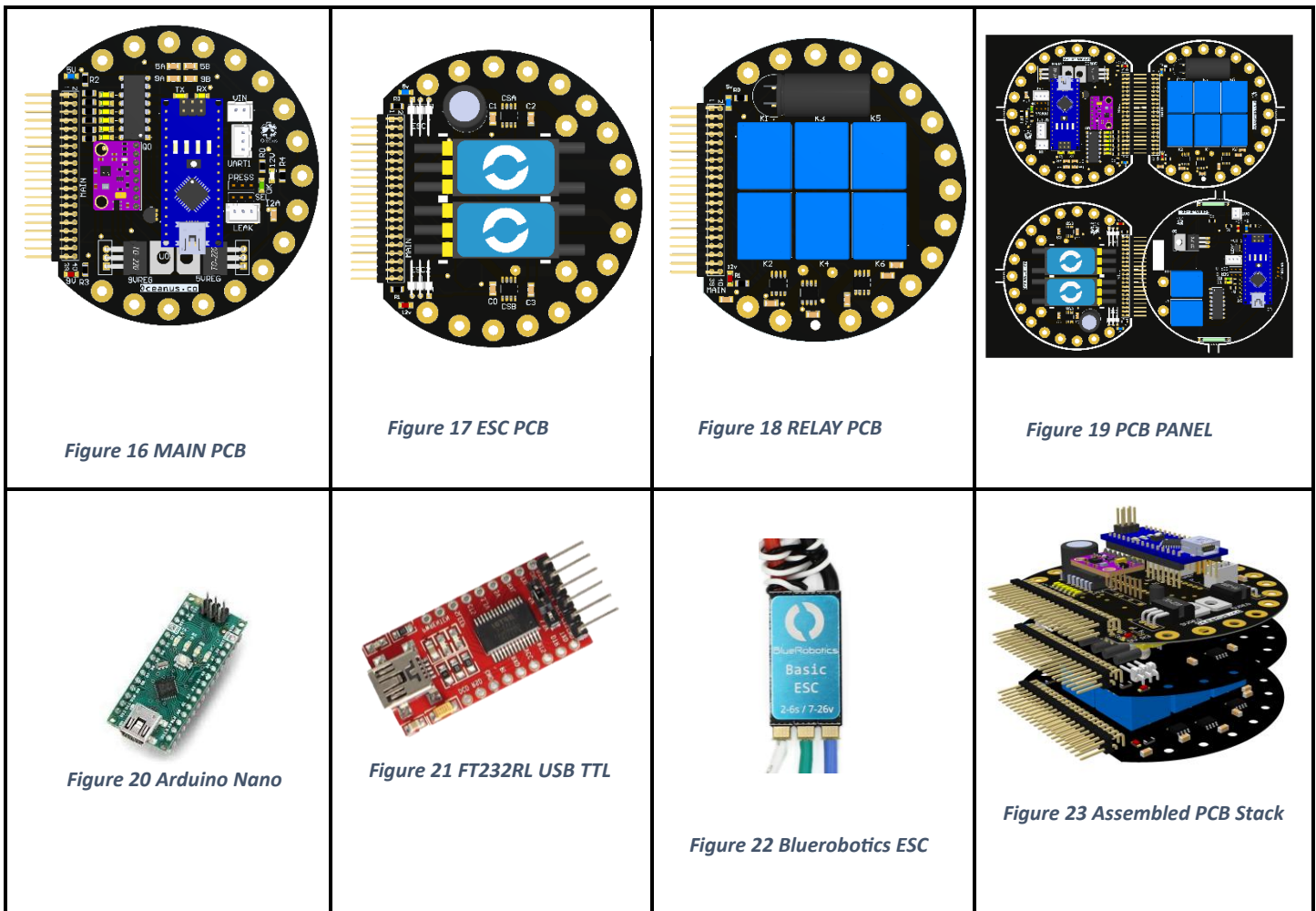
The material selection for each part was purely based on functionality and ease of fabrication. 3d printing was used for small parts that are hard to manufacture out of metal or parts that didn't need to be waterproof as they would already be submerged. It also helped reduce the overall weight of the vehicle. Milling was used to fabricate watertight parts that are mission-critical (eg. Penetrators), but not used for other task due to its high cost. Off-the-shelf parts were used for big structures (eg. Main frame made of extrusions) to simplify build times and expenses. 3d printing was also used for high stress parts like the thrusted brackets by increasing the infill (percentage of internal structure of the part that is plastic) from 30% to 50%.

8.2. Electrical

The electrical system is designed to provide reliable power distribution and minimize EMI noise and power losses. Power is delivered from the surface through the tether (8 conductors of 6mm²) and distributed across the vehicle using regulated voltage rails. Custom PCBs were fabricated to organize connections, reduce wiring, and improve system reliability. High-current components such as thrusters are isolated from sensitive control electronics to reduce electrical noise and prevent instability. Careful component placement and wiring strategies were used to shorten high-current paths and improve efficiency. Each electronics chamber has a stack of 3 circuit boards, which each handle different aspects of the ROV. The 1st PCB is the main control board, it houses an Arduino Nano (the main MCU of the ROV), 5v and 9v regulators for sensors, the IMU, the water pressure sensor, and a ULN2003 Darlington transistor array IC with built in flyback or freewheeling diodes to power the relays. A combination of 100uF and 100nF capacitors were used to dampen any low or high frequency noise that could affect the ROV. The 2nd PCB houses 2 Bluerobotics Basic R3 ESCs (Electronic Speed Controllers) for the 2 T100 thrusters connected per tube, as well as current sensing for both ESCs via ACS712 hall-effect current sensors. The SMD (surface mount device) package was used for many components to increase layout density. The 3rd and last PCB has 6 5v 16A relays, forming 3 H-bridges to power 3 DC motors. It also houses current sensing for all 3 channels and a 2200uF Bulk capacitor to handle any current surges that could cause brown-outs. Panelization was used to combine all PCBs into 1 board to reduce manufacturing costs of 4 individual boards as well as shipping costs. As shown in [Figure 27 \(SID\)](#), the system architecture clearly separates high-current motor lines from low-voltage control and sensor signal lines, reducing noise and improving overall system stability and safety.



Figure 15 GY-91 IMU



The control system is based on dual microcontrollers, which divide commands across different processors to improve reliability and responsiveness. Communication between the surface and vehicle is achieved through UART over the tether, allowing real-time control and feedback. Motor control is implemented using ESCs for thrusters and relay-based switching for additional motors, with a water pressure sensor for providing useful functions such as an altitude hold mode, prioritizing simplicity and robustness over unnecessary complexity.



Figure 24 Water Pressure Sensor

The tether thickness was calculated using ohm's law ($V = I \times R$). The original calculations were too conservative, with the ROV drawing around 14 amps at full load. Which resulted in too high of a voltage drop when under full load, so it was recalculated and the tether was doubled with 4 additional conductors, bringing the total to 8 conductors of 6mm² thickness. Integration between subsystems was a key design

focus. This results in a voltage drop of approximately 0.39 V over the full tether length, corresponding to a 3.3% drop from the 12 V supply. This voltage drop is within acceptable limits and does not significantly impact system performance or thruster operation. Mechanical layout decisions were influenced by electrical requirements, such as minimizing cable lengths and organizing power distribution. Similarly, control system architecture was designed to align with the propulsion layout, simplifying signal routing and improving vehicle agility. This tether was managed using a rolling spool that would be placed at the side of the pool and contain the excess tether until it is needed.

8.3. Software

The control system was designed to provide reliable real-time operation while maintaining simplicity and modularity. The system consists of a surface control station and an onboard control architecture using two Arduino-based microcontrollers operating in parallel.

The surface control station utilizes a laptop connected to a REV Robotics controller for operator input. Control commands are transmitted to the vehicle via UA RT over the tether. A custom communication protocol was implemented using structured packets with defined start and end characters, ensuring reliable data transmission and reducing the risk of corrupted commands.

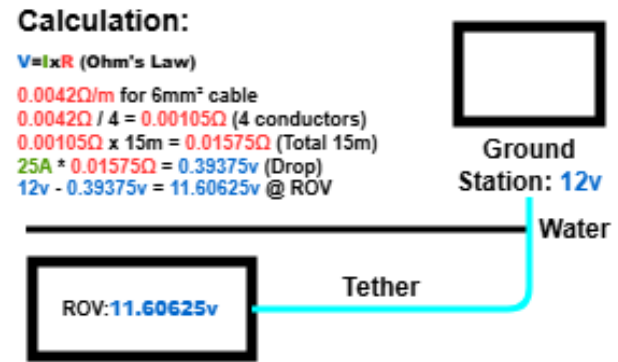


Figure 25 Tether Power Calculation



Figure 26 REV Robotics Controller

Onboard the vehicle, two identical Arduino microcontrollers are used to distribute control tasks. Each controller operates a subset of the ROV, including two T100 thrusters, two bilge pump motors, and an LED strip. One of the controllers additionally manages sensor inputs, including the inertial measurement unit (IMU), temperature sensor, water pressure sensor, and current sensing for the arm. The controllers are configured using a hardware ID jumper, allowing each PCB stack to process only its assigned segment of incoming data packets.

This distributed control architecture was selected as an alternative to using a single controller with I/O expansion. While a single-controller design could reduce component count, it would introduce additional complexity in wiring and software management. The dual-controller approach simplifies layout, aligns with the physical dual-chamber design of the vehicle, and improves modularity and fault isolation.

The software implements motor mixing algorithms to enable smooth and controlled movement, including forward motion, vertical control, and pitch adjustment. An altitude hold feature was implemented using pressure sensor feedback, where vertical thruster output is adjusted through a linear control mapping to maintain a consistent depth.

A custom graphical user interface (GUI) was developed using Python and CustomTkinter. The GUI allows the co-pilot to view multiple camera feeds, switch between cameras, capture images, and record video. It also displays real-time sensor data, including current, orientation, and depth, providing enhanced situational awareness. The pilot receives a direct video feed through a dedicated monitor, while the co-pilot interacts with the GUI for monitoring and control support.

The software was developed using an iterative approach and managed using GitHub for version control. Individual subsystems were tested independently on external

Arduino setups before integration. The system was then tested on the assembled electronics stacks outside the vehicle, followed by dry testing within the ROV structure, and finally validated through full wet testing. This staged testing approach ensured issues were identified and resolved progressively before they became severe. Safety features incorporated include all motors being initialized to a neutral state at startup, preventing unintended movement. A built-in self-test routine verifies motor functionality prior to launch. These measures improve operational safety and system reliability.

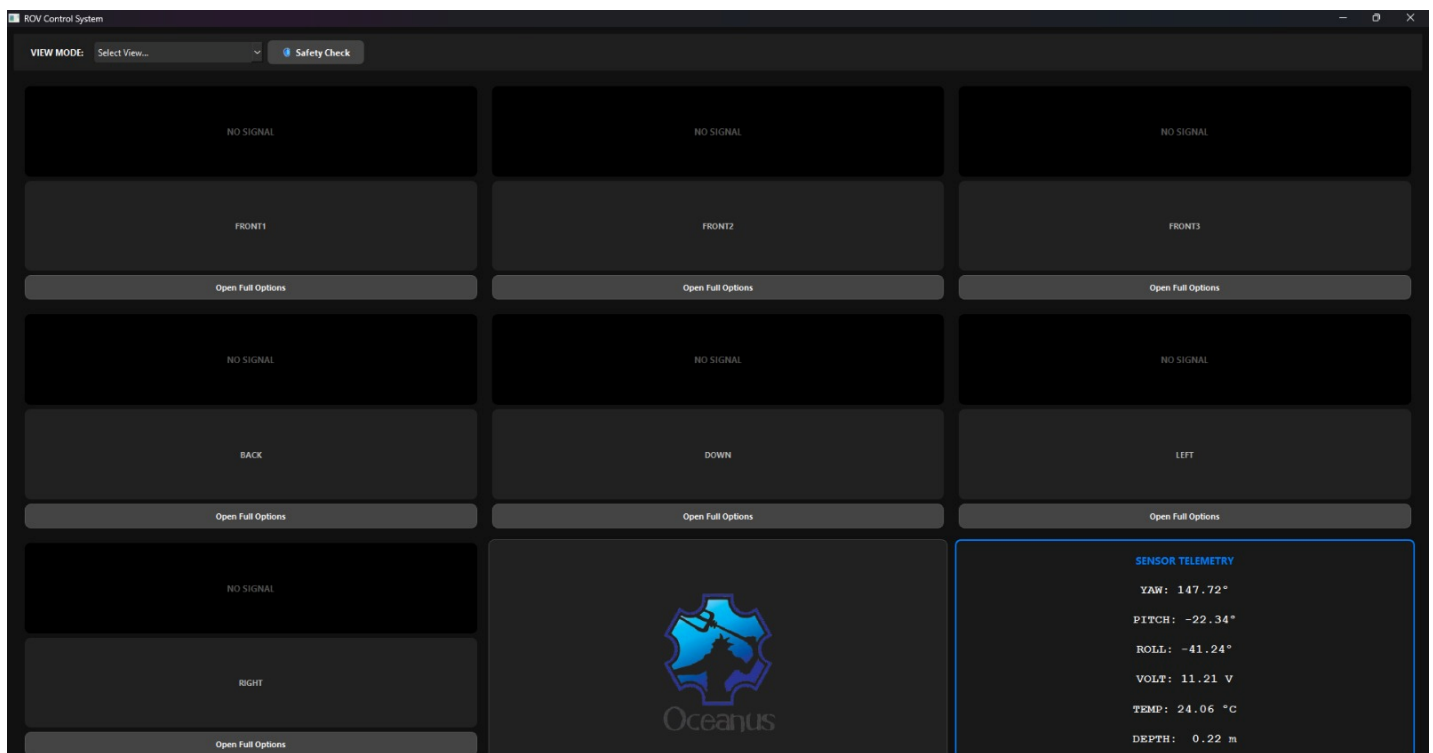


Figure 27 ROV GUI (Graphical User Interface)

8.4. Vision System

Our ROV is equipped with a unique and innovative combination of cameras, brackets, and video equipment that provide a clear, uninterrupted view to the pilot and allows easy processing by the co-pilot. The ROV is equipped with a total of 7 cameras, 3 are fisheye cameras and the other 4 are automotive backup cameras. All 7 cameras hook up into a Hikvision Turbo 8 channel DVR (digital video recorder). This allows the pilot to view and arrange the cameras, while the co-pilot can access the feed over ethernet and remotely snap pictures or take a video recording without disturbing the pilot.



Figure 28 Hikvision DVR

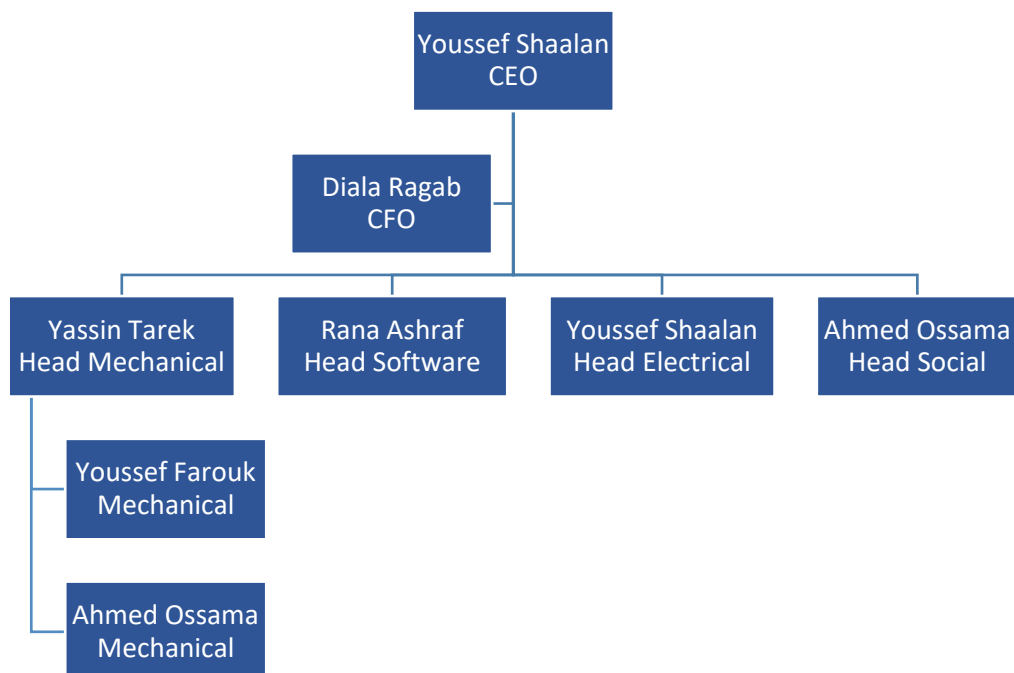


Figure 29 Car Camera



Figure 30 Fisheye Camera

9. Project Management



9.1. Team Structure

The team was organized into clearly defined roles, which were outlined on the cover page. Each member was responsible for a specific subsystem, including mechanical design, electrical systems, and software development. This distribution of responsibilities ensured efficient workflow and accountability, while maintaining coordination between subsystems during integration.

A hierarchical system diagram was developed to define subsystem relationships and responsibilities, allowing for clear communication and structured development across the team.

9.2. Planning and Scheduling

A Gantt chart ([Appendix 13.4, Fig.30](#)) was used to plan the project timeline, establish deadlines, and track progress throughout development. Key milestones included design finalization, subsystem implementation, integration, and testing phases.

The schedule was treated as a dynamic tool and was adjusted when necessary based on testing results and development progress, ensuring realistic and achievable deadlines.

9.3. Design and Development Process

The development process followed a structured engineering approach, beginning with system-level design and progressing into parallel subsystem development. Mechanical, electrical, and software components were developed concurrently, allowing for efficient use of time and resources. System integration was performed progressively, combining subsystems and verifying compatibility at each stage to reduce the likelihood of compounded issues later in development.

9.4. Iteration and Testing

Iteration was primarily focused on the software system, where continuous refinement was performed based on testing outcomes. Control algorithms, communication reliability, and system responsiveness were improved through repeated testing cycles.

A staged testing approach was followed:

- Individual subsystem testing
- Integrated system testing outside the ROV
- Dry testing of the full system
- Wet testing under real operating conditions

This structured testing pipeline allowed issues to be identified and resolved incrementally, improving overall system reliability.

10. Acknowledgements:

We would like to extend our heartfelt gratitude to Z-Hub for providing us with the resources and support necessary for this project. In addition, we express our sincere appreciation to our mentor, Eng. Shehab Ramy, for his helpful guidance and encouragement throughout this journey. His dedication was essential in the success of our project. We would like to thank Z-Hub for providing us with 4 Bluerobotics T100 thrusters with ESCs free of charge as a sponsorship. And we would like to thank our 3d printing supplier, Fabritech, for saving us lots of expenses in exchange of referrals to other students.

11. References:

1. [CustomTkinter documentation](#)
2. [Pygame documentation](#)
3. [ULN2003 datasheet](#)
4. [ACS712 datasheet](#)
5. [SnapEDA – Online Symbol and Footprint library](#)
6. [GrabCAD – Online 3d model library](#)
7. Onshape Tutorial by Aviv Makes Robots: [Part 1](#) & [Part 2](#)

12. Appendices:

12.1. ROV & Float SID

OCEANUS.CO ROV SID

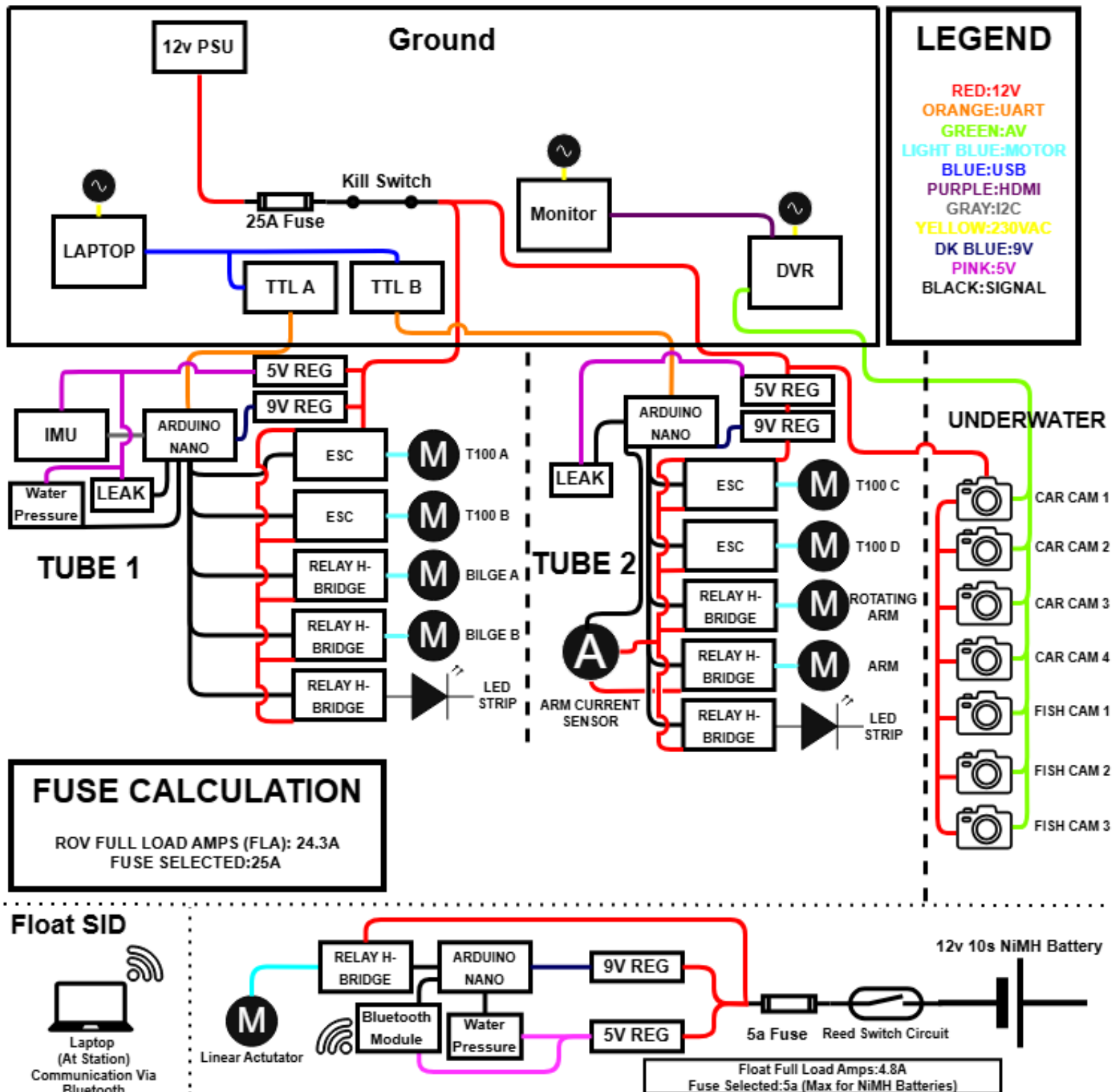


Figure 31 ROV & Float SID

12.2. Budgeting Sheet

Quantity	Components	Price in EGP per unit	Price in USD per unit	Total price in EGP	Total price in USD	New or Used	Description	Total budget	Remaining budget
Electrical									
1	DVR	£1,475.00	\$28.37	£1,475.00	\$28.37	NEW		£100,000.00	£30,372.65
8	BNC to analog connectors	£3.50	\$0.07	£28.00	\$0.54	NEW		\$2,000.00	\$656.83
4	Power Connectors	£250.00	\$4.81	£1,000.00	\$19.23	NEW			
4	DVR Connectors	£3.75	\$0.07	£15.00	\$0.29	NEW			
3	Fish Cameras	£5,000.00	\$96.15	£15,000.00	\$288.46	NEW			
4	Arduino Nano	£400.00	\$7.69	£1,600.00	\$30.77	NEW			
1	PCB	£3,400.00	\$65.38	£3,400.00	\$65.38	NEW			
1	PCB Import fees	£5,700.00	\$109.62	£5,700.00	\$113.80	NEW			
6	Relays	£11.00	\$0.21	£66.00	\$1.27	NEW			
4	ESC (Bluerobotics Basic R3)	£750.00	\$14.42	£3,000.00	\$57.69	USED	Sponsorship From Z-Hub		
1	Gripper (Bluerobotics Newton)	£16,000.00	\$307.69	£16,000.00	\$307.69	USED			
1	Tether Power line	£5,000.00	\$96.15	£5,000.00	\$96.15	NEW			
1	Tether Data line	£3,300.00	\$63.46	£3,300.00	\$63.46	NEW			
1	Tether Camera line	£4,000.00	\$76.92	£4,000.00	\$76.92	NEW			
1	Soldering Iron	£500.00	\$9.62	£500.00	\$9.62	NEW			
1	Cables	£2,800.00	\$53.85	£2,800.00	\$53.85	NEW			
1	ULN 2003	£20.00	\$0.38	£20.00	\$0.38	NEW			
1	PCB Components	£1,230.00	\$23.65	£1,230.00	\$23.65	NEW			
1	Current Sensor	£100.00	\$1.92	£100.00	\$1.92	NEW			
			\$0.00		\$0.00	NEW			
			\$0.00		\$0.00	NEW			
			\$0.00		\$0.00	NEW			
Mechanical									
1	Artelon and copper milling	£2,450.00	\$47.12	£2,450.00	\$47.12	NEW			
1	Copper rod	£600.00	\$11.54	£600.00	\$11.54	NEW			
5	Drill bit 1mm	£15.00	\$0.29	£75.00	\$1.44	NEW			
5	Drill bit 2mm	£1.67	\$0.03	£8.35	\$0.16	NEW			
5	Drill bit 3mm	£110.00	\$2.12	£550.00	\$10.58	NEW			
1	Wire cutter	£780.00	\$15.00	£780.00	\$15.00	NEW			
1	Fibre optic stripper	£700.00	\$13.46	£700.00	\$13.46	NEW			
1	Nails and screws	£2,000.00	\$38.46	£2,000.00	\$38.46	NEW			
2	Control Box Tube	£1,000.00	\$19.23	£2,000.00	\$38.46	USED			
26	Penetrators	£150.00	\$2.88	£3,900.00	\$75.00	NEW			
						NEW			
4	T100 thrusters	£2,850.00	\$54.81	£11,400.00	\$219.23	USED	Sponsorship From Z-Hub		
3	Johnson water pump	£500.00	\$9.62	£1,500.00	\$28.85	USED			
2	Propellers	£860.00	\$16.54	£1,720.00	\$33.08	USED			
1	PLA Filament	£750.00	\$14.42	£750.00	\$14.42	NEW			
1	3D printing	£2,700.00	\$51.92	£2,700.00	\$51.92	NEW	Saved £3000 By Affiliating people to the 3d printing company, Fabritech		
1	Tools	£3,000.00	\$57.69	£3,000.00	\$57.69	NEW			
1	Tether Cover	£400.00	\$7.69	£400.00	\$7.69	NEW			
1	Extrusions	£480.00	\$9.23	£480.00	\$9.23	NEW			
1	Screws	£650.00	\$12.50	£650.00	\$12.50	NEW			
1	CNC Laser	£600.00	\$11.54	£600.00	\$11.54	NEW			
1	CNC Router	£250.00	\$4.81	£250.00	\$4.81	NEW			
1	Epoxy	£200.00	\$3.85	£200.00	\$3.85	NEW			
1	Grease	£100.00	\$1.92	£100.00	\$1.92	NEW			
1	Miscellaneous Equipment	£900.00	\$17.31	£900.00	\$17.31	NEW			
1	Threads	£3,300.00	\$63.46	£3,300.00	\$63.46	NEW			
Total Spent		£69,627.35	\$1,343.17						

Figure 32 Expenses Sheet

12.3. Safety Checklist

Pre-startup:

- [] Station is unpacked and connections to tether are made and checked by an electrical engineer.
- [] ROV thruster propellers are free of obstructions
- [] Tether and all cables are inspected for damage
- [] Ethernet ,USB cable, and controller are connected to pilot's laptop
- [] Pilot's laptop is up and running with the python script opened

Startup:

- [] Co-pilot calls out "Powering up"
- [] Kill-switch is moved into on position
- [] Co-pilot calls out "On, Thruster tests"
- [] Pilot runs python script and proceeds to move the controls 1 by 1 checking thruster operation

ROV Launch:

- [] ROV is lifted by one of the pit members and verified that no thrusters are running
- [] ROV is slowly lowered into the water
- [] If any large bubbles appear after the ROV has been settled into the water, immediately retrieve the ROV
- [] If no issues are detected, the launch is successful and the pit crew calls out "launched!"

ROV retrieval:

- [] Pilot surfaces the ROV and calls out "Retrieval" and turns off the kill-switch after a successful surface.
- [] Pit crew member grabs the ROV but confirms it is not powered before removing the ROV from the water
- [] Pit crew member retrieves the ROV and calls out "Retrieved"
- [] If the ROV is to be modified, the pit crew completes the modification procedure
- [] If the mission tasks have been completed, the tether is collected and the ROV is moved away from the pool

Leak detected:

- [] Kill-switch is moved into off position immediately by the nearest crew member
- [] Pit crew performs visual inspection and an electrical engineer is brought onto the scene if a leak is suspected
- [] If the leak was a false alarm, the ROV can be re-launched and if another false warning would occur, the leakage sensor data can be disregarded till the end of the mission if the crew is sure no leak is suspected.
- [] If a leak exists, the mechanical team should find and repair the leak, while logging where it came from.
- [] If the leak is repaired and verified, an electrical engineer should check all of the components for water damage and repair/replace affected components

Communication Lost/ROV unresponsive:

- [] Reset python script to insure code is not the culprit
- [] If it does not help, restart communication by unplugging and re-connecting the USB cable
- [] If communication hasn't been restored, the crew may preform a power reboot via the kill-switch if no leaks are suspected
- [] If communication cannot be restored, the crew should proceed with the ROV retrieval procedure and an electrical engineer should asses and repair the cause.

ROV modification/payload change:

- [] ROV retrieval procedure is followed until completion
- [] Then, pit crew members insert the payload/preform the modification
- [] The modification/payload change has to be reviewed by a different pit crew member
- [] If changes are satisfactory, proceed with ROV launch procedure
- [] If changes are not agreed to, they may be re-done

ROV maintenance:

- [] ROV is powered down and dry
- [] No tripping tripping hazards or loose electrical connections are present
- [] ROV is safely placed on workbench and not at risk of falling off

Figure 33 Safety Checklist

12.4. Gantt Chart

Oceanus Co. MATE ROV Project Plan (Gantt Chart)

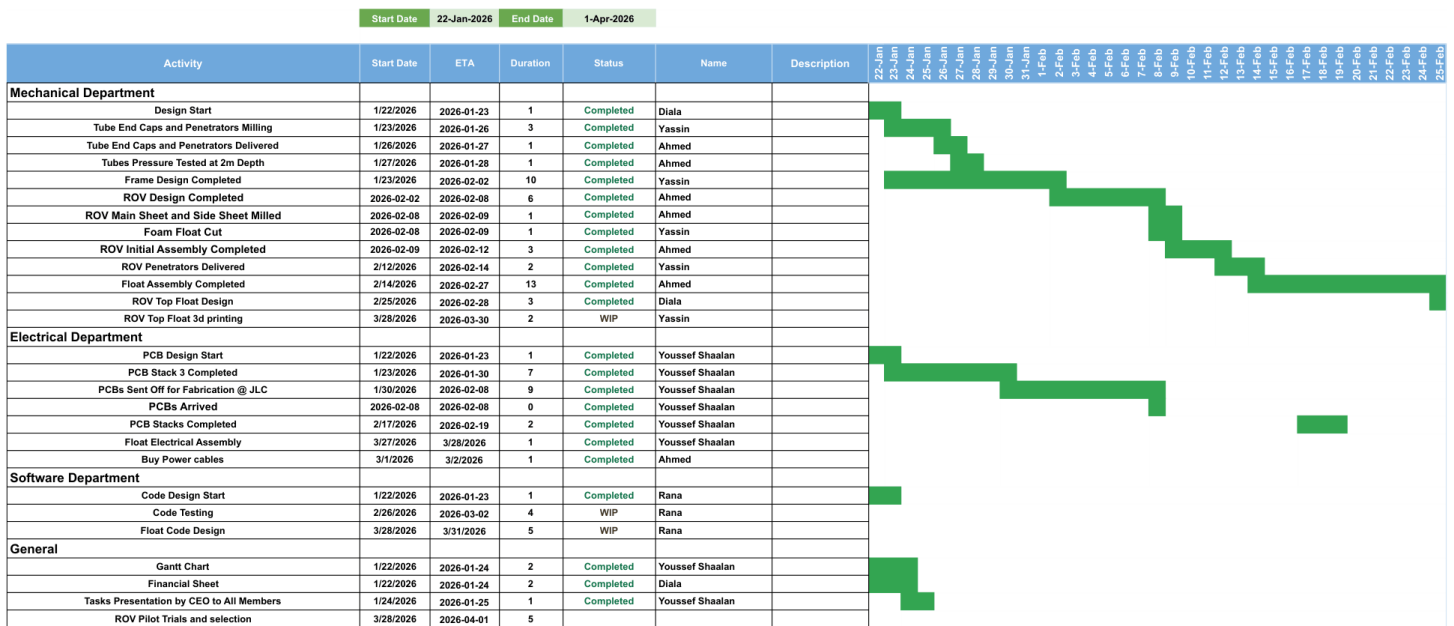


Figure 34 Gantt Chart

12.5. Motor Comparison Table

Motors	Propellers				Forward Thrust (kgf)	Backward Thrust (kgf)	Rotational Speed (rpm)	Current (Ampere)
	Diameter (mm)		Blades	Pitch (mm/rev)				
Rule Bilge Pump	50	Left	3	42	0.35	0.27	4100	2.07
		Right	3	42	0.41	0.12		2.03
	60	Left	3	45	0.48	0.12		2.45
		Right	3	45	0.48	0.12		2.45
	75	Left	3	?	0.6	0.4		4.35
		-	-	-	-	-		
	10	-	-	-	-	-		
		Right	4	65				
Rule Bilge Pump	50	Left	3	42	0.51	0.18	5770	2.85
		Right	3	42	0.51	0.14		2.855
	60	Left	3	45	0.46	0.31		2.9
		Right	3	45	0.49	0.44		3.055
	75	Left	3	?				
		-	-	-	-	-		
	10	Left	-	-	-	-		
		Right	4	65				
Johnson Bilge Pump	50	Left	3	42	0.45	0.16	5755	2.75
		Right	3	42	0.45	0.16		2.75
	60	Left	3	45	0.44	0.18		2.75
		Right	3	45	0.44	0.18		2.75
	75	Left	3	?				
		-	-	-	-	-		
	10	-	-	-	-	-		
		Right	4	65				6.15
Rule Bilge Pump	50	Left	3	42	0.75	0.25	7600	4.75
		Right	3	42	0.75	0.25		4.85
	60	Left	3	45	0.8	0.15		6.69
		Right	3	45	0.8	0.23		6.35
	75	Left	3	?				7.85
		Right	-	?	-	-		-
	10	-	-	-	-	-		-
		Right	4	65				9.5
Johnson Bilge Pump	50	Left	3	42	0.75	0.27	8225	4.35
		Right	3	42	0.75	0.26		4.7
	60	Left	3	45	0.82	0.54		6.45
		Right	3	45	0.82	0.54		6.45
	75	Left	3	?				7.7
		-	-	-	-	-		-
	10	-	-	-	-	-		-
		Right	4	65				8.85
Blue Robotics T100 Thruster	76.2	Left	3	48	2.36	1.82	300-4200	11.5
		Right	3					

Figure 35 Motor Test Data Table