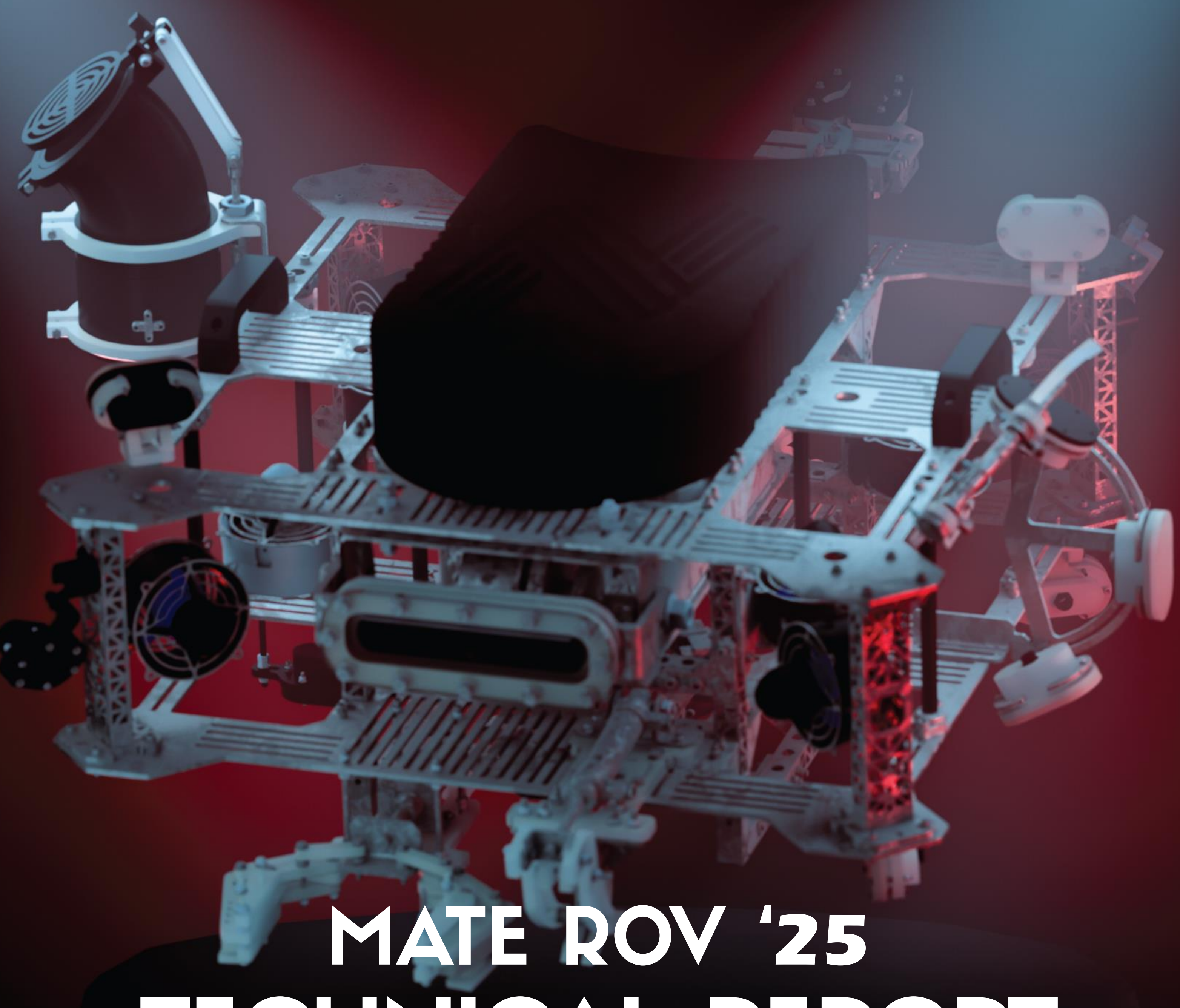

MATE ROV '25
TECHNICAL REPORT

Alexandria, Egypt

25 Abdallah Karam CEO
25 Ahmed Elsayed ESG
26 Mohamed Tarek CFO / Software CTO
25 Abdallah Milad Electrical CTO / Pilot
25 Ahmed Abdelmaksoud Mechanical CTO
26 Abelrahman Osama Electrical Leader
26 Ayman Muhammed Mechanical Leader
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26 Sama Abdou Software Leader
27 Karim Hany Electrical Vice Leader
26 Abdelrahman Elansasy Electrical Eng / R&D
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27 Ahmed Kamel Electrical Eng*
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جامعة الإسكندرية
ALEXANDRIA UNIVERSITY

NEXUS

MIA robotics

Abstract

Founded in 2011, **M.I.A. Robotics** is a team of 32 interdisciplinary students from **Alexandria University**, proudly returning to the **MATE ROV Competition** for the 12th consecutive year. With deep-rooted experience in providing solutions to environments facing the realities of **climate change**, **invasive species**, and shifting marine conditions, our team is driven to design technologies that preserve **aquatic ecosystems**, uncover and explore submerged **cultural treasures**, and promote long-term **ocean health**. Through the 2025 **MATE ROV Challenge**, **M.I.A.** reaffirms its mission to contribute meaningfully to global efforts in environmental monitoring and the sustainable stewardship of our planet.

Proudly presenting our top-of-the-line Remotely Operated Vehicle (ROV), **Nexus**, equipped with an innovative payload, improved electrical and mechanical designs, cutting edge image processing, high maneuverability, and precise control. **Nexus** has evolved to tackle this year's **RFP tasks** efficiently and swiftly. Characterized by the experience gained throughout the years, this technical document describes the **design process** and **manufacturing of Nexus**, prioritizing **efficiency** and balancing trading-offs between different aspects of the ROV for optimal solutions while placing the highest priority on the **safety** and well-being of its team members. The team's **safety policy** follows a clear hierarchy: it begins with ensuring **personal safety**, extends to the safe construction of the ROV, and culminates in maintaining operational safety during deployment and testing. This structured and consistent focus on safety has empowered us to innovate with confidence, knowing that every step of our development process is grounded in **careful planning**, **situational awareness**, and **mutual respect**.

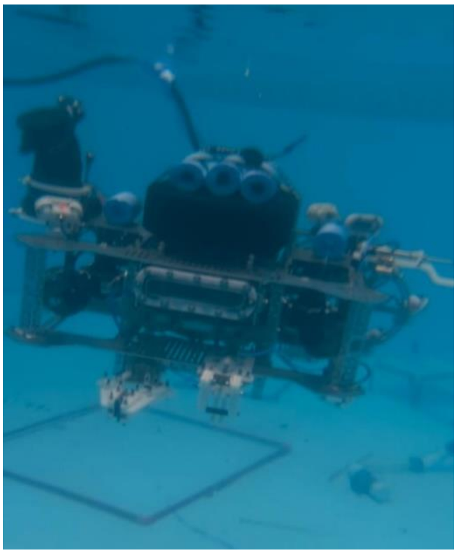

Figure (1): Nexus ROV

Figure (2): M.I.A. Robotics Members

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Acknowledgments

We're grateful to all of these organizations and individuals for their help and support that enabled us to overcome all the challenges that we have faced:

MATE Center - for sponsoring this year's competition and for their generous awards.
Arab Academy for Science and Technology (**AAST**) **-** for hosting and organizing the regional competition.
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Makers Electronics - for giving us discounts on electric components.
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Synthesis 3D - for giving us discounts on 3d Printing.
SolidWorks, **Altium**, **Ansys -** for providing the team members with access to their products.
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Youth Leader Foundation - for their award in their competition in the manufacturing track.
Team supervisor: Prof. Dr. Hassan Warda - for his constant efforts in supporting the team.
Our Families and Friends – for their ongoing support and encouragement.

Figure (3): M.I.A. Sponsors and Partners

1. Design Rationale

1.1 Design Evolution

The development of **Nexus** began with a comprehensive evaluation of our previous ROV models, identifying strengths, limitations, and opportunities for innovation. The company focused on integrating **new materials and technologies** to enhance **maneuverability, durability,** and **ease of operation**.

Through continuous **research, prototyping, and rigorous testing**, design improvements were systematically implemented to optimize performance. **Strategic planning** ensured efficient allocation of time, budget, and resources, balancing technical advancements with feasibility. The result is a **modular, high-performance ROV** equipped with **cutting-edge capabilities**, designed to meet competition requirements and push the boundaries of underwater exploration.

Figure (4): Nexus ROV

Sensors Fusion

Sensor fusion is widely regarded as a crucial technological advancement for enhancing control systems and addressing drifting problems that frequently occur in the data obtained from the IMU sensors. Since we are configuring multiple sensors, we used a **Kalman Filter** to fuse the IMU sensor embedded within our ZED stereo camera, the **MPU6050** 6DOF IMU, and the **BNO055** sensor.

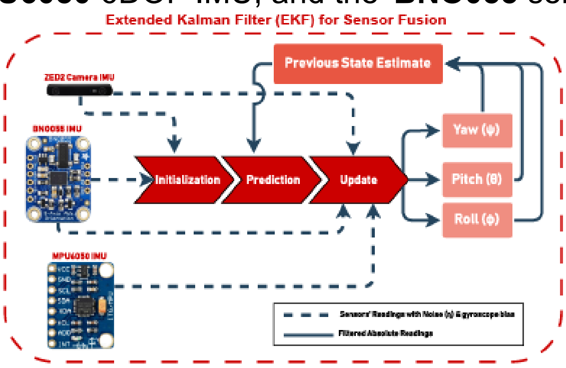

Figure (5): Sensors' Readings Pipeline

Software Simulation

Developing Nexus was challenging due to the need for continuous testing and prototyping while maintaining low costs, a safe testing environment, and overall efficiency. This year, we integrated software simulation using **Gazebo + ROS**, enabling rapid prototyping and remote testing for faster development. It also allowed early identification of design flaws before manufacturing, along with safe debugging of control systems and pre-tuning without real-world risks.

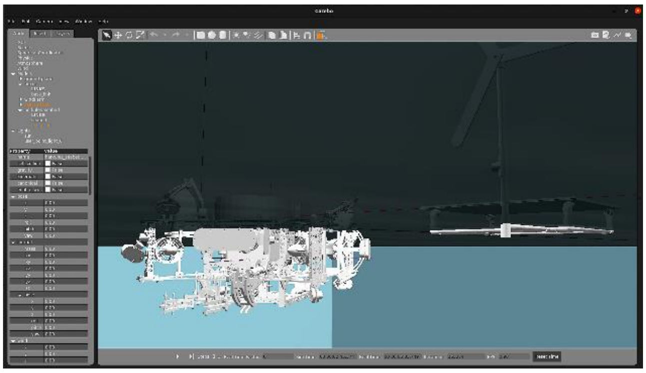

Figure (6): Gazebo Underwater Simulation

Maneuverability

Utilizing **8 T200 thrusters** with a huge arm moment, M.I.A. was able to provide the vehicle with improved **6 DoF**. Furthermore, the team added a **PID controller** and other software features for the stability of Nexus's smoothness and maneuverability.

Web-Based GUI

Traditional control systems often require dedicated software, limiting accessibility and usability. To overcome these challenges, a **web-based GUI** was implemented, enabling seamless interaction from any device without installation requirements. This approach simplifies access, enables **real-time data visualization**, smooth control, and integrated **camera streaming**, making underwater operations more efficient and precise, and providing users with a comprehensive view of underwater operations.

Figure (7): Web-Based Control GUI

Globalization

Last year's ROV redefined portability, paving the way for a new era of convenience. Building on this success, our latest advancements have made controlling Nexus effortlessly accessible from any device within the local network—no installations required. This breakthrough has elevated connectivity within our company.

Now, Nexus can be seamlessly operated **from anywhere in the world** with just a stable internet connection. With **secure HTTPS and WebSocket communication**, remote control and data transmission remain **encrypted and protected**, even when our pilot is testing from home. This innovation brings us one step closer to full-scale industry integration.

Multi-Camera Streaming

Nexus is capable of streaming up to 11 cameras simultaneously. Three are dedicated to the photosphere task, while seven provide visual feedback for the manipulators - one per manipulator - and a ZED2 camera with a servo motor enables dynamic navigation vision. These cameras capture various angles and provide comprehensive visual coverage of the playground and mechanisms. The video streams are managed and displayed on a Web GUI, allowing the operator to monitor all feeds efficiently. The streams are transmitted from the Jetson microprocessor, which provides the necessary computational power to process and encode them effectively.

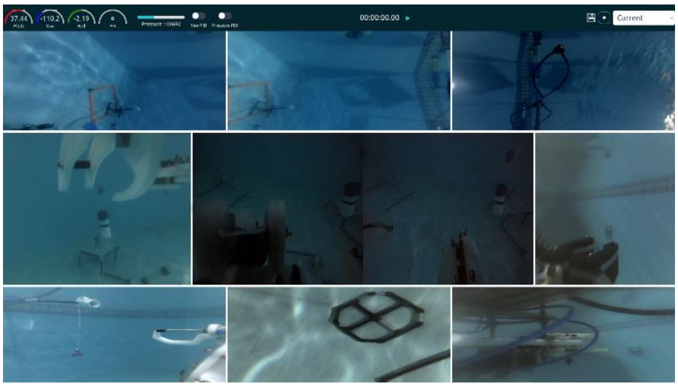

Figure (8): Web-Based Cameras GUI

Color Correction

Computer vision in underwater environments struggles with **color distortion and attenuation**, impacting vision tasks. AI-based solutions exist but lack real-time performance. To address this, we developed a fast image processing algorithm using OpenCV filters, achieving real-time speeds of up to **30 FPS**. It applies a **Gray World Algorithm** which balances color intensities by assuming the average color of the scene is neutral grey then **Red-Blue Compensation** is applied to restore lost red tones, enhancing **visibility and contrast**. Originally prototyped in Python, we optimized it in **C++** for **low-latency** operation without the computational overhead of machine learning. This ensures accurate color correction for improved navigation and computer vision tasks like the **photosphere** task.

Figure (9): Color Correction Result

Cuboidal Structure

One of the primary challenges faced by the mechanical team was balancing **structural rigidity** with the **flexibility** needed to integrate modular components and attachments. Nexus's chassis was designed to provide both **strength** and **adaptability**, enabling seamless customization and the integration of **mission-specific equipment**. The frame's design adopts a **cuboid geometry**, selected for this year's mission requirements due to its **optimal thruster alignment**, **Expansive mounting surface area** (compared to alternative designs) and **Enhanced load distribution.**

To achieve this, the structure was constructed using:

- Two aluminum plates (reinforced for torsional stability)
- Square Hollow Section (SHS) Extrusion bars (for modular adjustability)
- Carbon fiber rods (for uniform reinforcement)

Given its substantial size and weight, the ROV exemplifies a strategic trade-off between physical dimensions and multifunctional capability. Despite its larger footprint, the design incorporates multiple integrated mechanisms, ensuring **efficient multitasking** during operations.

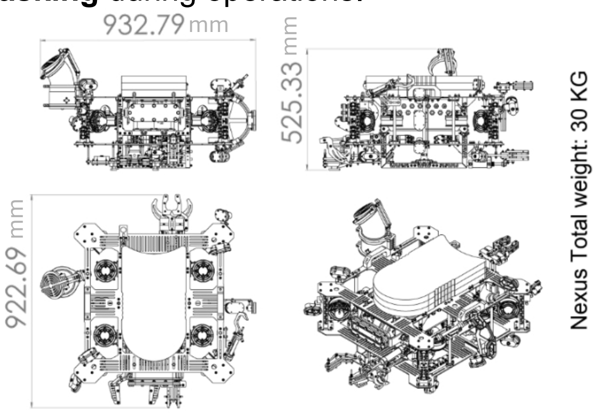

Figure (10): Nexus Drawing, Dimensions, and Weight

1.2 Mechanical System

Material Selection

The Nexus design process began with an interdepartmental collaboration between mechanical, electrical, and software teams, identifying which elements of the new ROV should retain legacy design features and which could be enhanced. A decision matrix was implemented to evaluate key factors such as **material availability, machinability, cost efficiency, and long-term suitability.** After analysis, the mechanical team selected **4mm Aluminum 7075** as the primary frame material due to its **high strength-to-weight ratio, corrosion resistance, and ease of fabrication,** offering a balanced improvement over the traditional alternative.

Table (1): Material Selection Criteria

Criteria	Aluminum 6 mm 5083	Aluminum 4 mm 7075	Aluminum 3 mm 5754
Strength	5	4	2
Weight	3	5	4
Corrosion Resistance	3	4	3
Manufacturing Complexity	4	3	4
Cost	3	4	5
Flexibility	3	4	3
Thermal Conductivity	5	5	5
Overall Score	3.714	4.143	3.714

Design And Manufacturing Process

MIA's mechanical engineering team follows a structured and iterative design process to optimize both the development and manufacturing of the ROV. This approach begins with **brainstorming sessions** to define key design parameters, utilizing **freehand sketches** to explore initial concepts. The process then progresses to **detailed modeling and refinement** using Computer-Aided Design (CAD) software, specifically SOLIDWORKS**,** ensuring **precision** and **manufacturability.**

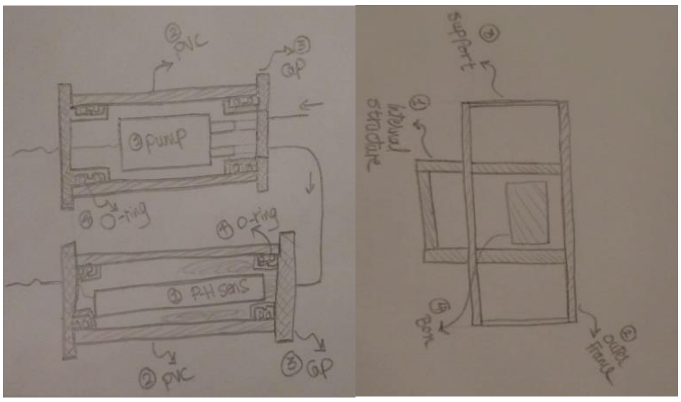

Figure (11): Free-hand Sketch of a Mechanism and the Frame

At the outset of each **design cycle**, the team conducts a **comprehensive review** of the previous year's ROV, identifying successful design elements to retain and areas for improvement. For example, in the prior year, a 6mm-thick aluminum sheet and V-slot extrusions were used to mount the thrusters. However, in the current iteration, the team opted for **rectangular aluminum tubes** due to their **superior strength-to-weight ratio**. This modification allowed for a reduction in overall frame weight while maintaining structural integrity, demonstrating the team's commitment to continuous improvement and performance optimization.

Table (2): Part Specifications

Criteria	V-Slots	Square Extrusion Bars
Strength	5	4
Weight	2	5
Corrosion Resistance	5	5
Manufacturing Complexity	2	5
Cost	2	5
Flexibility	4	4
Overall Score	3.33	4.67

Electrical Enclosure

The enclosure is constructed from **6mm-thick 5083 aluminum sheets**, shaped using metal forming technology and welded together using gas tungsten arc welding. Compared to last year's design, which had an internal volume of 308 × 190 × 130 mm³, the new enclosure has been reduced to **308 × 162 × 130 mm³ - resulting in a 15% reduction in internal volume**. This reduction enhances space efficiency while maintaining structural integrity. To ensure a **watertight seal**, the cover compresses **double-layer O-rings**, providing a **secure seal** capable of withstanding pressures of up to **six bar** (60 meters of water depth).

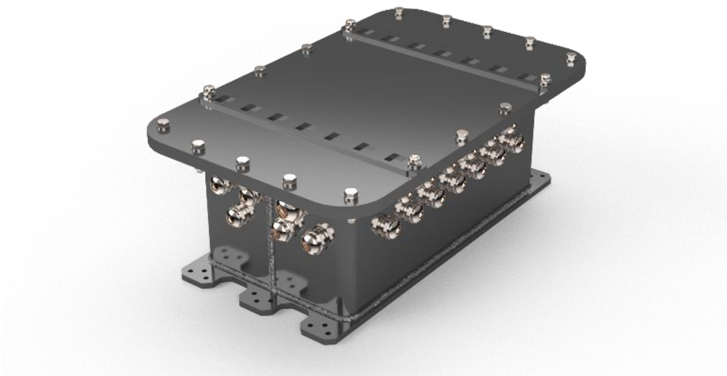

Figure (12): Nexus Electrical Enclosure

Frame Design

The frame serves as the structural backbone of the ROV, designed to be **modular, lightweight, and highly durable**. It provides secure mounting for critical components, including thrusters, the electrical enclosure, sensors, cameras, lights, and tools, ensuring all subsystems function cohesively. 20mm × 20mm × 2mm 6063-T6 aluminum square hollow section (SHS) extrusions, chosen for their ideal strength-to-weight ratio, make up the internal framework. This design reduces weight without sacrificing structural integrity because of the strategically positioned **trusses and circular cuts** that reinforce it. It also provides **comfortable connection points** on each of its four sides, allowing for versatile subsystem integration.

The structure improves hydrodynamic efficiency, reduces noise and vibrations caused by propulsion, and offers plenty of room for specific equipment. Two **4mm 7075-T651 aluminum plates** with exceptional strength make up the external construction; these plates can withstand collisions, mechanical stresses, and underwater pressure. Modular subsystem mounting is made easier by slot cuts, and the frame is strengthened by **carbon fiber rods**. Stability is further improved by the truss-like SHS extrusion at each corner, which also acts as a mounting place for **lateral thrusters**. A strong yet lightweight structure that guarantees structural integrity, effectiveness, and flexibility in demanding underwater operations is produced by the combination of these internal and external components.

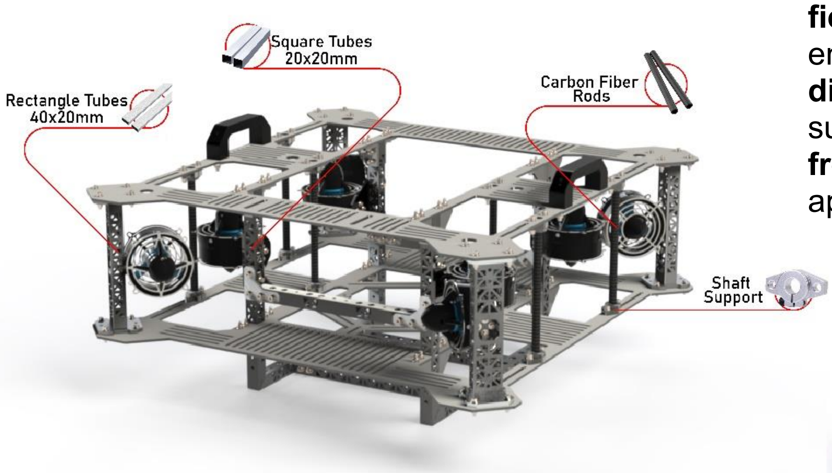

Figure (13): Nexus Aluminum Frame

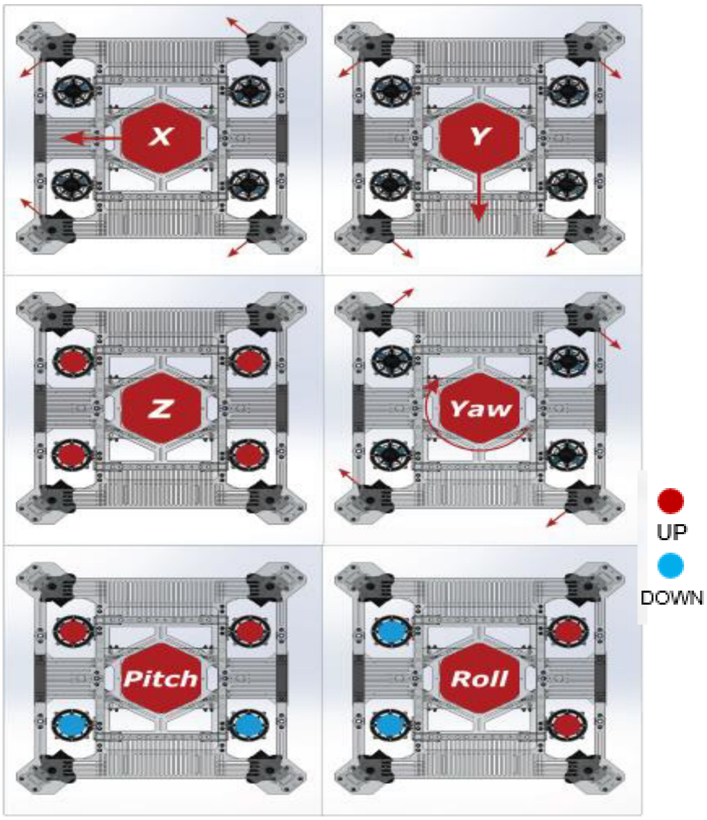

Figure (14): Nexus Degrees of Freedom

Camera Casing

To enhance **computer vision capabilities**, the software team selected the **ZED2** stereo camera, which posed a challenge for the mechanical team to design a lightweight and compact casing. Due to the camera's unique geometry, the casing was manufactured from **high-density polyethylene (HDPE)** using CNC milling. Additionally, to improve the accuracy and clarity of underwater vision.

The mechanical team integrated a **servo motor** into the design. This allows for **vertical adjustment** of the camera's angle, expanding its **field of view, enhancing perspective**, and enabling the creation of **detailed three-dimensional models**. This innovation also supports the development of a **multi-degree-of-freedom (DOF) robot arm** for advanced applications.

Figure (15): ZED Camera Servo Attachment

Manipulators and Mechanisms

Nexus features pneumatically actuated multi-functional mechanisms, utilizing both pneumatic and electrical power for various competition tasks. Constructed from 8mm thick **HDPE** material, chosen for its cost-effectiveness, machinability, non-corrosiveness, and high strength. Additionally, **PLA+** is used in 3D printing for lightweight parts, offering toughness, corrosion resistance, and impact resistance, which is ideal for underwater conditions. **PVC** components are also used, taking advantage of their durability**.**

Figure (16): Fish Species Mechanism

Fish Species Mechanism: The mechanism is powered by a T200 Blue Robotics thruster, that directs flow inwards towards an angled path. The container is mainly constructed of an **elbow PVC**, a lightweight and durable solution. A **3D printed piston-powered gate** is counteractively used to **capture the Ping-Pong balls** and prevent escape in **Task 2.2**. This gate is **perforated** to avoid reversing the current when it opens.

Figure (17): Polyps Hook Mechanism

Polyps Hook Mechanism: Inspired by carabiners, a **hook-like mechanism** was designed to capture and trap polyps in **Task 2.2**. This lightweight mechanism is capable of a 12B x 50S piston rod, used as an active gate that allows the passage of polyps into the hook. The mechanism fixation allows for a variation of positions and angles, adding to its efficiency in capture.

Water Sample Mechanism: The mechanism is for **Task 1.3** consists of two sealed containers:

Figure (18): Pump Housing

Pump Housing: A **self-priming Micro Water Pump** is enclosed in a **2" PVC pipe** with **HDPE caps**. **PG 7 glands** allow wiring and tubing access.

Sample Container: A **sealed canister** with an **integrated pH sensor** prevents liquid mixing for accurate readings. It is mounted vertically using **3D-printed straps** and has **PG 7 glands** for tubing and wiring. A **non-return valve** prevents pressure buildup, and the container is enclosed in a **2" PVC pipe** with **piston-seal HDPE caps**.

Figure (19): Sample Container

Injector System: A **pneumatic tube**, supported by a **vertical stud**, enables safe and stable sample collection. A **3D-printed cone** helps center the injector, ensuring reliability without sharp edges.

Figure (20): Jaw Gripper

Jaw Gripper Manipulator: The gripper is designed to hold different item cross-sections with a diameter of 9 to 91 mm. It is powered by pneumatic force with a 30 mm bore - 50 mm stroke piston. To increase the gripping contact area, the gripper features a **big, wide finger**. On the other hand, it contains **two movable end effectors** that are held by a **carbon fiber rod**. The **Jaw Gripper** is primarily used for gripping **pins** and **covers** (e.g., the **PCO2 cover**) in **Task 1.1**, **Task 2.1**, and **Task 2.2**.

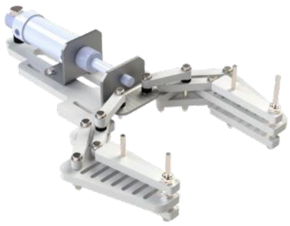

Figure (21): Main Gripper

Main Gripper Manipulator: A four-bar mechanism-based manipulator used by ROVs to **clamp objects** underwater. The mechanism is pneumatically-actuated with a 30 mm bore - 20 mm stroke piston. The end effectors of the mechanism can hold various **cross-section objects** up to **109 mm in diameter**. Two of these manipulators are mounted on **Nexus** for general gripping, retaining multiple objects within the ROV during a **single dive**, and carrying an attachment for the Medusa jelly. They are used in **Task 1.2** and **Task 2.1**.

Mechanical Virtual Prototyping

Building **computer models** of products for **realistic graphical simulation**—often in a virtual reality (VR) environment—is known as **virtual or computational prototyping**. It makes it feasible to test a part's behavior in a functionally realistic setting **without having to manufacture the part**.

CFD

A computational fluid dynamics (CFD) study was performed on an ROV to evaluate **flow characteristics** around its hull, assess its resistance to pressure forces, and calculate drag. The following figure illustrates **streamlines around the Nexus design**, demonstrating the efficiency of its frame structure with multiple cavity points, which promote smooth water flow during operation. The CFD results indicate a drag force of **20.5 Newtons** at an ROV velocity of **0.8 m/s**.

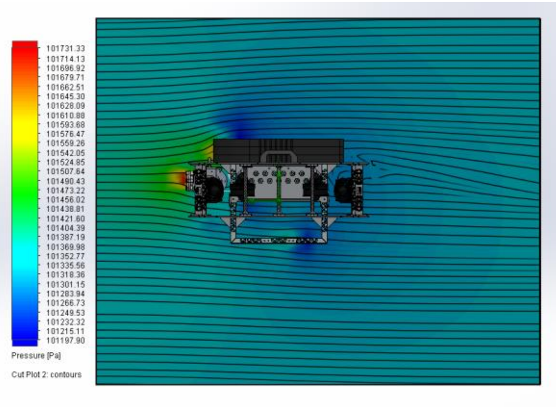

Figure (22): Nexus CFD

Propulsion

The ROV is powered by eight **T200 Blue Robotics thrusters**, selected for their high thrust output, rapid response, and reliable performance. While these thrusters are highly efficient, their primary drawback is elevated power consumption, particularly during high-speed operation, as indicated by the drag force dynamic equation below:

$$F_D = \frac{1}{2}\rho v^2 C_D A$$

F_D: *Drag force*

ρ: *Density of the fluid*

v: *Speed of the vehicle relative to the fluid*

C_D: *Coefficient of Drag*

A: *Cross Sectional Area*

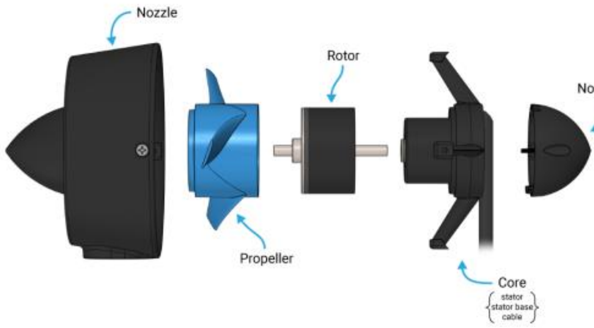

Figure (23): T200 Thruster Disassembled

Buoyancy and Stability System

The buoyancy system in **Nexus** is designed to ensure neutral buoyancy, enhance hydrostatic stability, and facilitate control during underwater operations. The calculations were based on **Archimedes' Principle**, where the buoyant effect of each component was analyzed. The results showed that Nexus experiences **a total negative buoyancy value of around 110 N**, requiring the addition of buoyant elements to achieve the desired balance.

To ensure dynamic stability, **buoyancy boards** were integrated into the structure and positioned to keep **the center of buoyancy above the center of mass**. This distribution helps enhance the vehicle's self-stabilization, reducing the need for constant corrections during operation.

A comprehensive analysis of each component in Nexus was conducted, considering **its mass, volume, and resulting buoyant force**. This data was used to determine the optimal size of the buoyant elements needed to compensate for the excess weight. Additionally, the internal distribution of buoyant components was designed to achieve **a near-neutral buoyancy state**, allowing Nexus to maintain its position in water without frequent thruster corrections.

This balance between buoyancy and stability enables Nexus to accurately maintain its required position during underwater tasks while reducing power consumption and improving dynamic control.

Table (3): Nexus Buoyancy Table

Item	QYT	Total Mass (Kg)	Volume (cubic cm)	Displaced mass (Kg)	Buoyant Force (Newton)
Top plate	1	1.6658	594.38796	0.59281	-10.5260319
Bottom plate	1	2.03322	729.90989	0.72001	-12.8825901
Enclosure Box	1	7.96159	3558.09197	8.82007	8.4216888
Lateral Thrusters	4	1.98336	796.65824	0.81932	-11.4192324
Internal Thrusters	4	1.95172	869.94528	0.86996	-10.6120656
Square Hollow Extrusions	14	1.24652	408.86328	0.46168	-7.6992804
Zed Camera	1	1.27308	846.9252	1.0891	-1.8048438
Rapoo Camera	8	0.97513	651.77984	0.78295	-1.8852858
Carbon fiber support	6	0.2973	120.86322	0.12084	-1.7310726
Handle	2	0.17842	138.3054	0.1383	-0.3935772
Solenoids	8	1.2	366.5484	0.42216	-7.6306104
Fittings	42	0.42	109.2924	0.1092	-3.048948
Strain Relief	1	0.0649	24.39892	0.0244	-0.397305
L Bracket	22	0.3729	138.11578	0.13816	-2.3027994
Cast Corner	2	0.01234	4.57118	0.00458	-0.0761256
Glands	47	0.91368	117.12729	0.11703	-7.8151365
Main Gripper	1	0.4079	342.23956	0.35588	-0.5103162
Jaw Gripper	1	0.47849	304.4411	0.30345	-1.7171424
180 Gripper	1	0.44334	187.20986	0.18721	-2.5126353
Upper Thermistor	1	0.39168	346.97897	0.34698	-0.438507
Lower Solar	1	0.59859	304.36531	0.32604	-2.6737155
Ping Pong Mechanism	1	1.14922	743.63177	0.74369	-3.9782493
Polyps Mechanism	1	0.20356	77.97932	0.13336	-0.688662
Bolts	289	1.83152	232.5914	0.23518	-15.6600954
Washers	540	0.26073	33.41202	0.03327	-2.2313826
Nuts	379	0.5185	66.3045	0.0665	-4.43412
Total	-	28.83689	12115.37442	17.96257	-106.6770792
Total Buoyancy	Negative Buoyancy				-106.6770792

1.3 Electrical System

Nexus's electrical system is built on four main pillars established through harsh testing and years of experience: Safety, Streamlined assembly, Modularity, and mechanical efficiency. Each section of the following will highlight one of these pillars.

A **grounded ROV enclosure box** eliminates any **unwanted EMI** and protects the Tetherman from any dangerous return currents**.**

Streamlined assembly and debugging were achieved through **color-coded wiring** for each voltage level, as demonstrated in **Fig(24).** Moreover, the electrical components are organized into three vertically stacked layers based on how frequently they are accessed, which facilitates the debugging process and achieves modularity in design.

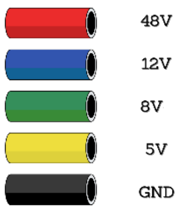

Figure (24): Wiring Color Code

Tether

The tether is designed to offer reliable electrical power, compressed air, data transmission, and a physical connection to the ROV, all while allowing unrestricted movement. All lines are protected within a flexible sheathing to increase safety during operation. Power is transmitted to the ROV through a pair of low-resistance **10 AWG** wires that were selected after a thorough analysis of power stability under heavy current loads, and maintain minimal voltage drop and meets power requirements for DC Buck Converters. The tether contains two pneumatic tubes, an intake tube supplying air to the pneumatics manifold, and a redundant fail-safe one. Data is transmitted at 1000 Mb/s between surface control and the ROV via a **CAT6e-shielded ethernet cable** which offers low latency and a reliable gigabit connection.

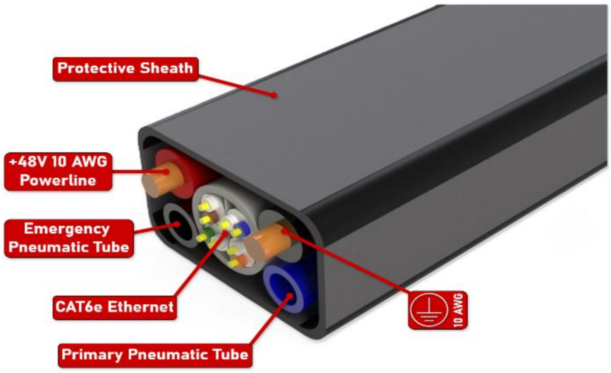

Figure (25): Tether Cross-Section

Power Management & Connectors

Building from the bottom up, our main power management layer receives **48V** through the **XT90 power connector**, which offers **lower resistance** than previously used XT60, lowering power loss and providing higher thermal performance. This choice aligns with our design requirements for safety, durability, and optimal power delivery.

Secondly, our ROV mainly has **3 × (48V - 12V) DC-DC Buck converters**, which were carefully selected based on the following criteria:

Table (4): Buck Converter Comparison

Current Rating (A)	Volume (mm)^3	Weight (kg)	Qty. Needed	Total Volume Required (mm)^3	Total Weight (kg)	Total Cost (USD)
20A Buck	180,708	0.3	9	1,626,372	2.7	270
60A Buck	345,600	0.550	3	1,036,800	1.65	180
80A Buck	714,000	1.2	2	1,428,000	2.4	200

Based on the shown table, it is concluded that using **three 60A (48V - 12V) DC-DC Buck converters** is the most cost-efficient, most weight-efficient, and most power-dense solution.

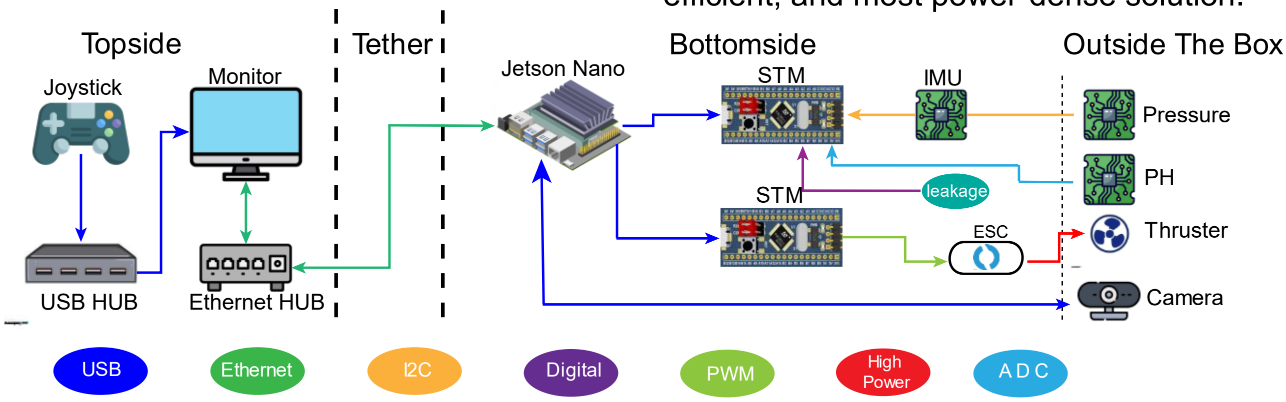

Figure (26): Nexus System Logic Level Schematic

Additionally, a **(48V–5V) and a (12V–5V) DC-DC converter**, with smart chip protection, anti-overheating, overcurrent safeguards, and **96% efficiency at high load**, are used for safely powering the **SBC** and the **10 Rapoo cameras**.

Single Board Computer & Cooling

In the topmost layer, exists the ROV's central computing unit, which was required to fulfill the need for a GPU for ZED2 processing, an Ethernet bandwidth, USB3.0 & video compression rate for interfacing with **10 Rapoo cameras** and a **minimum 1.1GHz Quad-Core CPU**, ensuring low-latency data processing for smooth operation.

As shown in **Table(5)**, **Jetson Nano** has exhibited several merits over **Raspberry Pi 4B** based on our software engineers' vision and requirements.

Stress testing Jetson Nano revealed **high temperatures**, increasing **data processing latency**. To squeeze every bit of performance, a **thermoelectric cooler** cools down the SBC and dissipates the heat in the enclosure's ceiling. This setup lowers the nominal temperature to **20°C**, enhancing computational efficiency.

Table (5): Nexus SBC Tradeoff Analysis

Features	Jetson Nano 4GB	Raspberry Pi 4B	Required	Decision
CPU	ARM Cortex-A57 (quad-core) @ 1.43 GHz	Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit	~1.1GHz Quad Core System	Both
GPU	128-core NVIDIA Maxwell @ 921MHz	Broadcom VideoCore VI	GPU Available	Jetson Nano
Memory	4GB 64-bit LPDDR4 @ 1600 MHz | 25.6 GB/s	2GB, 4GB & 8GB LPDDR4-3200 SDRAM with one-die ECC	At least 4GB RAM	Both
Storage	MicroSD card	MicroSD card	Expandable Storage	Both
Encoder	4Kp30 | 4x 1080p30 | 9x 720p30 (H.264/H.265)	H.264 (1080p30)	Approx. 8x 720p30 Cameras and ZED2 at 1080p30	Jetson Nano
Ethernet	10/100/1000 BASE-T Ethernet	Gigabit Encoder	>800 MB/s	Both
USB	4x USB 3.0 A | 1x USB 2.0 Micro-B	2x USB 3.0 A | 2x USB 2.0 A	Min. 4 USB 3.0 ports (ZED2 & 3 USB 3.0 A)	Jetson Nano
Power	5V / 10-20W	5V / 10-15W	Not more than 20W	Both

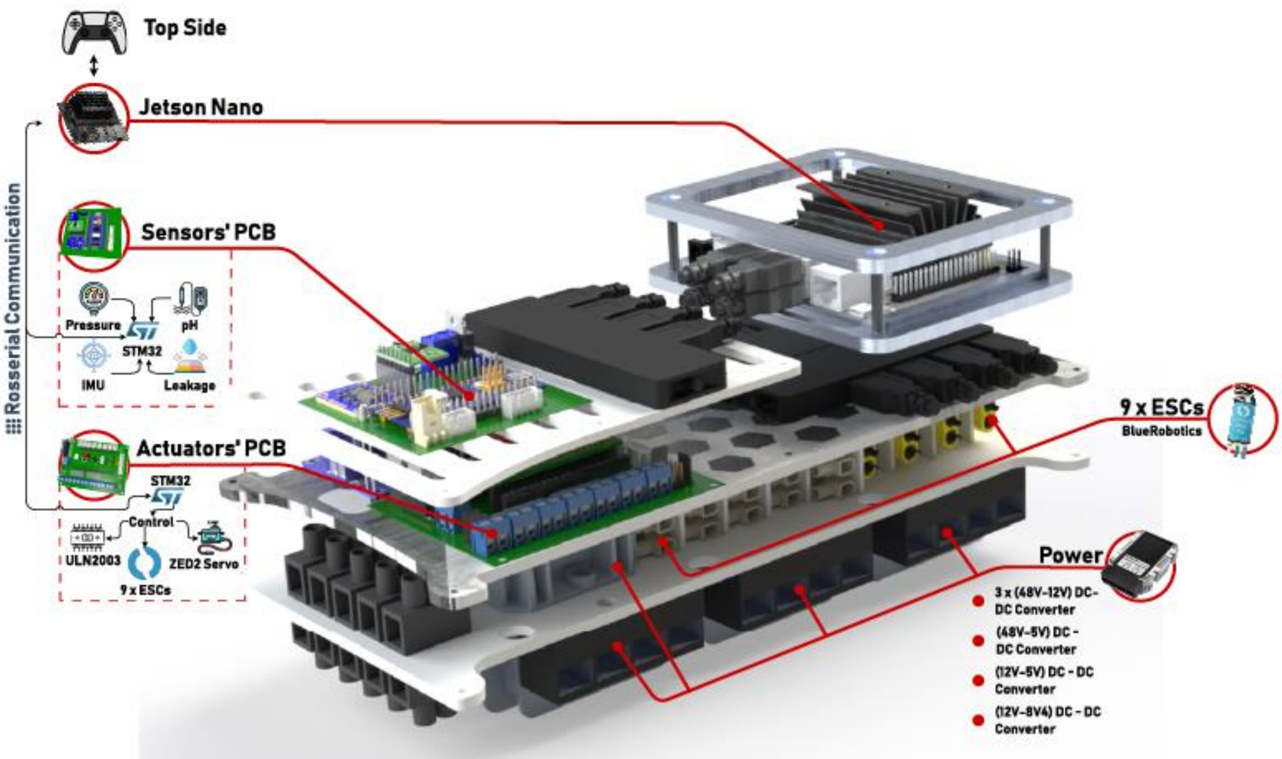

Figure (27): Nexus Hardware Description

Hardware Control

Emphasizing **customizability** and **Immediate adaptation** to new requirements without relying on third-party manufacturers, in the top-most layer (Control Layer) we have our custom-made Printed Circuit Boards (PCB): Actuators' PCB & Sensor' PCBs both designed by Altium Designer proved exceptional performance and cost-effectiveness.

Actuators PCB

The ROV is equipped with an **STM32f103C8** driven PCB for its number of pins and 4 independent hardware timers, allowing Nexus to control up to **10 thrusters**—8 for movement, one for collecting fish species, and a redundant one if needed. Nexus can also support up to **12 solenoid-based actuators**. Pushing the limits further, **2 servo ports** are added: one for tilting the main ZED camera. Lastly, a **DC motor** with direction control for **collecting water samples** is supported.

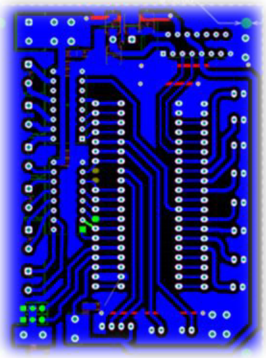

Figure (28): Actuators PCB

Navigation Sensors

Accurate depth and heading information are essential for underwater navigation and control. Employing a multi-sensor strategy, our sensor board integrated **two Inertial Measurement Units (IMUs)** with distinct strengths: one emphasizing precision and the other prioritizing high accuracy. Through **Extended Kalman Filters (EKF)**, data fusion from both IMUs produces highly stable and precise readings for depth and heading (roll, pitch, yaw), surpassing reliance on raw sensor data alone.

This high-speed data is transferred back via USB to the SBC (Jetson Nano) with high frequency for accurate control.

pH sensing

Two solutions were considered for measuring water acidity in **Task 1.3** : **disposable litmus paper** and **electronic transducers**. Litmus paper was excluded since relying on it undermines the fact that the water samples might be of different colors. After comparing different sensors, we used the Analog Water pH Sensor V2 from **DFRobot Gravity**.

This required a special signal conditioning circuit to be designed and calibrated on the sensor board. Then we carefully calibrated the sensor to the standard buffer solutions (pH 7.0) and (pH 4.0).

Figure (29): pH Sensor

Safety First

Safety is our priority. Early **leakage sensors** at all entry points in the ROV's electrical enclosure detect water and humidity, triggering an **immediate shutdown** to isolate components and prevent damage, ensuring crew safety.

Control Station

M.I.A.`s station is the collection of equipment the pilot uses to operate the ROV. The surface station computer, router, monitors, controller, and all other equipment are enclosed in a single grab-and-go package for rapid deployment and easy setup with minimal clutter. To make it suitable for movement, the router and the power supply have been secured in the downstage box. The monitor has been mounted on the other half of the station for easy access and viewing.

Figure (30): M.I.A. Control Station

Tether Management Protocol

Preparation: Conduct pre-deployment checks on the tether, ensuring it is free from damage and properly connected.
Deployment: Deploy the tether carefully, avoiding tangles, while maintaining communication with the control station.
Monitoring: Continuously monitor tether tension during operation to prevent overloading.
Adjustment: Make dynamic adjustments to tether length and tension as needed to accommodate changes in conditions.
Retrieval: Retrieve the tether systematically at the end of the mission, avoiding twists.
Inspection: Inspect the tether post-mission for any signs of wear or damage.

1.4 Software System

Control System

Our ROV uses **8 T200 thrusters** in a vectored configuration, enabling **full 6-DOF maneuverability** and increased vertical payload capacity. With 4 vertical thrusters, it achieves a maximum lifting thrust of 14.8 kg.

For our configuration, the relation between propulsion and thrusters' contributions can be expressed by the kinematic matrix, K.

$$\begin{bmatrix} forward \\ lateral \\ vertical \\ yaw \\ pitch \\ roll \end{bmatrix} = \mathbf{K} \times \begin{bmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \end{bmatrix}$$

Hold Your Depth

Our control system maintains **constant depth** using a **PID controller** with water depth sensor inputs. The pilot can choose between **auto-depth** (ROV holds depth automatically) or **manual-depth** (pilot sets depth manually). This precise depth control enhances maneuverability in the missions like the thermistor task (Task1.1).

Active Stability

We developed **attitude control** with 3 PID controllers to correct for pitch, roll, and yaw. This ensures stability, even with uneven payloads, and allows the ROV to lock its heading when needed. The pilot can select auto or manual mode for orientation control. This helps in missions that need rotation stability like the photosphere (Task1.1) and Task1.3.

Soft-Starting Thrusters

T200 thrusters draw high instantaneous current when starting abruptly. To prevent power system strain motion, we implemented a gradual ramp-up system, smoothing out **current spikes** and **inertia shifts**. This enables **precise rotations** for tasks like the anode removal and replacement, and photosphere tasks.

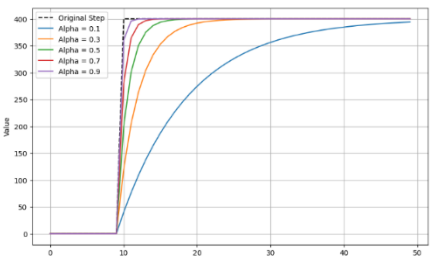

Figure (31): Effects of Exponential Smoothing

Precision Mode

At low speeds, T200 thrusters have a **dead zone (~300 RPM)** where motion is inconsistent. **Precision mode** keeps them just above this threshold, ensuring **smooth control**, **better depth and attitude response**, and reduced inrush current. It's like idling a car at a traffic stop vs. turning the engine on/off.

Communication System

Our communication system has evolved significantly over the years. In 2021, we relied on serial communication with microcontrollers, but their bandwidth and range were limited. A year later, we transitioned to **ROS** as our primary communication system, incorporating an onboard computer and Ethernet connectivity. ROS's topic-based architecture allows efficient communication between multiple nodes, supporting transport protocols such as **TCP**, **UDP**, and **shared memory**. By integrating low-level system microcontrollers into ROS via the **Rosserial package**, we enhanced communication capabilities, enabling seamless interaction with other nodes and scripts. Additionally, the extensive ROS community provided ready-to-use packages, greatly reducing development time.

Web Communication between TCU and SBC

More recently, we further improved our communication system by integrating the **Rosbridge package**, which utilizes **webSockets** for fast, **real-time communication**. This enhancement enables seamless integration with web applications like our topside GUI while maintaining ROS's topic-based structure. Rosbridge converts ROS messages into JSON format and transmits them via webSockets, improving both efficiency and responsiveness.

Traditionally, ROS applications require a Linux-based environment with direct access to ROS nodes, which limits flexibility for remote interactions. Using Rosbridge, however, eliminates this barrier by serving as a middleware that converts ROS messages sent to and received from the ROV into a web-friendly format, allowing our web-based GUI to communicate with it in real time through WebSockets.

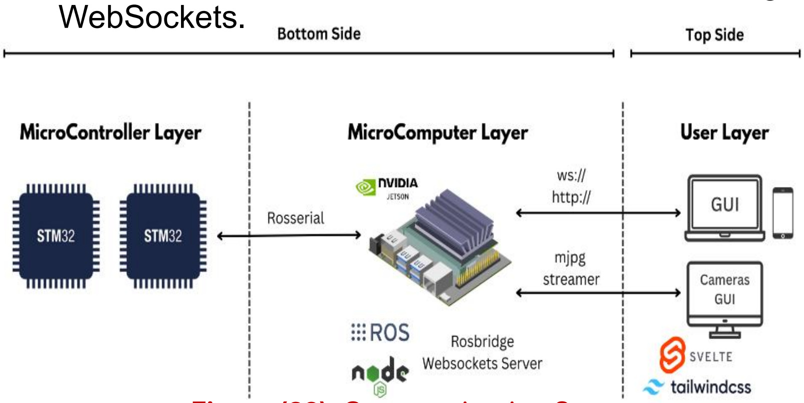

Figure (32): Communication System

Topside Control System

Web-Based GUI Functionality

The aim of the GUI is to maximize Nexus's capability by providing the user **full control**, real-time **status monitoring**, **camera streaming** and, **sensor data display**. And this year, the GUI provides features to aid our company's engineers in developing the ROV by providing **terminal to the SCB** and **commands to deploy embedded software**-all while making it intuitive and as simple as possible to the user, hence why this year's GUI features **7 tabs** to enhance functionality and organization, offering more space and features without cramping the interface. The GUI is completely portable as in the client can use any number of devices anywhere without internet or the need of downloading any dependencies or set up anything, as all they need is to simply connect the controller to the host device, all thanks to the transition from desktop-based to web-based for the third year in a row.

Automation Scripts

For a **quick** and **seamless startup**, we automated the launch of all critical systems on our Jetson Nano. Camera streaming, thruster control, the GUI, and other essential scripts run automatically at system startup, eliminating the need for manual setup and enhancing reliability.

Software MVC Architecture

Due to the ever-increasing size of the GUI, extensibility and reactivity become crucial. To address these challenges, the **MVC model** and the **observer design pattern** are utilized extensively. Main technologies used are **Svelte** for highly reactive and efficient frontend, **Tailwind** for its large customizability, **Rosbridge** for communication with the ROS topics via WebSockets, and **Node.js's Express framework** for simple server-side communication and data access with the SCB.
Svelte was chosen for the second year in a row for its smooth learning curve, great integration with tailwind, and highly efficient compiler, which transforms code at build time into lightweight, vanilla JavaScript. This results in smaller, faster files with no Virtual DOM overhead, making it more efficient to serve compared to other frameworks. Express was chosen due to its wide range of libraries and middleware to choose from all the while maintaining a simple smooth learning curve.

Dockerization

To ensure **consistency**, **portability**, and **efficiency**, we integrated **Docker** into our system architecture. By containerizing our software, we maintain a uniform environment across different hardware platforms like the Jetson Nano and the topside computer, eliminating compatibility issues and enabling seamless deployment across devices.

Figure (33): Control GUI Components

Vision System

MJPG Streaming

Nexus employs MJPG (Motion JPEG) streaming for video transmission. MJPG encoding significantly enhances performance as it uses **C++**, ensuring efficient image processing and minimal latency. This encoding method provides a balance between image quality and bandwidth efficiency.

Table (6): Camera Streaming Comparison

Feature	MJPG-streamer	FFmpeg	GStreamer
Performance	High	Moderate	High
Power Consumption	Low	High	Moderate
Hardware Acceleration	✗	✓	✓ (via plugins)
Latency	Low	High	Low
Processing Overhead	Low	High	Moderate

ZED 2 Stereo Camera

The ROV features a **ZED 2 stereo camera**, a high-resolution depth-sensing camera used for **stereo measurement**. The ZED 2 camera enables **3D mapping, object detection, and distance estimation**, which are essential for navigation and obstacle avoidance.

Software and Integration

The MJPG streams are transmitted via the Nvidia Jetson, which encodes and distributes the video feeds efficiently. The GUI is designed to receive, process, and display the camera feeds in real time, providing an intuitive interface for operators. The ROS-based ZED 2 camera stream integrates with the ROV's control system, enhancing autonomous navigation and object recognition capabilities.

Stereo Calibration

We calibrated our ZED 2 stereo camera, achieving a resolution of 0.2 cm. It was used for measuring the **shipwreck length** in (Task 1.1). Once the pilot locates the target, the copilot marks its endpoints, and the system calculates the length using a **disparity map** technique.

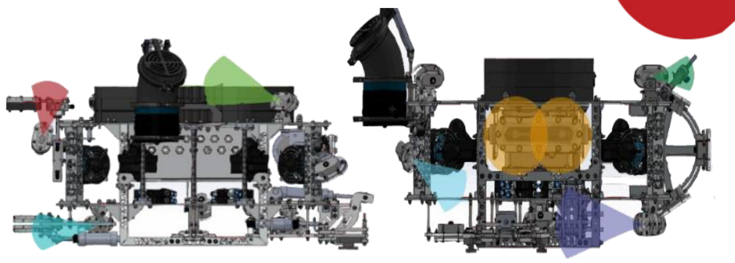

Figure (34): Cameras' FOV

Photosphere

During initial trials, various methods were researched and tried to capture a complete photosphere while ensuring complete target coverage, **minimizing distortion**, and achieving seamless and fast stitching of the images. As shown in Table(7), we decided to continue with **PTGui**.

Table (7): Photosphere Software Comparison

Software	Flexibility	Time	Reliability	Quality	Automation
OpenCV	High	Very High	Low	Moderate	✓
Hugin	Moderate	High	Moderate	Moderate	✓
Photoshop	High	High	High	High	✗
PTGui	Moderate	Moderate	High	High	✓

Photosphere Multi-Camera Setup: Three cameras were used: one ZED2 (120° horizontal FOV) mounted on a servo for vertical rotation, and two Rapoo cameras (80° FOV) capturing top and bottom views. This setup ensures full vertical coverage with overlaps. As the ROV rotates, images are taken at set angles to achieve horizontal coverage with **minimal number of cameras**.

Further refinements: We developed a script as a contingency measure to address blind spots in photospheres. It processes a photosphere by converting it into a cube map, inpainting any blind spots using the AI-pretrained **Mask-Aware Transformer** for Large Hole Image Inpainting and then reconstructing the corrected photosphere.

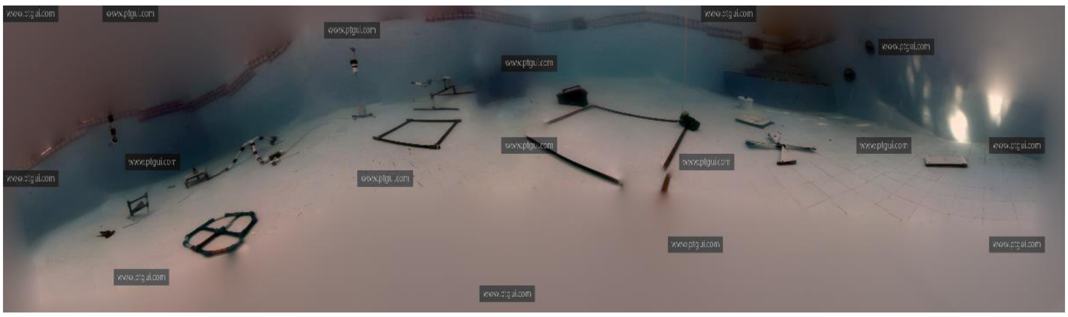

Figure (35): PTGui Result

2. Safety

2.1 Safety Philosophy

At M.I.A Robotics, safety is a cornerstone of our operations. We are committed to creating a secure and comfortable work environment for all company employees by proactively identifying and mitigating risks before they escalate into unsafe situations.

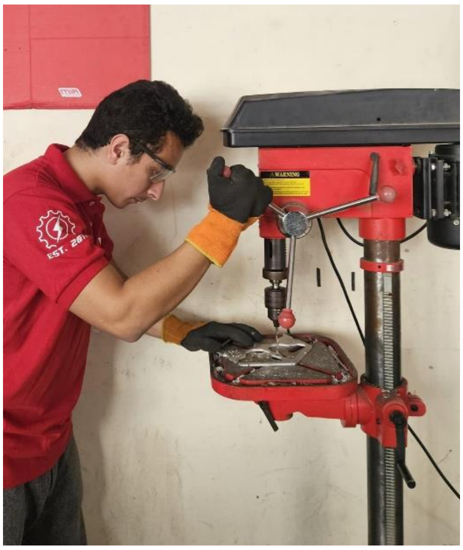

Figure (36): Safety Measures Taken While Working

2.2 Awareness Training

Although our workspace is compact, we operate at peak efficiency by maintaining a structured and collaborative environment. Each year, as new employees join our company, we emphasize the importance of adhering to our strict **code of conduct**. These guidelines ensure that every company employee can focus on innovation, collaboration, and productivity without distractions. By fostering a culture of respect and professionalism, we create an environment where everyone can thrive and contribute to our shared success.

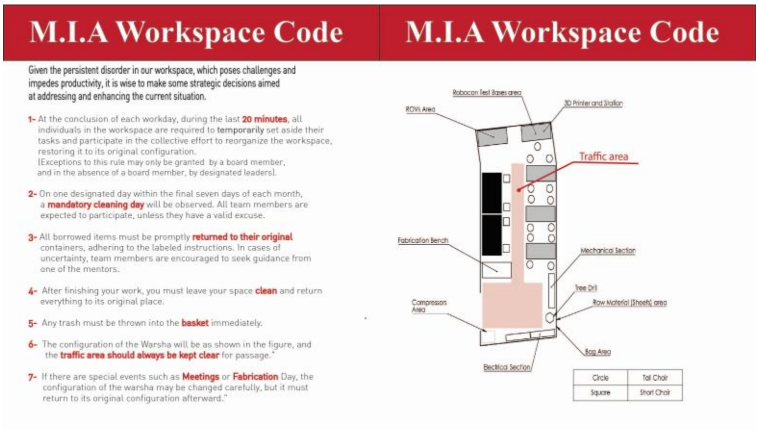

Figure (37): Workspace Organization Code

2.3 Safety Standards

At M.I.A Robotics. All company employees are required to adhere to our comprehensive standards of operation. Before operating Nexus, new employees must complete mandatory hazard training to ensure both their safety and the integrity of the equipment.

A dedicated **Safety Director** oversees all operations to ensure strict compliance with our safety protocols. This includes verifying that all employees follow the detailed safety checklist **(refer to Appendix B)** during pool tests and other activities.
Additionally, **personal protective equipment (PPE)** is always mandatory when operating Nexus or working with hazardous equipment.

2.4 Safety Features

Nexus is equipped with comprehensive **safety features** integrated into both its **mechanical** and **electrical systems**. The frame is meticulously sanded to eliminate sharp edges, and all bolts are securely covered to prevent injuries. Thruster propellers are fitted with protective shrouds, ensuring safe handling during operation.

The tether features strain-relief mechanisms on both ends to safeguard connectors and maintain reliable, uninterrupted connections. Additionally, a properly sized fuse is installed 30cm from the Anderson Power-pole connectors to prevent electrical hazards. For added safety, kill-switches are installed on the main power supply unit and the TCU, allowing for immediate power shutdown in emergencies.

To further enhance safety, the **electronics housing**, **thrusters**, and **cameras** are fully waterproofed, preventing short circuits and eliminating risks to personnel. These features collectively ensure a secure and efficient operational environment for both Nexus and its handlers.

Figure (38): T200 Shrouded Thruster

3. Testing and Troubleshooting

3.1 Testing Strategy

To ensure the ROV's reliability and performance, a thorough and systematic testing process was implemented across all subsystems to allow us to validate functionality, identify potential issues, and optimize the system for both normal and extreme operating conditions. By conducting rigorous tests, we ensured the ROV was mission-ready and capable of handling the challenges of underwater environments.

Electrical Testing

Component Testing: Each electrical component was individually tested for proper operation and compatibility with the overall system. Diagnostic tools, such as oscilloscopes, were used to identify and address potential issues. Theoretical power consumption calculations were compared with practical readings to ensure stable power delivery under full load.

Circuit Simulation: Before fabrication, circuit simulators were used to analyze voltage and current for every wire and component. Prototypes were built and tested to validate functionality, and components were continuously checked during PCB assembly to catch faults early in the process.

Software Testing

HTTP and WebSocket Server Testing: Our APIs were tested using endpoint testing software like Postman to ensure valid communication with our APIs, ensuring seamless data exchange and enabling reliable mission execution.

Performance Testing:

- Latency Testing: Measure between user inputs as joystick movements and the ROV's response to ensure real-time control.
- Resource Usage Testing: Monitor CPU, memory, and network usage to ensure the software runs without overloading the system.

ROS-Based Testing: The Robot Operating System (ROS) was utilized for live logging, debugging, and communication between system nodes. Its extensive libraries and packages simplified testing, while our custom GUI provided easy access to logs for real-time monitoring.

Figure (39): Nexus GUI Debugger and Logger

Mechanical Testing

Sealing Test: The electronics enclosure underwent rigorous testing to ensure it remained watertight under high-pressure conditions. Using a hydrostatic pressure test unit, the enclosure was filled with water, and pressure was gradually increased to 6 bars, equivalent to a depth of 60 meters. This far exceeds the competition's standard of 5 meters, ensuring the ROV can operate safely in deeper and demanding environments.

Pneumatic Test: All pneumatic circuits were visually inspected and tested multiple times to verify proper connectivity and performance. Each joint and connection was carefully examined to ensure the system operated safely and efficiently during missions, minimizing the risk of leaks or failures.

Mission-Specific Testing

We ensured competition readiness through mission-specific tests, which led to refinements in camera angles, navigation, stability, and manipulators' designs. Simulations of tasks like photosphere capture, object retrieval, and obstacle navigation also enhanced pilot performance.

Full System Test

Table (8): Testing Criteria

Full System Test
Dry Test
□ Power the control station
□ Connect the tether to the power supply
□ Verify the tone of the ESCs
□ Connect the Ethernet cable from the SBC and TCU
□ Verify Camera Feeding
□ Confirm all readings are read by the GUI
□ Connect the joystick
□ Test the thrusters with low speeds
□ Test the solenoids (grippers)
□ Test the ZED's servo and motor functionalities
□ Initiate underwater test
Underwater Test
□ Adjust flotation
□ Test motion and ensure the ROV moves
□ Test and adjust PID settings if necessary

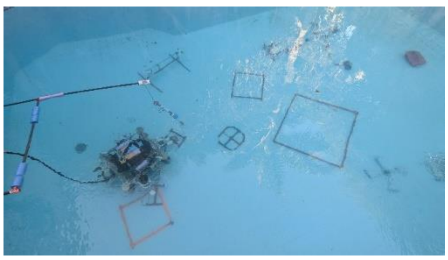

Figure (40): Nexus in a Trial Run

3.2 Troubleshooting Strategy

Nexus followed a structured and methodical troubleshooting process to ensure the ROV operated reliably before any dry or underwater testing. Throughout development and testing, we encountered various challenges, which we addressed using an effective "**isolate, divide, and conquer**" strategy. Each issue was first categorized as mechanical, electrical, or software-related, then broken down into smaller components to pinpoint the root cause and implement a targeted solution.
See the troubleshooting flowchart in **Figure (41)**.

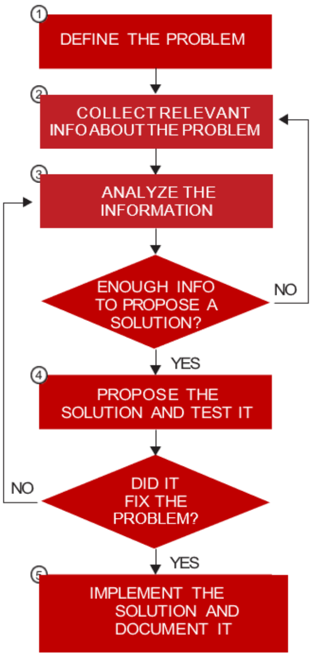

Figure (41): Troubleshooting Flowchart

Mechanical Troubleshooting

Mechanical issues, such as pneumatic manipulator malfunctions, were diagnosed by systematically testing the pneumatic circuit. The team checked whether the air compressor maintained the correct pressure, inspected for leaks in hoses, fittings, and piston seals, and tested each component sequentially using a pressure gauge to ensure proper air distribution and actuator function.

Electrical Troubleshooting

Electrical issues, such as voltage converter failures under full load, were diagnosed by isolating components and using oscilloscopes to pinpoint faults. Faulty parts were replaced to restore stability and optimize power distribution.

Software Troubleshooting

For software challenges like algorithm inefficiencies and node communication delays, we used the Jetson microcomputer running Ubuntu OS to inspect kernel logs, optimize drivers, and debug performance bottlenecks. Logs were systematically analyzed, and incremental debugging was performed to ensure that fixes did not introduce new issues elsewhere in the system.

4. Logistics

4.1 Teamwork

M.I.A. Robotics, part of Alexandria University's Faculty of Engineering, unites students from electrical, mechanical, software, AI, and media teams to develop cutting-edge robotic solutions, culminating in the Nexus ROV project. Our organizational structure consists of Board Members, including a **CEO**, **CTO**, **CFO**, and **ESG**, who oversee strategy, budgeting, recruitment, and project execution. Each subteam is led by a **leader**, with some teams also having a **vice-leader** to facilitate operations, ensuring smooth onboarding of new members and breaking down major tasks into manageable assignments. Additionally, our Advisory Committee, composed of **supervisors** and **mentors**, provides invaluable guidance, aiding in decision-making and project advancement. Company Structure in **Appendix(A)**.

4.2 Project Management

At M.I.A. Robotics, maintaining and building upon our technical expertise is a top priority. To ensure a seamless transfer of knowledge and continuous innovation, we allocate substantial time at the start of each season to recruiting and training new members. Our workflow is structured, as in **Fig(44)**, into five key phases:

- **Training and R&D Phase**: This initial phase focuses on equipping new members with essential skills while conducting research and development to improve our robotic capabilities.
- **Application and ROV Design Phase**: In this stage, findings from Phase 1 are applied to the design and development of the ROV, refining its core systems.
- **Mission Specification Brainstorming Phase**: Following the release of the Request for Proposal (RFP), this phase is dedicated to defining mission objectives and aligning them with MATE competition requirements.
- **Intensive Testing Phase**: The final phase subjects the ROV to rigorous testing to verify its electrical and mechanical stability, ensuring optimal performance before the competition.

- **Post-Competition Review and Strategic Planning Phase**: After the competition, the team assesses challenges, analyzes performance, addresses design flaws, and refines strategies for future improvements. Insights from other teams contribute to continuous learning and optimization.

Resources, Procedures, and Protocols

To enhance efficiency and collaboration, we have adopted **Agile methodologies** for project management and software development. This approach allows for greater flexibility, continuous improvement, and iterative development. We utilize the following tools to streamline our workflow:

- **Discord:** Selected for its real-time communication capabilities, automation features, and integrated voice/video calls, facilitating **biweekly team meetings** and live updates.

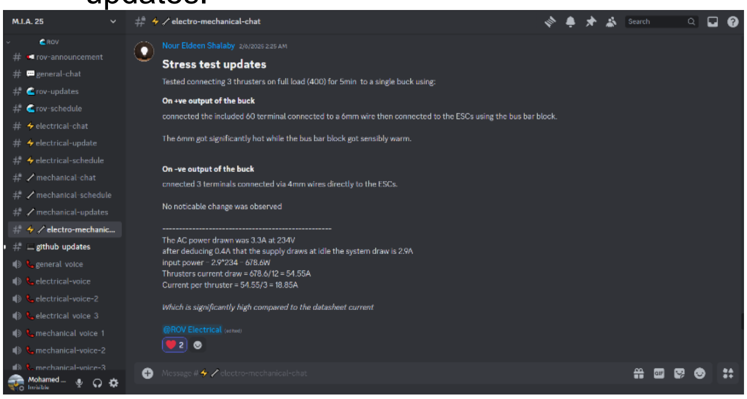

Figure (42): M.I.A. Discord Server

- **GitHub**: Supports Continuous Integration and Continuous Deployment (CI/CD), providing **version control**, issue tracking, and code reviews, ensuring seamless software integration.

- **Notion**: Used for sprint planning and documentation, with **Kanban boards** to track progress and organize tasks efficiently.

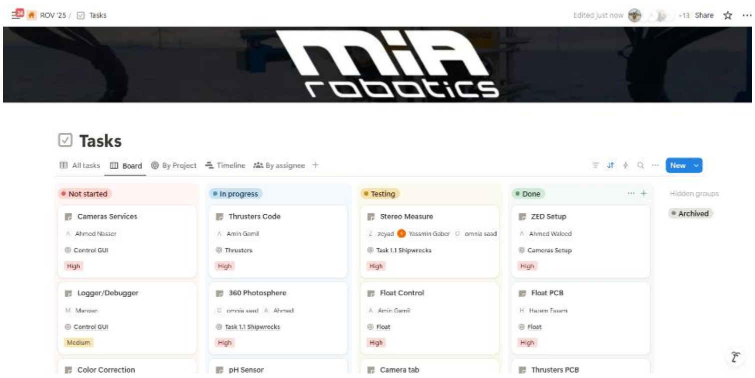

Figure (43): M.I.A. Notion Kanban Chart

In our team meetings, members present **slides** detailing their ongoing projects, including recent achievements, current tasks, blockers, and plans for the upcoming week. This open forum fosters transparency, allowing for immediate feedback, insight sharing, and swift resolution of challenges. By encouraging open discussions about designs and strategies, we ensure that operational issues are rapidly identified and addressed, strengthening overall team efficiency.

4.3 Accounting

Creating an estimated budget for the season marks one of the initial responsibilities shouldered by the company's board, essential for strategic planning throughout the project. With ten years of experience in MATE ROV, each season's budget reflects a combination of past expenditures and anticipated new costs.

Due to global and local inflation, we adopted a cautious budget estimation approach, intentionally overestimating certain costs by a small percentage to account for potential price increases. Additionally, our company has implemented strategic fundraising initiatives, getting discounts from our partners and cost-management measures to mitigate financial risks and ensure budget stability.

For a comprehensive breakdown of the budget, refer to **Appendix (F)** for a detailed analysis.

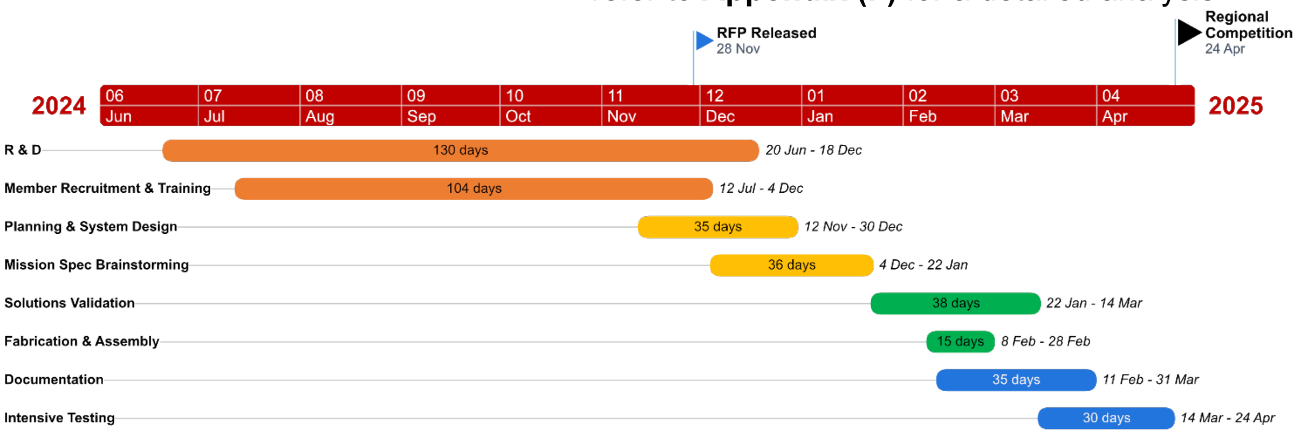

Figure (44): Timeline for MATE ROV 2025 Competition

5. Conclusion

5.1 Build vs Buy, New vs Used

M.I.A. follows a **strategic reuse approach**, repurposing ROV components that meet performance requirements without creating bottlenecks. This reduces costs, improves reliability, and lets us focus on critical upgrades.

Reused Components

Some components from previous years were retained for their **compatibility and cost-effectiveness. See Appendix(F) for more details.**

Table (9): Reused Components

Component	Purpose	Reason for Reuse
T200 Thrusters	Propulsion	High performance, fully compatible with this year's design
Zed2 Stereo Camera	Vision System	Essential for **Task 1.1 - (Shipwreck Measurement)**, remains compatible
Jetson Nano	Microprocessor	Provides sufficient **GPU processing power** for this year's system

Custom-Built Components

When off-the-shelf solutions were cost-effective, like the **pH sensor for Task 1.3**, we **used** them; otherwise, we built in-house alternatives for better compatibility and value.

Table (10): Custom-Built Components

Component	Purpose	Reason for Build
Topside Control System	Software/Vision	Fully **custom-built GUI, streaming, and color correction** for tasks like **Photosphere (Task 1.1)**
Pressure Sensor	Motion Control	Provides **precise depth-based motion** at a fraction of the cost of commercial alternatives
Sealed Servo Motor	Zed2 Camera Actuation	Cost-effective alternative to expensive underwater servo motors

Leveraging Past Designs

We maintain an **archive** of all mechanisms from our 10 years of participation in MATE, refining and reusing designs with lessons learned. For instance, our **Fish Species mechanism (Task 2.2)** was enhanced based on past iterations, improving efficiency. This approach ensures continuous improvement while balancing cost, performance, and innovation.

5.2 Lessons Learned

This year's ROV development strengthened **teamwork, leadership, and problem-solving** skills. Facing challenges in sourcing unavailable components locally, we learned to **design and build custom solutions**, improving our adaptability. The rising **inflation rate** also impacted our financial plans, teaching us **cost management and resource optimization**. Additionally, tackling **R&D projects** enhanced our problem-solving approach, paving the way for **more advanced future ROVs**. Through it all, we refined **project management, budgeting, and sponsorship outreach**, gaining hands-on experience in **financial planning, negotiation, and strategic decision-making,** critical for professional growth.

5.3 Future Plans

In the upcoming years, a key objective for us is to create a **Virtual Reality (VR)** experience that simulates the sensation of being an ROV, embarking on exciting adventures. To enhance our capabilities in **Autonomous** movement, we plan to employ advanced cameras and sensors, such as Sonar, for more accurate **Localization**.

5.4 References

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6- Appendix

A- Company Structure

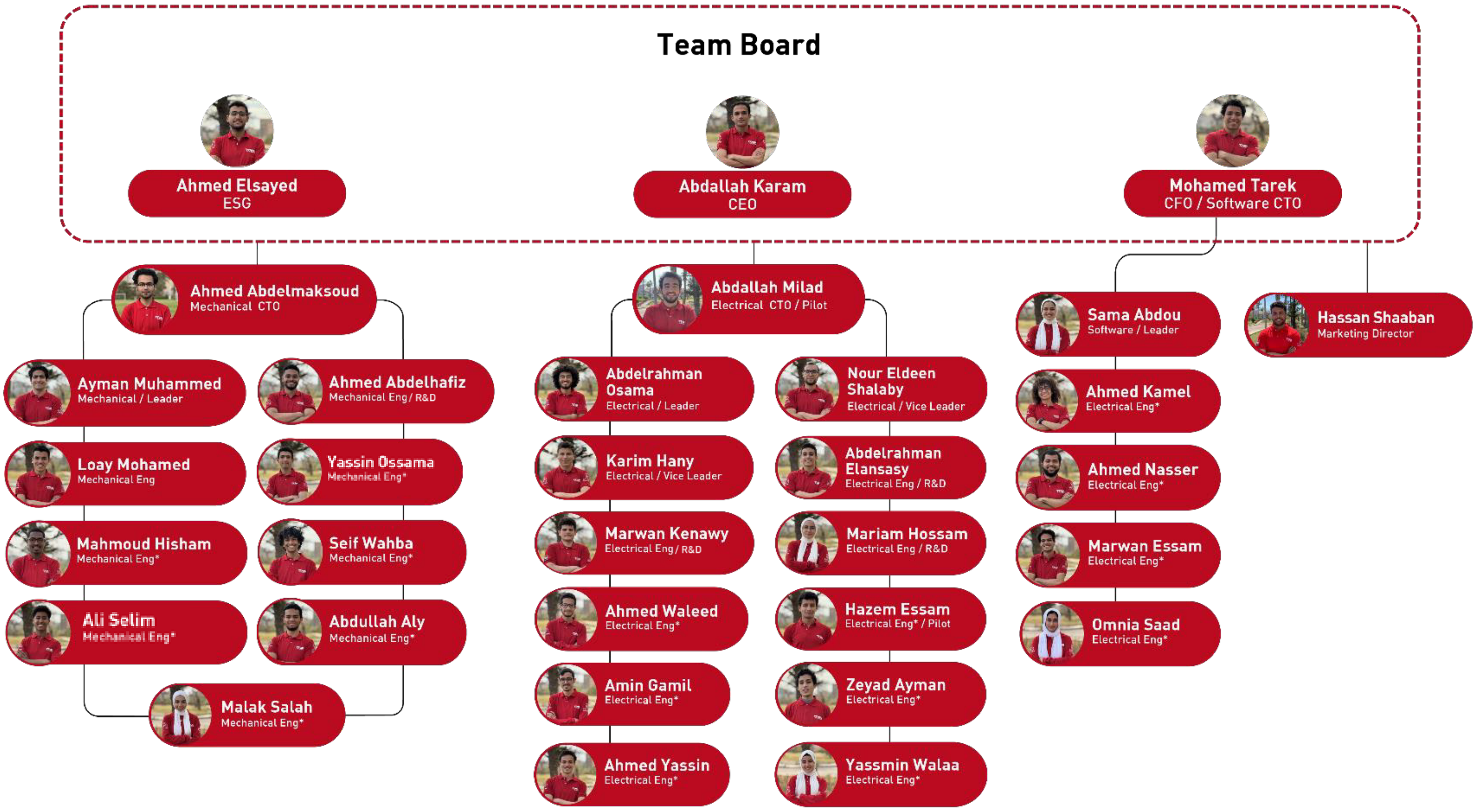

Figure (45):M.I.A. ROV Company Structure

B- Safety Checklist

Table (11): Safety Checklist

Construction	Operation	
	Pre-Power Test	**In Water**
□Keep the workspace clean and free of debris.	□ Area safe (no tripping hazards, items in the way)	□ Check for bubbles, if large, pull ROV to surface
□Store materials properly to prevent tripping hazards	□ Verify switches and circuit breakers are off	□ Visual inspect for water leaks
□Use safety goggles or face shields when cutting and grinding.	□ Tether flaked out on deck secured to ROV	□ Engage thrusters and begin operations
□Use appropriate gloves for handling materials	□ Strain relief connected to ROV	**Loss of Communication**
□Inspect all machinery for any damage or wear before use.	□ Electronics housing sealed	□ Cycle power on TCU to reboot ROV
□Ensure all guards and safety devices are in place and functioning.	□ Visual inspection for damaged wires	□ If no communication, power down ROV
□Follow manufacturer's instructions and safety guidelines.	□ Nuts tight on electronics housing	□ If communication is restored, resume operation
□Ensure all energy sources are properly isolated before servicing.	□ Thrusters free from obstructions	**Pit Maintenance**
□Store materials securely to prevent falls or spills.	□ Set compressor output to 2.75 bar Power Up	□ Verify thrusters are free of foreign objects
□Inspect electrical cords for damage before use.	□ Power source connected to TCU	□ Visual inspection for any damage
□Ensure proper grounding of electrical equipment.	□ TCU receiving 48 Volts nominal	□ Ensure that all cables are neatly secured
□Disconnect power when changing accessories or making repairs.	□ Control computers up and running	□ Verify tether is free of kinks
	□ Ensure deck crew members are attentive	□ Visual inspect for leaks
	□ Power on TCU	□ Test onboard tools
	□ Verify thrusters are working properly	□ Verify camera positions
	□ Verify video feeds	□ Washdown thrusters with water

C- Pneumatic SID

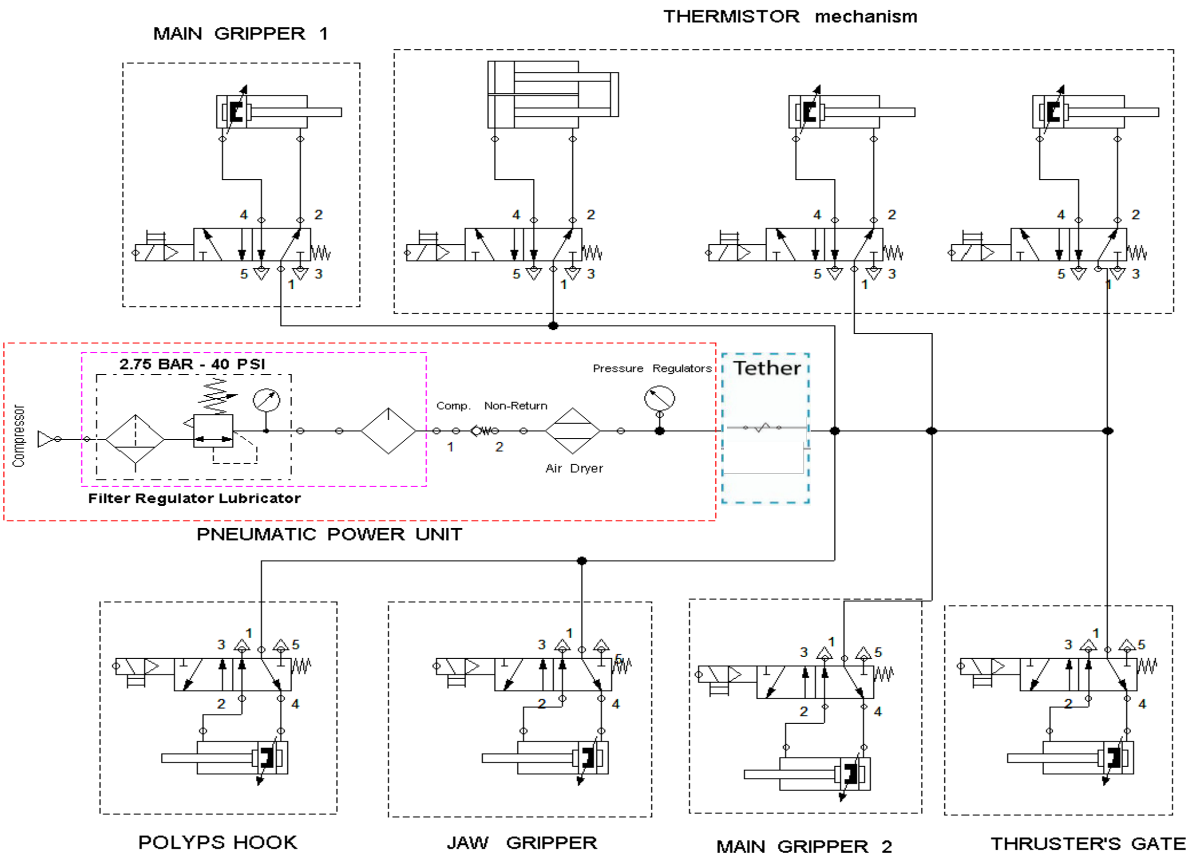

Figure (46): Nexus Pneumatic SID

D- Electrical Power Budget

Table (12): Nexus Power Budget

Componen t(s)	Voltage Drop / Item (V)	Nominal Current / Item (A)	Max Current / Item (A)	Nominal Power / Item (W)	Max Power / Item (W)	Qty.	Total Nominal Power Consumption (W)	Total Max Power Consumption (W)
IMU Sensing Unit	5	0.0159	0.0159	0.0795	0.0795	1	0.0795	0.0795
STM32	5	0.15	0.15	0.75	0.75	2	1.5	1.5
Movment Thrusters	12	6	10	72	120	8	576	960
Solenoids	12	0	0.3	0	3.6	8	0	28.8
Jetson Nano	5	2	4	10	20	1	10	20
Buck Converters (48-12)	0.48	6	8	2.88	3.84	3	8.64	11 .52
Buck Converter (48-5)	0.2	6	6	1.2	1.2	1	1.2	1.2
Buck Converter (12-5)	0.5	6	6	3	3	1	3	3
AWG10 Tether	0.03552	30	30	1.0656	1.0656	200	213.12	213.12
Rapoo Camera	5	0.3	0.5	1.5	2.5	7	10.5	17.5
ESCs	12	0.3	0.3	3.6	3.6	9	32.4	32.4
Suction Thruster	12	0	8	0	96	1	0	96
pH Sensor	5	0.025	0.025	0.125	0.125	1	0.125	0.125
Diaphragm Pump	12	1.2	1.2	14.4	14.4	1	14.4	14.4
ZED2 Stereo Camera	5	0.38	0.38	1.9	1.9	1	1.9	1.9
Servo Motor	8.4	1.5	2	12.6	16.8	1	12.6	16.8
Total							885 .4645	1418 .3445
Max current drawn from MATE Power Supply (A) / Full Load Amps (A)							29.5488437 5	
Fuse Value (A)							30	

- Primary component which provides foundational functionality for ROV's system in various aspects: **(such as power regulation, 6-DOF motion, controlling manipulators for mechanical tasks, feedback and stablization).**
- Specialized for task 1.1: ***(Determine type of ship - Determine cargo of ship - Identify shipwreck - Create 360° photosphere image)***
- Specialized for task 1.1: ***(Determine length of ship)***
- Specialized for task 1.3: ***(Determine the pH of the water sample - Measure the dissolved $CO2$ levels of the water sample)***
- Specialized for task 2.2: ***(Collect fish species aggregated underneath the solar panel array)***

Note: Any color combination indicates multiple functionality for the same component(s).

Our power system consumes ≈ **1418.3445 W** at maximum consumption, which is indeed considered high for long-term and continuous use. This also limits further additions and challenges our modularity-based ideology.
So, we have established the following protocols to limit the system for the desired mission:

1. Manipulators shouldn't all be turned on at the same time, only those needed for the desired mission.
2. Vertical thrusters and lateral thrusters are regulated by a power management algorithm, which in turn disables the ability for both to be on simultaneously without noticeable limitation in movement.
3. Rapoo cameras are divided into two sets:
General Purpose Set = **{6 Cameras}**
Photosphere Set = **{2 Cameras(in addition to ZED2 as a non-rapoo camerainvolved in task 1.1)}**
with **one common** camera shared between both sets, such that only one set is active (neglecting the common camera which is always ON), this depends on the desired mission.

These protocols have been established through software optimizations with intentional limitations and a well-trained pilot who is aware of our power-efficient control system.
As a result, we have achieved a maximum power consumption of **1009.4395 W**, observed during **Task 2.2:** ***"Collect fish species aggregated underneath the solar panel array".***

E- Electrical SID

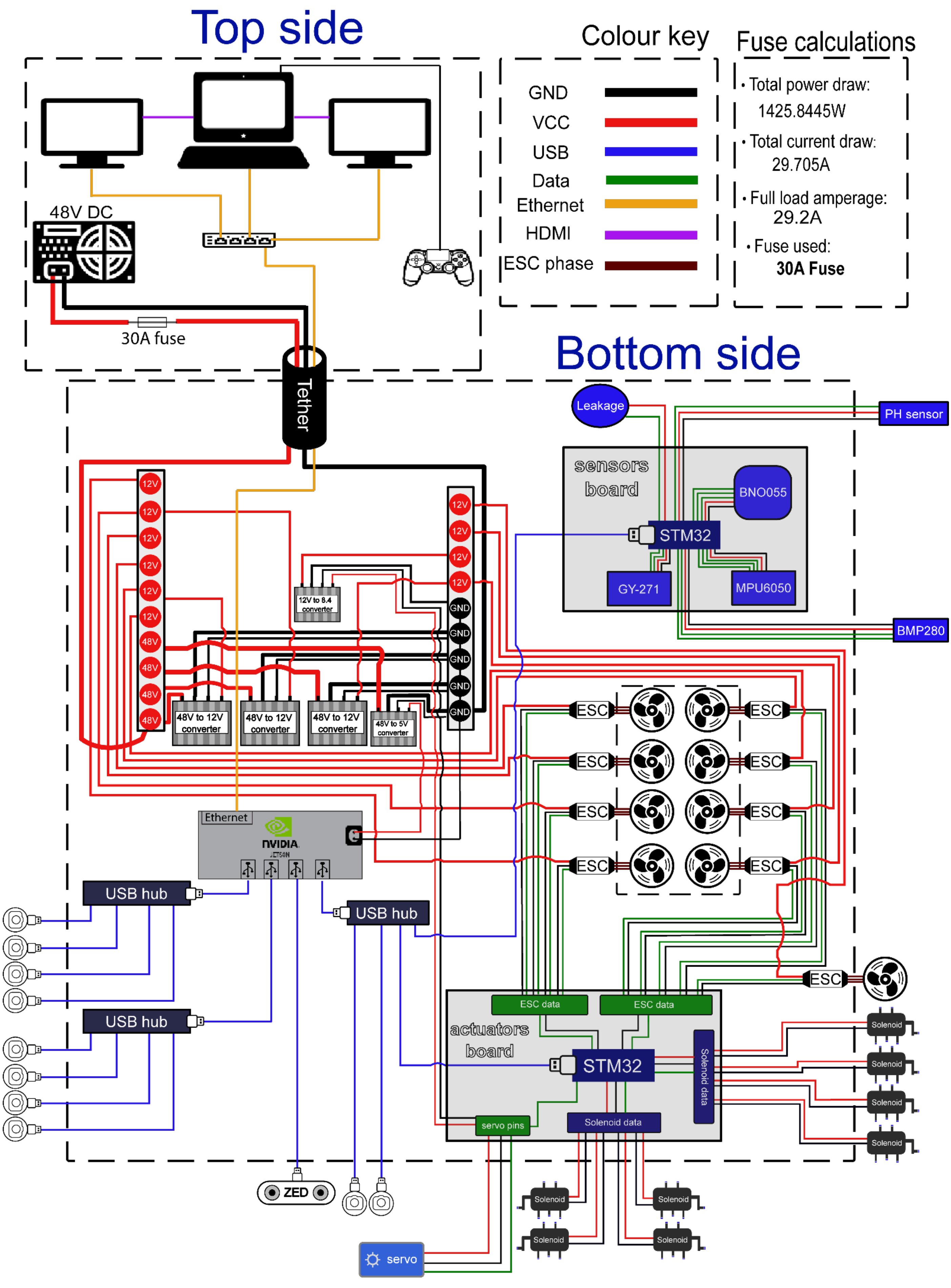

Figure (47): Nexus Electrical SID

F-Budget Planning

Table (13): Budget Planning

Budget Planning (From 1/8/2024 to 14/4/2025)
1 USD ≈ 50.5 EGP

Category	#	Type	Item(s)	Description	Amount (USD)	Projected Value Per Category (USD)	Budgeted Value Per Category (USD)
			Incomes				
Incomes	1	Cash Raised	YLF	Won the 1st place at "YLF 2024" competition supervised by Youth Leaders Foundation.	1980		
	2	Cash Raised	UWRC (Underwater Robotics Challenges)	Won the 1st place in both ROV and AUV challenges	660		
	3	Cash Donated	MATE 2024 - Schmidt Ocean	Scholarship from MATE last season (500 left out of 2000)	500		
	4	Cash Raised	Employee Dues	Each member pays a certain amount	5200		
			Raw Material				
Mechanical – Categories	1	Purchased	Aluminum Sheet (7075-T651 Alloy)	External Frame Material	170		
	2	Purchased	Aluminum Sheet (5083 Alloy)	Enclosure Material	75		
	3	Purchased	Aluminum Sheet (5754 Alloy)	Mechanisms Material	60		
	4	Purchased	PLA+ Filament	3D Printing Material	33		
	5	Purchased	Acrylic Sheet	Cameras' Casing Cap, Mechanisms, Enclosure Electrical Structure	25		
	6	Purchased	Aluminum Extruded Links (6063 Alloy)	Frame Material	21		
	7	Purchased	HDPE Sheet	Mechanisms Material	60		
	8	Re-used	Carbon Fiber Rods	External Frame Material	43.5		
			Machining Services				
	1	Purchased	Laser Cutting	Aluminum Sheet and Extruded Links	60		
	2	Purchased		Aclyric For Mechanisms & Camera Casings	11		
	3	Purchased	Milling	Camera Casings	14		
	4	Purchased		Aluminum For Enclosure	14		
	5	Purchased		ZED Camera Motor Casing	12		
	6	Purchased	Turning	Motor Couplings	12		
	7	Purchased		PH Mechanism	3		
	8	Purchased	Router	HDPE Cutting For Mechanisms	38		
	9	Purchased	Metal Forming	Sheet Metal Parts	13	1155.78	972.7
	10	Purchased	Welding	Electrical Enclousure Joining & Frame	28		
			Pneumatic Components				
	1	Re-used	Air Compressor	Fluid Power Supply	125		
	2	Re-used	Pneumatic Regulators		14.58		
	3	Purchased	Pneumatic Hoses	Fluid transportation Lines (ROV Tether and Internal Connections)	13.5		
	4	Purchased	Pneumatic Fittings and Connections		12.4		
	5	Purchased	5/2 Solenoid Actuated - Pilot Operated DCVs	Control Actuators' Direction	30		
	6	Purchased	Pneumatic Actuator	Linear Actuators	67		
			Miscellaneous				
	1	Purchased	4020 Aluminum Brackets	Frame Structure	20.2		
	2	Purchased	Fasteners	Bolts, Nuts and Washers for Fixation	65		
	3	Purchased	T200 Propellers	Maintenance For The Re-used Thrusters	30.3		
			Sealing Components				
	1	Purchased	O-rings	Electrical Enclosure & Cameras' Casings	26.3		
	2	Purchased	Wire Glands	Wires Sealing	32		
	3	Purchased	Teflon	Threads' Sealing	3		
	4	Purchased	Mechanical Seals	Dynamic Seal for The Motors	1.5		
	5	Purchased	Epoxy	Wires Sealing	22.5		
			Equipment				
General – Categories	1	Re-used	Electric Screw Driver	Small-Job Fabrication	48		
	2	Purchased	Circlip Pliers, Crimpers		12.6		
	3	Re-used	Crimpers, Wire Cutters/Strippers		12		
	4	Re-used	Driller, Grinder, Tree Drill and Snappers		290		
			Research, Development and Prototyping				
	1	Purchased	2x Diaphragm Pump	Mechanisms Material	8.6	464	374
	2	Purchased	Aluminum Extrusion Welding	Strength Testing	5		
	3	Purchased	Aluminum 7075-T651 Laser CNC Cutting	Aluminum Machining Process (Optimum Selection)	3.5		
	4	Purchased	Floatation Boards	New Technique For The Buoyancy	49.2		
	5	Purchased	Bladder	Float	2.6		
	6	Purchased	Water Flow Sensor	Float	2.5		
	7	Parts Donated	Cloud Hosting	Control GUI and Website	30		
			Vision System				
Electrical – Categories	1	Re-used	1x Stereo ZED Camera	-	449		
	2	Re-used	5x Digital Mono Camera		178.6		
	3	Purchased	5x Digital Mono Camera	-	178.6		
			Sensors				
	1	Purchased	BMP Presure Sensor	For ROV Motion Feedback	1.5		
	2	Re-used	BNO55 Sensor		15.6		
	3	Re-used	MPU6050		2.5		
	4	Purchased	PH Sensor		32		
	5	Purchased	Leakage Sensor	For Safety	0.5		
			Electrical Components				
	1	Purchased	3x DC-DC Converter (48V to 12V)	For Voltage Step-down	140		
	2	Re-used	DC-DC Converter (48V to 5V)		9.5		
	3	Purchased	30m 10M CAT6 6e Ethernet Cable	For ROV Tether	15		
	4	Purchased	30m Power Cable 10AWG		150		
	5	Purchased	Connectors, Data Headers and Cables	PCB Power and Communication	13	3581.8	577.6
	6	Re-used	9x Blue Robotics T200 Thrusters	8x For ROV Movment 1x For Ping Pong Mechanism	1800		
	7	Re-used	9x Blue Robotics ESCs	For thrusters' control	224		
	8	Re-used	4x USB Hub	-	10.2		
	9	Purchased	1x Diaphram Pump	Water Sample Mechanism	5		
			Microprocessors				
	1	Re-used	Jetson Nano	Main Computer of the ROV	291.1		
	2	Purchased	4x STMs 32F103C8, 2x ESP32S	Microcontroller	15		
			PCB Fabrication				
	1	Purchased	Etching Solution Acid	-	2		
	2	Purchased	3x Soldering Paste Flux	-	2		
	3	Purchased	Fiber glass PCB Boards	-	16		
	4	Re-used	2x Hot Gun	Tools	5.1		
	5	Re-used	2x Digital Soldering Iron		16.6		
	6	Re-used	3x Desoldering Pump 366-D		2		
	7	Purchased	Tin Lead Soldering wire Sn63/Pb37	-	7		
			Top Side Control Unit				
Operation – Categories	1	Re-used	Station Box	Station Components	59.2		
	2	Re-used	2K Screen Monitor		60		
	3	Re-used	PS5 Controller		95		
	4	Re-used	Power supply		485		
	5	Re-used	Switch Connector		13		
	6	Re-used	Fuse Holder	For Safety	11.91		
	7	Purchased	30A - Fuses		11		
	8	Re-used	Anderson Connector		11.3		
			Propbuilding				
	1	Purchased	PVC	For building the underwater playground to test the ROV missions	50	882.61	114
	2	Re-used	PVC		20.2		
	3	Purchased	Extra Items (Example: Ping pong balls)		15		
			Safety				
	1	Re-used	2x Life Jackets	Tethermen's Safety	13		
	2	Purchased	Water Resisting Shoes		12.5		
	3	Purchased	2x Safety Goggles		6.5		
	4	Purchased	Non-slip Gloves		5		
	5	Purchased	4x Ear Plugs		1		
	6	Purchased	3x First Aid Kit	For Workshop	13		
			MATE ROV Competiton				
Administration – Categories	1	Purchased	MATE ROV Registration Fees	International Competiton	390		
	2	Purchased	MATE ROV Registration Fees	Regional Competition	260		
	3	Purchased	Fluid Power Quiz Fees	-	35		
			Marketing Purposes				
	1	Purchased	Poster	-	20		
	2	Purchased	Flyers	-	68	1847	1847
	3	Purchased	Banners	-	27		
	4	Purchased	T-Shirts	-	297		
	5	Re-Used	2x Flag	-	25		
			ROV Testing Logistics				
	1	Purchased	Villa Rent	With a swimming pool to test the ROV	700		
	2	Purchased	Transportation	Fuel, Tolls &material transportaion	25		

Total		Description
Total Costs (USD)	7931.19	Total costs of the project including the re-used items
Total Re-Used and Donation (USD)	3943.29	Donations and re-used items from the last years' project
Total Budget Allocated (USD)	3885.3	Expected budget at the beginning of the project
Cash Income (USD)	6360	Funds raised from the employees, prizes, and donations
Funds Needed (USD)	-	Total budget allocated minus cash income

Travel Expenses for 12 Memebers (From 14/6/2025 to 24/6/2025)

	Flight (USD)	Accomodation (USD)	Transportation (USD)
Per Member	850	180	30
Total	10,200	2,160	360
Total Members Travel Expenses			12,720
ROV Travel Expenses			2,250
Total Travel Expenses			14,970

Table (14): Project Costing

Project Costing (From 1/8/2024 to 14/4/2025)
1 USD ≈ 50.5 EGP

#	Type	Item(s)	Description	Amount (USD)	Project Cost(USD)	Running Balance (USD)
		Incomes				
1	Cash Raised	18	Won the 1st place at "YLF 2024" competition supervised by Youth Leaders Foundation.	1980		1980
2	Cash Raised	UWRC (Underwater Robotics Challenges)	Won the 1st place in both ROV and AUV challenges	660		2640
3	Cash Donated	MATE 2024 - Schmidt Ocean	Scholarship from MATE last season (500 left out of 2000)	500		1160
4	Cash Raised	AI Bootcamp	Holding a bootcamp to teach ML	60		1220
5	Cash Raised	Employee Dues	Each member pays a certain amount	5200		6420
		Raw Material				
1	Purchased	Aluminum Sheet (7075-T651 Alloy)	External Frame Material	164.4	164.4	6255.6
2	Purchased	Aluminum Sheet (5083 Alloy)	Enclosure Material	70.8	235.2	6184.8
3	Purchased	Aluminum Sheet (5754 Alloy)	Mechanisms Material	60.4	295.6	6124.4
4	Purchased	PLA+ Filament	3D Printing Material, Camera Rolls	32.2	327.8	6092.2
5	Purchased	Acrylic Sheet	Cameras' Casing Cap, Mechanisms, Enclosure Electrical Structure	24.7	352.5	6067.5
6	Purchased	Aluminum Extruded Links (6063 Alloy)	Frame Material	20.3	372.8	6047.2
8	Purchased	HDPE Sheet	Mechanisms Material	60.5	433.3	5986.7
9	Re-used	Carbon Fiber Rods	External Frame Material	43.5	476.8	5986.7
		Machining Services				
1	Purchased	Laser Cutting	Aluminum Sheet and Extruded Links	57.4	534.2	5929.3
2	Purchased		Aclyric For Mechanisms & Camera Casings	10.3	544.5	5919
3	Purchased	Milling	Camera Casings	13.8	558.3	5905.2
4	Purchased		Aluminum For Enclosure	13.2	571.5	5892
5	Purchased		ZED Camera Motor Casing	12.6	584.1	5879.4
6	Purchased	Turning	Motor Couplings	11.3	595.4	5868.1
7	Purchased		PH Mechanism	2	597.4	5866.1
9	Purchased	Router	HDPE Cutting For Mechanisms	36.8	634.2	5829.3
10	Purchased	Metal Forming	Sheet Metal Parts	13.2	647.4	5816.1
11	Purchased	Welding	Electrical Enclousure Joining & Frame	26.7	674.1	5789.4
		Pneumatic Components				
1	Re-used	Air Compressor	Fluid Power Supply	125	799.1	5789.4
2	Re-used	Pneumatic Regulators		14.58	813.68	5789.4
3	Purchased	Pneumatic Hoses	Fluid transportation Lines (ROV Tether and Internal Connections)	13.5	827.18	5775.9
4	Purchased	Pneumatic Fittings and Connections		12.4	839.58	5763.5
5	Purchased	5/2 Solenoid Actuated - Pilot Operated DCVs	Control Actuators' Direction	30	869.58	5733.5
6	Purchased	Pneumatic Actuator	Linear Actuators	67	936.58	5666.5
		Miscellaneous				
1	Purchased	4020 Aluminum Brackets	Frame Structure	20.2	956.78	5646.3
2	Purchased	Fasteners	Bolts, Nuts and Washers for Fixation	61.4	1018.18	5584.9
3	Purchased	Buffer Solutions	For PH Sensor Callibration	8.5	1026.68	5576.4
4	Purchased	T200 Propellers	Maintenance For The Re-used Thrusters	30.3	1056.98	5546.1
		Sealing Components				
1	Purchased	O-rings	Electrical Enclosure & Cameras' Casings	26.3	1083.28	5519.8
2	Purchased	Wire Glands	Wires Sealing	32	1115.28	5487.8
3	Purchased	Teflon	Threads' Sealing	3	1118.28	5484.8
4	Purchased	Mechanical Seals	Dynamic Seal for The Motors	1.5	1119.78	5483.3
5	Purchased	Epoxy	Wires Sealing	22.5	1142.28	5460.8
		Equipment				
1	Re-used	Electric Screw Driver	Small-Job Fabrication	48	1190.28	5460.8
2	Purchased	Circlip Pliers, Crimpers		12.6	1202.88	5448.2
3	Re-used	Wire Cutters/Strippers		12	1214.88	5448.2
4	Re-used	Driller, Grinder, Tree Drill and Snappers		290	1504.88	5448.2
		Research, Development and Prototyping				
1	Purchased	2x Diaphragm Pump	Mechanisms Material	8.6	1513.48	5439.6
2	Purchased	Aluminum Extrusion Welding	Strength Testing	5.2	1518.68	5434.4
3	Purchased	Aluminum 7075-T651 Laser CNC Cutting	Aluminum Machining Process	3.4	1522.08	5431
4	Purchased	Floatation Boards		49.2	1571.28	5381.8
5	Purchased	Bladder	Float	2.4	1573.68	5379.4
6	Purchased	Water Flow Sensor	Float	2.6	1576.28	5376.8
7	Purchased	Stain Releif Design		2.2	1578.48	5374.6
8	Parts Donated	Cloud Hosting	Control GUI and Website	30	1608.48	5344.6
		Vision System				
1	Re-used	1x Stereo ZED Camera		449	2057.48	5344.6
2	Re-used	5x Digital Mono Camera		178.6	2236.08	5344.6
3	Purchased	5x Digital Mono Camera		178.6	2414.68	5166
		Sensors				
1	Purchased	BMP Presure Sensor	For ROV Motion Feedback	1.5	2416.18	5164.5
2	Re-used	BNO55 Sensor		15.6	2431.78	5164.5
3	Re-used	MPU6050	For IMU Sensor Fusion	2.5	2434.28	5164.5
4	Purchased	PH Sensor	For The Mission	31.23	2465.51	5133.27
5	Purchased	Leakage Sensor	For Safety	0.5	2466.01	5132.77
		Electrical Components				
1	Purchased	3x DC-DC Converter (48V to 12V)	For Voltage Step-down	136.2	2602.21	4996.57
2	Re-used	DC-DC Converter (48V to 5V)		9.5	2611.71	4996.57
3	Purchased	30m 10M CAT6 6e Ethernet Cable	For ROV Tether	15	2626.71	4981.57
4	Purchased	30m Power Cable 10AWG		150	2776.71	4831.57
5	Purchased	Connectors, Data Headers and Cables	PCB Power and Communication	12.6	2789.31	4818.97
6	Re-used	9x Blue Robotics T200 Thrusters	8x For ROV Movment 1x For Ping Pong Mechanism	1800	4589.31	4818.97
7	Re-used	9x Blue Robotics ESCs	For thrusters' control	224	4813.31	4818.97
8	Re-used	4x USB Hub		10.2	4823.51	4818.97
9	Purchased	1x Diaphram Pump	Water Sample Mechanism	4.3	4827.81	4814.67
10	Purchased	Zed Camera Cable		7.2	4835.01	4807.47
		Microprocessors				
1	Re-Used	Jetson Nano	Main Computer of the ROV	291.1	5126.11	4807.47
2	Purchased	4x STMs 32F103C8, 2x ESP32S	Microcontroller	10.6	5136.71	4796.87
		PCB Fabrication				
1	Purchased	Etching Solution Acid		1.5	5138.21	4795.37
2	Purchased	Soldering Paste Flux		2	5140.21	4793.37
3	Purchased	Fiber glass PCB Boards		17.2	5157.41	4776.17
4	Re-Used	Hot Gun	Tools	5.1	5162.51	4776.17
5	Re-Used	Digital Soldering Iron		16.6	5179.11	4776.17
6	Re-Used	Desoldering Pump 366-D		2.9	5182.01	4776.17
7	Purchased	Tin Lead Soldering wire Sn63/Pb37		6.2	5188.21	4769.97
		Top Side Control Unit				
1	Re-Used	Station Box	Station Components	59.2	5247.41	4769.97
2	Re-Used	2K Screen Monitor		58.45	5305.86	4769.97
3	Re-Used	PS5 Controller		95	5400.86	4769.97
4	Re-Used	Power supply		485	5885.86	4769.97
5	Re-Used	Switch Connector		13	5898.86	4769.97
6	Re-Used	Fuse Holder	For Safety	11.91	5910.77	4769.97
7	Purchased	30A - Fuses		10.94	5921.71	4759.03
8	Re-Used	Anderson Connector		11.3	5933.01	4759.03
		Propbuilding				
1	Purchased	PVC	For building the underwater playground to test the ROV missions	39.6	5972.61	4719.43
2	Re-Used	PVC		20.2	5992.81	4719.43
3	Purchased	Ping Pong, Paints, Ropes, Wires, etc..		12.3	6005.11	4707.13
		Safety				
1	Re-Used	2x Life Jackets	Tethermen's Safety	13	6018.11	4707.13
2	Purchased	Water Resisting Shoes		12.5	6030.61	4694.63
3	Purchased	2x Safety Goggles		6.5	6037.11	4688.13
4	Purchased	Non-slip Gloves		5	6042.11	4683.13
5	Purchased	4x Ear plugs		1	6043.11	4682.13
6	Purchased	3x first aid kit	For Workshop	13	6056.11	4669.13
		MATE ROV Competiton				
1	Purchased	MATE ROV Registration Fees	International Competiton	390	6446.11	4279.13
2	Purchased	MATE ROV Registration Fees	Regional Competition	260	6706.11	4019.13
3	Purchased	Fluid Power Quiz Fees		35	6741.11	3984.13
		Marketing Purposes				
1	Purchased	Poster		17	6758.11	3967.13
2	Purchased	Flyers & Stickers		67.6	6825.71	3899.53
3	Purchased	Banners		27	6852.71	3872.53
4	Purchased	T-Shirts		297	7149.71	3575.53
5	Re-used	2x Flag		25	7174.71	3575.53
		ROV Testing Logistics				
1	Purchased	Villa Rent	With a swimming pool to test the ROV	693.3	7868.01	2882.23
2	Purchased	Compressor Maintenance		10.5	7878.51	2871.73
3	Purchased	PH Sensor Maintenance	KCl and HCl for cleaning the PH Sensor	20.3	7898.81	2851.43
4	Purchased	Transportation	Fuel, Tolls &material transportaion	19.8	7918.61	2831.63

Total		Description
Project Cost (USD)	7918.61	Total costs of the project including the re-used items
Re-Used and Donations (USD)	4330.24	Donations and re-used items from the last years' project
Project Cost without Re-Used and Donated Parts (USD)	3588.37	Paid project cost
Total Income (USD)	6420	Funds raised from the employees, prizes, and donations
Total Balance (USD)	2831.63	Incomes - Expenses
Total Production Cost (USD)	4559.03	Materials, Fabrication and Components used for Nexus without including r&d costs and logistics

G- System Testing

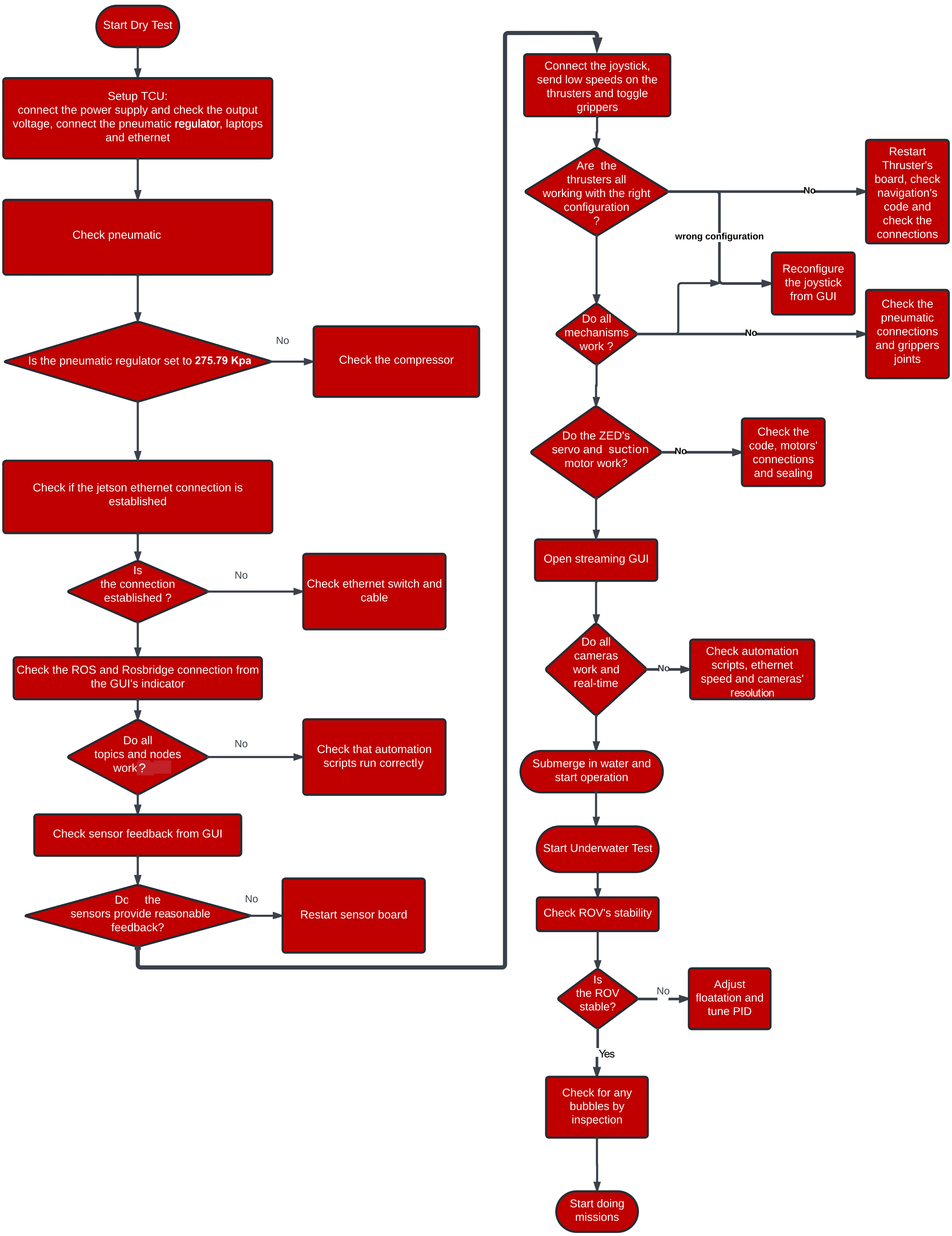

Figure (48): Troubleshooting Flowchart