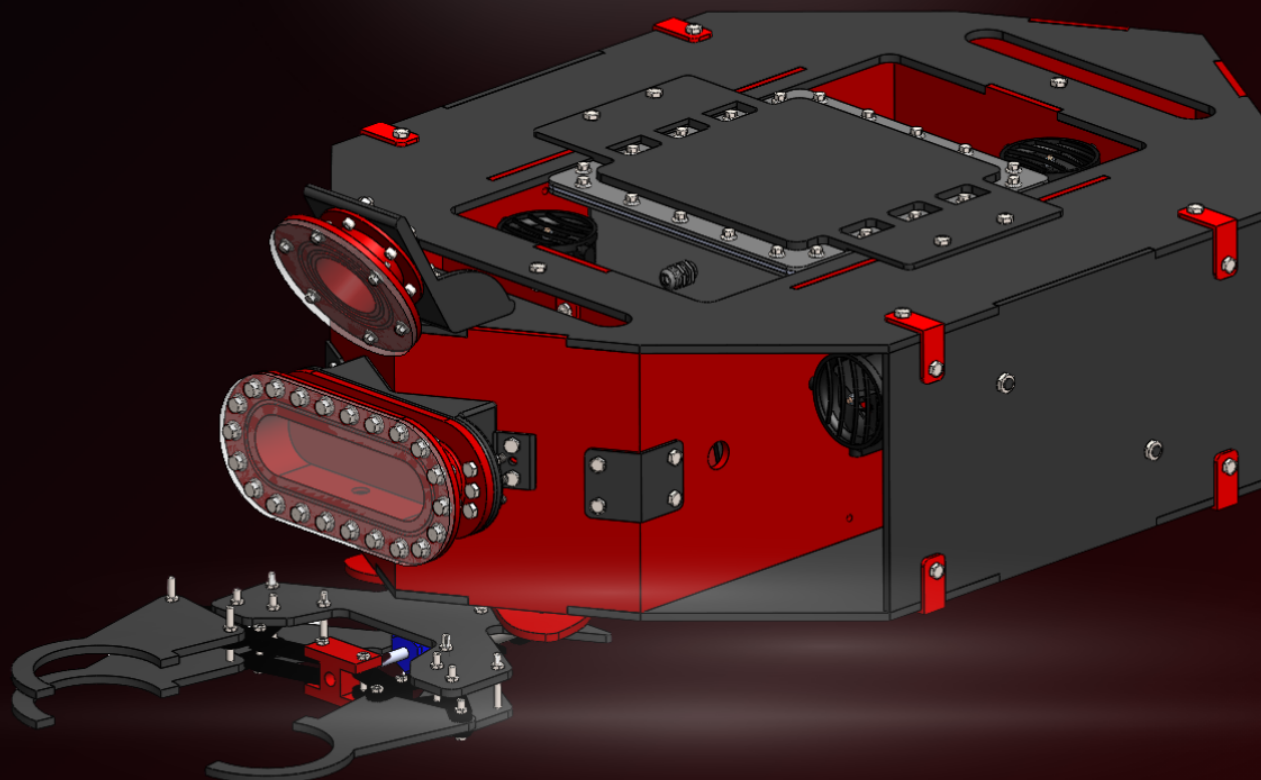




MONA V2



Mind-Tech Robotics

2026 MATE ROV Competition Pioneer Class Technical Report

ALEXANDRIA-EGYPT

Mentors

Prof. Dr. Tamer Helmy - Eng. Omar Al-Azab - Eng. Nour Eldin Sakr - Eng. Ahmed Hossam

28' Osama Al-Azab **CEO**

28' Amr Khaled **Pilot | CTO**

29' Seif Eldin Walid **CFO**

27' Ibrahim El-Kady **Software Lead**

29' Habiba Habib **Electrical Lead**

28' Ziad Khaled **Mechanical Lead**

27' Eman Saad **Safety Officer**

29' Mohamed Islam **Software**

29' Seifeldeen Ali **Software**

27' Habiba Khamis **Software**

28' Eyad Khaled **Electrical**

27' Abdelrhman Hany **Electrical**

28' Mostafa Erakat **Electrical**

28' Rahma Yahia **Electrical**

28' Youssef Alkady **Electrical**

29' Adam Elaraby **Mechanical**

29' Ahmed Hussein **Mechanical**

29' Ahmed Mohammed **Mechanical**

29' Marc mina **Mechanical**

28' Mohamed Alaaeldin **Mechanical**

29' Noureldin Amr **Mechanical**

28' Mahmoud Emad **Mechanical**

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Abstract

Mind-Tech Robotics (MTR) at Alexandria National University is an undergraduate student team that designs, builds, markets, and competes at the MATE ROV Competition. MTR is proud to present MONA V2, a highly modular remotely operated vehicle (ROV) and its accompanying autonomous profiling float, engineered to complete the complex tasks outlined in the 2026 MATE Request for Proposals (RFP). These tasks include precise environmental monitoring, autonomous data collection, and complex subsea intervention within marine renewable energy infrastructure.

MONA V2 features a robust Stainless Steel 304 (SS304) electronics enclosure and a skeletonized High-Density Polyethylene (HDPE) chassis. The vehicle is driven by eight modified bilge pump thrust-ers paired with custom 52 mm propeller assemblies and controlled through a custom ROS 2 distributed software architecture running on a Raspberry Pi 4. A pneumatic end-effector provides reliable gripping force for physical intervention tasks, while stereo-vision cameras and a PID depth-hold algorithm enable the autonomous monitoring capabilities demanded by the RFP.

This document provides a comprehensive overview of the development and design of MONA V2, covering the project timeline, engineering design rationale, safety protocols, critical analysis of challenges encountered, and a total project fair market value of \$1,643.00 USD.



Figure 1: Team Photo.

2.0 PROJECT MANAGEMENT & TEAMWORK

2.1 Company Profile & Roles

Mind-Tech Robotics (MTR) operates as a simulated commercial engineering firm headquartered at Alexandria National University in Alexandria, Egypt. To efficiently tackle the multifaceted challenges of the MATE ROV Pioneer class, MTR strictly adheres to a corporate hierarchy that divides the workload into four specialized departments: Mechanical, Electrical, Software, and Business & Safety.

The team is composed of dedicated undergraduate students bringing interdisciplinary academic rigor to the project. The company is led by Osama Al-Azab (CEO), whose foundation in Mechatronics and Robotics Engineering enabled direct management of overall systems integration across all departments, ensuring strict adherence to both the project timeline and the competition rubrics. Department heads were given the autonomy to make low-level design decisions — such as material selection or code formatting — while presenting high-level system changes to the CEO and CTO for final approval and integration checks. This structure eliminated any single point of failure in project management.

2.2 Development Methodology

To manage the rapid prototyping required for MONA V2, MTR adopted an Agile engineering framework. The development cycle was broken into two-week “sprints,” focusing on iterative design rather than attempting to build a perfect vehicle on the first pass.

This approach proved critical when early pool testing revealed systemic issues with the PCB power rails and I2C signal integrity, allowing the team to diagnose and resolve both problems within a single sprint cycle (see Section 5.0 for full analysis).

- Digital Collaboration & Concurrent Engineering:

- Before any physical material was cut, the team developed a “digital twin” of the ROV. The mechanical team modelled the chassis in cloud-based CAD software while the electrical team concurrently designed the custom motor driver boards in EasyEDA Pro. By exporting the 3D PCB models from EasyEDA directly into the mechanical CAD assembly, the team verified spatial tolerances within the SS304 enclosure, eliminating costly manufacturing errors before a single component was ordered.

- Communication & Data Synchronisation:

- All internal communications, rapid problem-solving, and meeting coordination were managed through dedicated, organised channels on Discord. Version control, documentation, and file sharing were handled via a centralised Google Drive repository. This meant that when the software team pushed an update to a ROS 2 node, the hardware team had immediate access to synchronised documentation to verify I2C bus compatibility.

- Weekly Stand-Ups:

- Every sprint included a mandatory all-hands “stand-up” meeting. Each department lead reported on three metrics: what was accomplished, what was planned for the next week, and any critical “blockers” preventing progress. This transparency allowed MTR to dynamically reallocate resources, ensuring the project remained on budget and on schedule.

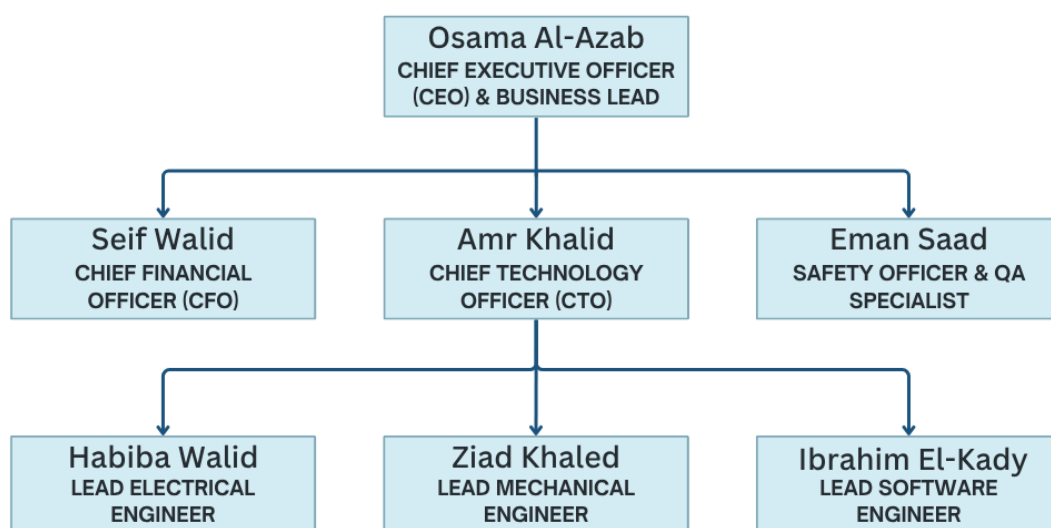


Figure 2: MTR Company Organisation Chart showing departmental hierarchy and reporting lines

To enforce these sprints, the Business Lead maintained a strict master Gantt chart mapping exact deadlines for the CAD phase, PCB manufacturing, and final pool testing, ensuring the vehicle was competition-ready by the required date.

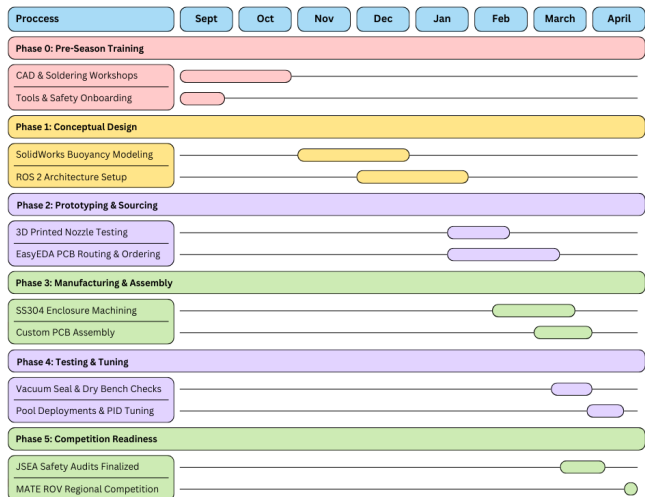


Figure 3: Gantt chart of the full MTR project timeline from September 2025 to April 2026

3.0 DESIGN RATIONALE

MONA V2 is built around a holistic systems philosophy: every subsystem decision was made with explicit consideration of its impact on the other subsystems. For example, the choice of a lighter custom thruster assembly directly reduced the payload on the electrical power budget; the placement of thrusters was constrained by the internal acrylic rack that resolved the EMI challenge; and the selection of the Raspberry Pi 4 as the onboard computer was validated against the processing demands of the ROS 2 node network and the OpenCV vision pipeline simultaneously. The sections below present each subsystem in sequence, but the integration rationale is woven throughout.

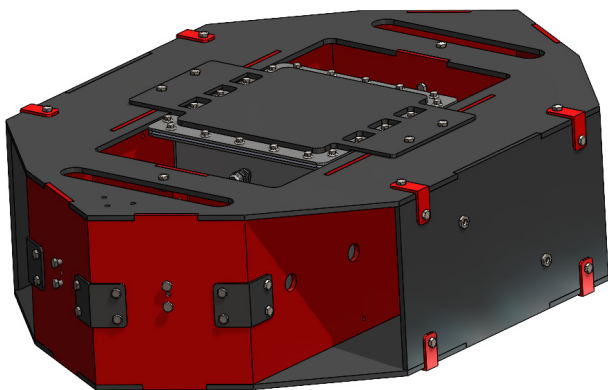


Figure 3: 3D CAD render of the skeletonized HDPE frame and the SS304 electronics enclosure.

3.1 Mechanical

3.1.1 Frame Material & Structure

The chassis of MONA V2 is engineered from High-Density Polyethylene (HDPE). HDPE was selected over PVC through a material trade study that evaluated four criteria: strength-to-weight ratio, machinability with the team's available CNC router, cost, and aquatic performance. PVC was rejected because it becomes brittle under impact loads and offers a lower strength-to-weight ratio. Aluminium was considered but rejected due to its cost (approximately three times that of HDPE per kilogram) and its negative buoyancy, which would have required significantly more XPS foam ballast. HDPE is naturally buoyant in freshwater, is resistant to impact shattering, and machines cleanly without specialist tooling.

The frame was heavily skeletonised using a CNC router to reduce drag profiles and improve hydrodynamic flow across the thruster arrays. Material was removed from non-structural regions following a simple finite-element stress analysis performed in the CAD environment, ensuring no stress concentration points were introduced at the cutout boundaries.

For the main electronics housing, MTR upgraded from the previous season's acrylic tube to a Stainless Steel 304 (SS304) cylindrical enclosure. SS304 was chosen because it provides immense crush resistance against hydrostatic pressure, and its high thermal conductivity (approximately 16 W/m·K) allows it to act as a massive passive heatsink, directly transferring internal thermal buildup from the power electronics into the surrounding pool water without any active cooling system.

3.1.2 Buoyancy Principles

To achieve the precise maneuverability required for the 2026 subsea tasks, MONA V2 is designed to be slightly positively buoyant. The engineering team calculated this condition by applying two fundamental physics principles.

First, using Newton's Second Law of Motion ($W = m \times g$), the team calculated the total downward gravitational force. The total mass of the fully-configured ROV including the submerged tether payload is $m = 14.5$ kg. Multiplied by standard gravitational acceleration ($g = 9.81 \text{ m/s}^2$), the downward weight force is $W \approx 142.2 \text{ N}$.

To counteract this, MTR integrated precision-cut blocks of Extruded Polystyrene (XPS) foam. XPS was specifically chosen over Expanded Polystyrene (EPS) because its closed-cell structure resists hydrostatic compression, preventing the ROV from losing buoyancy at

depth as an open-cell foam would. To find the required upward lift, the team applied Archimedes’ Principle ($F_b = \rho \times V \times g$), which states that the upward buoyant force equals the weight of the fluid displaced by the ROV. Assuming a standard freshwater pool density ($\rho = 1000 \text{ kg/m}^3$), the ROV’s measured displaced volume of $V = 0.0151 \text{ m}^3$ (15.1 litres) displaces exactly 15.1 kg of water. Multiplying by gravity yields an upward buoyant force of $F_b \approx 148.1 \text{ N}$. This results in a net positive buoyancy of approximately 5.9 N (0.6 kg), ensuring the vehicle will safely float to the surface in the event of a total power failure.

3.1.3 Thrusters & End-Effectors

Propulsion is achieved using an array of eight modified Sailflo 1100 GPH brushed DC bilge pumps operating at 12 V. The 8-thruster vectored configuration allows for true 6-Degree-of-Freedom (6-DOF) movement. Four thrusters are arranged in a horizontal plane to provide surge, sway, and yaw control. The remaining four thrusters are oriented vertically at the four corners of the chassis to provide heave, roll, and pitch control. This configuration was chosen over a 6-thruster arrangement because the additional redundancy means the vehicle can still manoeuvre in all axes even if one thruster fails.

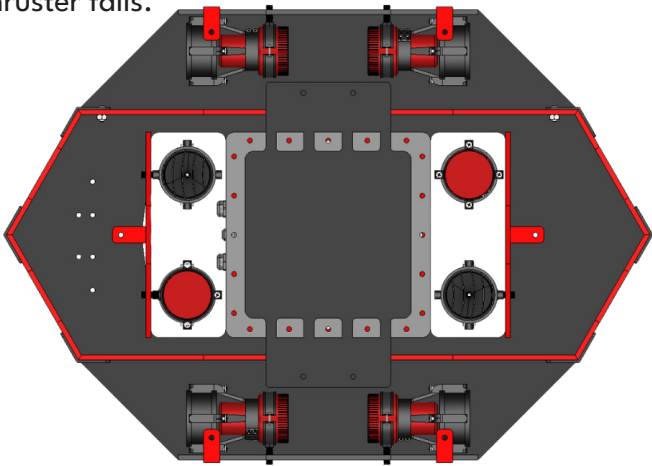


Figure 4: Top-view thruster placement showing the horizontal and vertical arrays

The T200 setup proved hydrodynamically inefficient for MTR’s high-speed, low-torque brushed bilge pump motors. Applying Annular Actuator Disk Theory — which dictates that the centre hub of a propeller blocks fluid and does no work — the team calculated the actual “wetted” surface area of each propeller using the formula $A = (\pi/4) \times (D_{out}^2 - D_{hub}^2)$. The 52 mm propeller yields an active area of 0.00201 m^2 , while the T200 propeller yields 0.00330 m^2 . This 64% greater wetted area presents a severe drag penalty against low-torque motors, causing the T200 assembly to stall at high throttle, pull over 15 A, and risk thermal failure of the motor’s internal enamel coils.

To resolve this, MTR engineered a custom 3D-printed PETG Kort nozzle paired with the 52 mm high-pitch RC boat propeller. Applying Screw Propeller Kinematics ($v = \text{Pitch} \times \text{RPM}/60$), the 52 mm propeller’s aggressive 80 mm pitch theoretically accelerates the water column 26% faster than the T200’s 63.5 mm pitch at identical RPM, compensating for the smaller disk area. This optimised pairing draws a safe, sustainable 7.6 A at 12 V ($P = I \times V = 91.2 \text{ W}$ under heavy load), achieving a confirmed real-world continuous bollard pull of 1.2 kgf and a peak thrust of 1.4 kgf per motor — a four-fold improvement in thrust-to-power ratio at one-quarter of the cost.

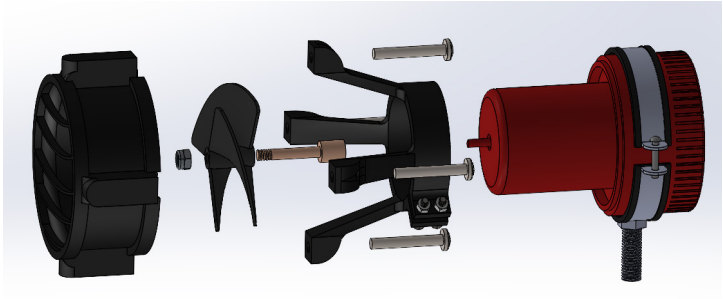


Figure 5: Exploded CAD assembly of the final optimised 52 mm propeller, custom PETG Kort nozzle, and modified bilge pump motor

For physical intervention, the primary end-effector is a custom pneumatic gripper system. MTR selected pneumatics over traditional waterproof micro-servos after evaluating three failure modes: (1) servo motor stall under heavy mechanical loads, (2) saltwater intrusion through servo shaft seals, and (3) the torque limitations of micro-servo actuators when engaging heavy marine infrastructure. The pneumatic system addresses all three risks. The gripper is actuated by a dual-acting pneumatic cylinder controlled by 12 V DC solenoid valves housed safely inside the main SS304 enclosure, completely isolated from the aquatic environment. This provides immense, repeatable clamping force without any risk of electrical intrusion.

Table 1: Thruster assembly trade-off matrix. (darker means in favour)

Trade-off table for thruster assembly.		
	Blue Robotics T200 thruster	Custom 52mm propeller Thruster
Manufacturing complexity	Requires 3d parts and lathe for the coupler (more complex)	Requires 3d parts (less complex)
Design complexity	Nothing was designed except the coupler (less complex)	Everything was designed except the propeller and coupler (more complex)
Sourced (baught) parts	Blue Robotics T200 propeller (5\$)	3 blade rc boat propeller 52mm with coupler (4\$)
Thrust	Continuous 500g, Peak 700g	Continuous 1200, Peak 1400g
Thrust to power ratio	Continuous 3.3 g/W	Continuous 13.1 g/W
Total cost for single thruster	22\$	6\$

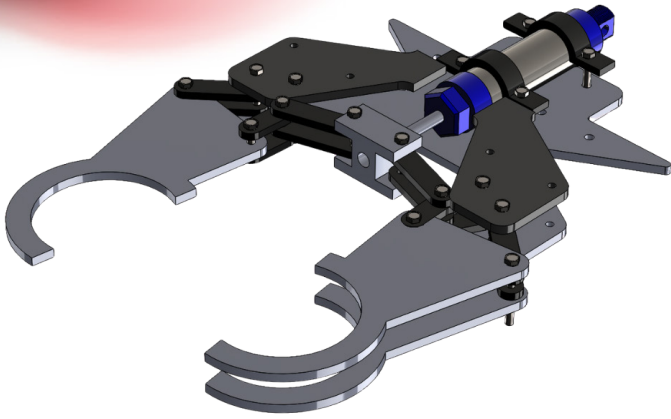


Figure 6: Custom pneumatic gripper system and dual-acting cylinder assembly

3.1.4 Tether Design & Management Protocol

The tether connecting MONA V2 to the surface station is a 15-metre, multi-conductor thermoplastic-jacketed cable. The following design requirements governed its selection and configuration:

- Power conductors: two 18 AWG conductors rated for 48 V DC at the required current load, with a combined resistance of under 0.5 Ω across the full 15 m length to maintain acceptable voltage drop before the onboard buck converters.
- Signal conductors: two twisted-pair conductors for the Ethernet-over-USB data link, shielded to prevent EMI cross-talk from the power conductors running in the same jacket.
- Mechanical strength: a minimum tensile rating of 200 N to withstand accidental tether tension during pool deployment without risk of conductor separation.
- Buoyancy floats: distributed polyurethane foam floats are spaced every 1.5 m along the tether to prevent it from sagging onto the pool floor or fouling the thruster arrays.

The Tether Management Protocol governs all deployment and recovery operations to prevent tangling, mechanical damage, and electrical hazards:

- Pre-dive: the tether is fully uncoiled and laid flat on the pool deck before power is applied. Any kinks or tight bends are straightened by hand and logged. The tether jacket is visually inspected for abrasion or cuts.
- During operation: a dedicated Tether Manager role is assigned for every pool session. The Tether Manager maintains a minimum 0.5 m of slack at the pool-side entry point at all times, feeds tether in and out smoothly as the ROV moves, and never allows the tether to cross the thruster guard plane.
- Post-dive: the tether is recovered by coiling in large 0.3 m diameter loops to avoid memory-induced kinks. The cable gland entry points are dried and inspected before storage.

3.2 Electrical System

3.2.1 Power Distribution System (PDS) & Power Math

Power is supplied from the surface via a 48 V DC power supply and transmitted at high voltage down the 15-metre tether to minimise resistive voltage drop. Onboard, the ROV steps the power down directly inside the SS304 enclosure using high-efficiency synchronous buck converters, generating a stable 12 V rail for thrusters, solenoid valves, and cameras, and a regulated 5 V rail for the Raspberry Pi 4 and all sensor logic.

To ensure the mandatory 30 A surface fuse never blows during an operation, MTR conducted strict Full Load Ampere (FLA) calculations by applying Kirchhoff's Current Law ($I_{\text{total}} = I_1 + I_2 + I_3 + \dots + I_n$), which states that in a parallel electrical circuit the total current entering the system equals the sum of all branch currents:

- Under maximum stall torque, each modified Sailflo thruster draws 1.2 A. Eight thrusters therefore draw 9.6 A total.
- The Raspberry Pi 4, 12 V pneumatic solenoid valves, and sensor payload draw a combined maximum of 2.6 A.
- Total System FLA = 12.2 A. At this maximum draw, the vehicle utilises less than 41% of the 30 A safety limit, guaranteeing electrical stability under all competition conditions.

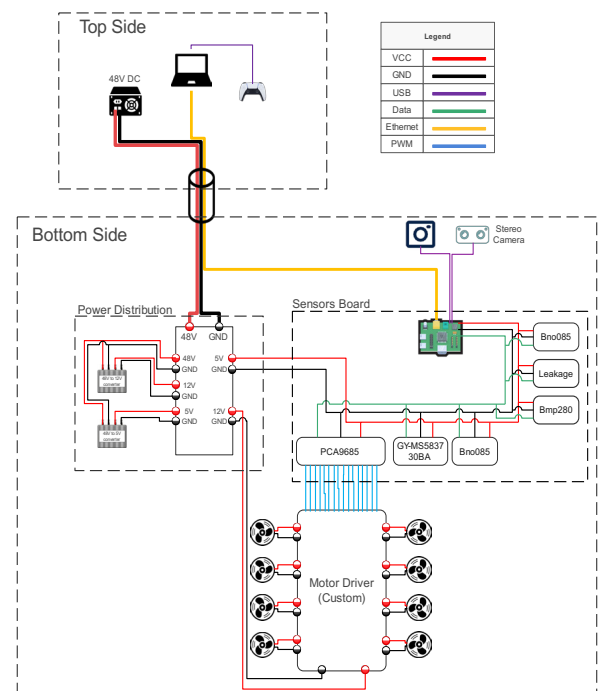


Figure 7: Electrical System Power Tree illustrating the 48V input, tether transmission, and step-down to 12V and 5V power rails with branch current labels

3.2.2 Custom Breakout & Motor Drivers

To satisfy the mission requirement for a compact, lightweight ROV, MTR conducted a structured Build vs. Buy trade study evaluating commercial motor controllers against custom PCBs. Commercial modules evaluated included the L298N dual H-bridge module and the Sabertooth 2×12 — both of which were rejected because their large physical footprint and through-hole component layout would have consumed over 60% of the available enclosure volume and introduced multiple loose jumper wire connections as points of failure.

The Trade Study concluded that engineering a proprietary Power Distribution Board (PDB) in EasyEDA Pro reduced the physical footprint by 40% compared to commercial alternatives. The custom board integrates surface-mount Wuxi Wenkang RZ7886 High Current DC Motor Drive ICs, which handle the PWM switching logic required for variable speed control. By consolidating all switching, fusing, and distribution on a single board, the electrical team drastically reduced the wiring harness complexity and eliminated the standard point-of-failure associated with loose jumper wires.

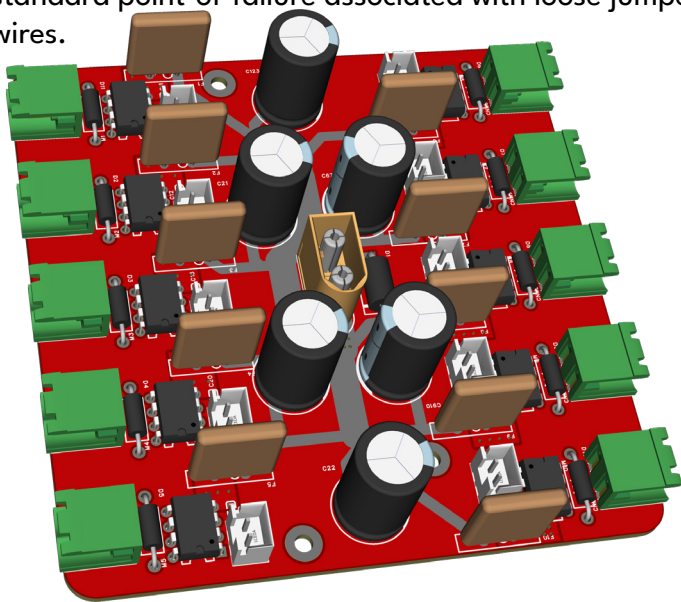


Figure 8: Custom EasyEDA Power Distribution Board featuring surface-mounted RZ7886 ICs

3.2.3 Enclosure Connections & Sealing

All penetrations into the SS304 electronics enclosure are secured using marine-grade brass cable glands fitted with dual-nitrile O-rings. Brass was selected over plastic glands because it provides greater compression force on the O-rings and resists corrosion in chlorinated pool water. To prevent capillary action — the phenomenon by which water wicks along the inside of a wire jacket against gravity — all external thruster and sensor connections are stripped, tinned,

soldered, and fully cast in two-part marine epoxy potting compound before being passed through the bulkhead. This ensures that even if the outer jacket is breached, water cannot travel inward to the enclosure.



Figure 9: Marine-grade brass cable glands and epoxy potting detailing on the main SS304 enclosure

3.3 Control System (Software-Based Path)

3.3.1 Software Development Process & Version Control

MTR selected the Software-Based Path for the 2026 control system. The software architecture was developed under a strict Agile methodology using two-week sprint cycles. All code was written in Python and C++ and managed through a centralised Git repository hosted on GitHub. The repository employed a protected main branch: the software team would branch out to develop and test new motor-mixing algorithms or specific I2C sensor drivers independently, then submit pull requests for peer review before merging into the main branch only after successful bench testing. This strict versioning discipline prevented system-breaking bugs from propagating into the competition build during rapid development.

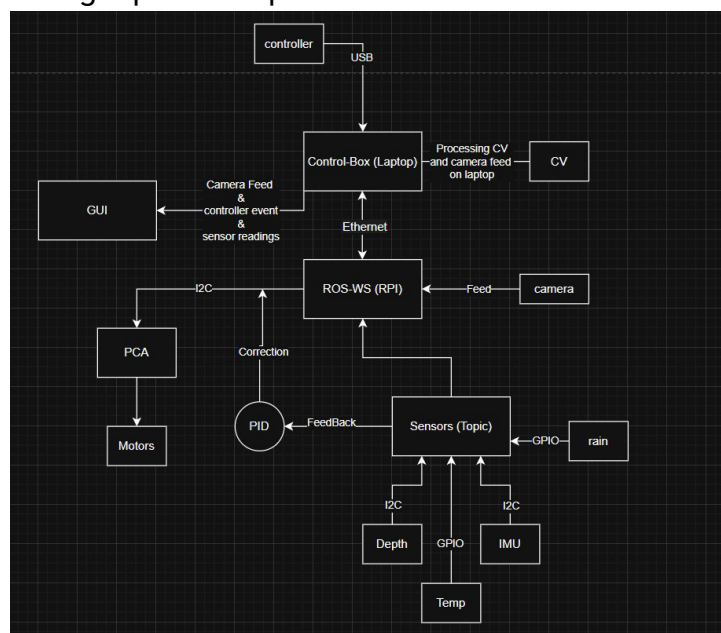


Figure 10: Software architecture flowchart showing the ROS 2 Publisher-Subscriber node network, from the surface laptop gamepad input to PWM motor commands via the Raspberry Pi 4

The ROS 2 (Humble) framework was selected over a monolithic control loop architecture because it allows individual functional modules — motor mixing, depth-hold PID, object detection, telemetry publishing — to run as isolated nodes that communicate over a message bus. This means a crash in the object detection node cannot corrupt the motor control node, improving overall system reliability. The primary limitation of this approach is that ROS 2 introduces message-passing latency on the order of a few milliseconds; this was evaluated and deemed acceptable for all competition tasks, as the ROV does not require sub-millisecond response times.

3.3.2 Micro-controller Integration & GUI

When evaluating processing hardware, the team conducted a formal New vs. Reused asset analysis. For the complex logic required by the ROS 2 node network and the OpenCV vision pipeline, MTR evaluated three options: (1) reuse an inherited Raspberry Pi 4 (4 GB RAM), (2) purchase a new Raspberry Pi 5, or (3) implement an Arduino-based distributed controller. Options 2 and 3 were rejected: the Pi 5 offered no functional benefit over the Pi 4 for the identified workloads and would have consumed significant budget, while the Arduino lacked sufficient processing power for real-time OpenCV operations. The inherited Pi 4 was selected and validated by benchmarking the combined CPU load of all ROS 2 nodes and the vision pipeline, which peaked at approximately 65% — well within the sustained operating limit.

The ROV operates as a distributed network of ROS 2 “nodes.” The surface laptop acts as the Publisher, sending gamepad joystick data down the tether via an Ethernet-to-USB protocol. The Pi 4 acts as the Subscriber, receiving the telemetry stream, executing the motor-mixing mathematics, and distributing the correct PWM signals to the custom RZ7886 motor drivers via the I2C bus.

To improve operator performance, the team developed a custom topside Graphical User Interface (GUI) that displays real-time telemetry including vehicle depth, internal temperature, and thruster duty cycles. The GUI features automated safety alerts: screen borders turn red if the internal BME280 environmental sensor detects an internal temperature spike above 45°C, or if the internal analog moisture sensor detects a water ingress event. This gives the pilot an immediate visual warning to surface the vehicle before any electronic damage can occur.

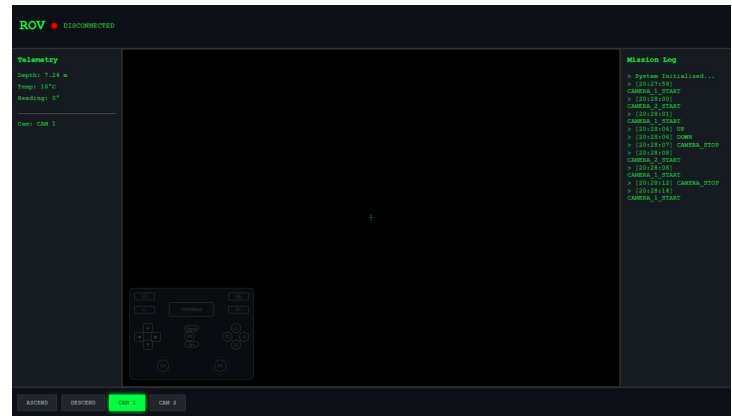


Figure 11: The topside Graphical User Interface displaying real-time telemetry, depth readout, thruster duty cycles, and safety alert borders

3.3.3 Object Detection & Depth-Hold

To fulfil the autonomous monitoring requirements of the 2026 RFP, the software team integrated two mission-critical autonomous features.

First, a PID (Proportional-Integral-Derivative) control loop was implemented to provide an “Autonomous Depth-Hold” assist. The pressure transducer (ADS1115 16-bit ADC reading the analog output of a waterproof pressure sensor) provides continuous depth feedback. The ROS 2 depth-hold node computes the error between the target depth and the measured depth, and adjusts the duty cycle of the four vertical thrusters accordingly. The PID gains were tuned empirically during pool testing sessions — starting with proportional-only control to establish a baseline, then adding derivative gain to suppress overshoot, and finally adding integral gain to eliminate steady-state depth error. This feature allows the pilot to release the vertical joystick entirely, significantly reducing cognitive load during precision manipulation tasks. Second, the ROV utilises dual GXIVISION USB cameras feeding into a custom OpenCV Python script. The GXIVISION cameras were selected because they provide a wide 120° field of view, operate reliably in low-light underwater conditions, and connect via standard USB — eliminating the need for any custom camera drivers within the ROS 2 environment. The stereo-vision baseline between the two cameras is fixed at 80 mm, calibrated using a standard checkerboard pattern to establish the camera intrinsic and extrinsic matrices. The OpenCV pipeline applies stereo disparity mapping to calculate metric distances to detected objects, allowing the system to identify and measure the specific shipwreck anomalies and coral features mandated by the competition tasks.

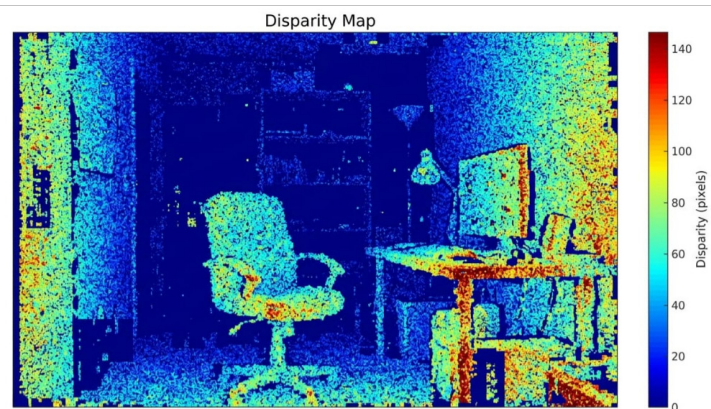


Figure 12: OpenCV stereo-vision object detection disparity map.

4.0 Safety

4.1 Safety Philosophy

At Mind-Tech Robotics, safety is a proactive, integrated engineering discipline — not a post-build checklist. MTR enforces industrial-grade safety protocols across all phases of the engineering lifecycle, under the direct supervision of Safety Officer & QA Specialist Eman Saad. The safety programme is designed to protect three stakeholder categories: personnel (team members and bystanders), equipment (the ROV, surface station, and laboratory tools), and the operational environment (the pool and the university laboratory).

•Preventative Training & PPE:

Access to the manufacturing labs requires completion of a mandatory safety briefing. ANSI-rated safety glasses, active fume extraction during PCB assembly, and cut-resistant gloves when machining HDPE and SS304 components are strictly enforced at all times.

•High-Current Electrical Discipline:

Bench testing of the 48 V surface-supplied power system is heavily regulated. Live circuits are never manipulated while energised. High-power motor testing is conducted behind polycarbonate blast shields, and the team utilises a physical dead-man switch. The main 30 A Littelfuse is treated as a mandatory hardware gatekeeper and is visually verified before any power is applied to the vehicle.

•Pneumatic System Safety:

The onboard pneumatic circuit is operated at a maximum regulated pressure of 60 PSI. All air lines are rated to at least 150 PSI and are visually inspected for kinks or abrasion before every pressurisation. The pneumatic circuit includes a pressure relief valve set to 70 PSI to prevent over-pressurisation events.

•Environmental Stewardship:

MONA V2 undergoes strict vacuum testing prior to all wet deployments to detect any enclosure seal failures before they can release hazardous substances (such as electrolytic capacitor fluid) into the pool. All manufacturing waste is separated into appropriate streams, and lithium-based batteries used in the autonomous profiling float are stored in fire-retardant LiPo bags when not in use.

4.2 Job Safety and Environmental Analysis (JSEA) Matrix

To formally identify, assess, and mitigate operational risks, MTR uses a JSEA framework governing all major technical tasks:

Table 2: JSEA Risk Matrix

Task	Hazard	Mitigation / Safeguard	Responsible
Custom PCB Assembly & Soldering	Inhalation of toxic flux fumes; thermal burns from soldering irons operating above 300°C	Work restricted to well-ventilated stations with active fume extractors. Safety glasses and heat-resistant silicone mats mandatory.	Lead Electrical Engineer
Machining SS304 & HDPE Enclosures	Flying debris; severe lacerations from sharp metal edges; noise-induced hearing damage	ANSI Z87.1 safety glasses and ear protection required. All freshly cut SS304 edges must be immediately filed and deburred to comply with competition rule MECH-007.	Lead Mechanical Engineer
High-Current Bench Testing (48 V System)	Electrical shock from 48 V supply; thermal burns from overloaded DC-DC converters or motor coils	“Dead-man” power switch utilised. The 30 A fuse is verified before powering. Wires routed with strict 20 mm clearances. No active manipulation while energised.	CEO
Pneumatic System Pressurisation	Hose burst; projectile from unseated fittings; over-pressurisation of components	All lines pressure-tested to 90 PSI (1.5× operating pressure) before use. Pressure relief valve set to 70 PSI. Polycarbonate shield deployed during initial pressurisation.	Safety Officer
Pool Deployment & Recovery	Slip and fall on wet pool decks; muscle strain from lifting the ROV; water-electricity interaction	Mandatory closed-toe non-slip footwear. Strict two-person lift protocol. Pre-dive visual inspection of all cable glands and enclosure seals per rule ELEC-018P.	Safety Officer

4.3 Construction & Assembly Safety Checklist

Strict adherence to this checklist is mandatory before and during all ROV fabrication activities in the Mechatronics and Robotics Engineering laboratory.

Pre-Fabrication & Lab Entry

- ☐ Verify all personnel are wearing ANSI Z87.1 safety glasses and closed-toe shoes.
- ☐ Ensure loose clothing is secured and long hair is tied back.
- ☐ Locate the nearest fire extinguisher, eye-wash station, and first aid kit before beginning work.
- ☐ Clear the workstation of any unnecessary tools, liquids, or debris.
- ☐ Verify pneumatic regulator is set to safe operational pressure (< 40 PSI) and inspect all external air lines for leaks before pressurisation.

Machining & Mechanical Assembly (HDPE & SS304)

- ☐ Verify the CNC router or lathe is completely de-energised before changing bits or securing stock.
- ☐ Ensure HDPE and SS304 stock is securely clamped to the work surface before cutting.
- ☐ Immediately file and deburr all freshly cut SS304 edges to prevent lacerations.
- ☐ Never use gloves while operating rotating machinery — entanglement risk.

Electrical Assembly & Soldering

- ☐ Ensure the active fume extractor is positioned over the soldering station and running.
- ☐ Verify soldering irons are placed securely in their stands when not actively in use.
- ☐ Allow all soldered joints and heat-shrink tubing to cool completely before handling.
- ☐ Wash hands thoroughly after handling solder before eating or leaving the lab.

High-Current Bench Testing (48 V System)

- ☐ Verify the main 30 A Littelfuse is physically removed from the circuit before making any connections.
- ☐ Ensure the physical dead-man switch is within immediate reach of the testing operator.
- ☐ Double-check all polarity connections on the custom EasyEDA motor driver boards.
- ☐ Verbally announce “System Energised” to all personnel in the room before inserting the fuse and applying power.

Pool Deployment & Recovery

- ☐ Perform vacuum seal test on SS304 enclosure before every wet deployment.
- ☐ Visually inspect all marine cable glands and O-rings for signs of damage or compression set.
- ☐ Confirm Tether Manager role is assigned and briefed on the management protocol (see Section 3.1.4).
- ☐ Confirm all personnel are wearing non-slip footwear on the pool deck.
- ☐ After recovery, dry all exterior surfaces and inspect for seal integrity before storing.

5.0 Critical Analysis

5.1 Testing & Troubleshooting

Mind-Tech Robotics relies on a rigorous, multi-phase testing methodology that progresses from dry bench diagnostics to vacuum enclosure testing, and finally to active pool deployments. This Agile approach is designed to identify and isolate failure points as early in the development cycle as possible, when the cost of correction is lowest. During the engineering of MONA V2, the team encountered and successfully resolved two major systemic challenges.

Challenge 1: PCB Thermal Bottleneck on High-Current Rails

•The Problem:

During initial load testing of the custom Power Distribution Board, thermal imaging revealed that the 12 V actuator rail experienced excessive heat buildup and unacceptable voltage drops when multiple thrusters were engaged simultaneously.

•Root Cause Analysis:

Mathematical analysis using the PCB trace resistance formula ($R = \rho \times L / A$, where ρ is copper resistivity, L is trace length, and A is cross-sectional area) confirmed that standard 1-ounce copper traces — the maximum thickness available within the team's rapid manufacturing budget — lacked the cross-sectional area to safely carry the combined amperage of the thruster array without excessive resistive heating.

•Engineered Solution:

Rather than redesigning the entire board or paying a premium for heavy-copper PCB fabrication, MTR implemented a highly effective manual workaround. In EasyEDA Pro, the engineers explicitly removed the solder mask layer over the critical 48 V and 12 V power planes. During physical assembly, the hardware team manually applied a thick, continuous layer of tinning solder across these exposed tracks. This massively increased the conductive cross-sectional area of the power traces, effectively creating custom busbars on the PCB surface. The modification completely resolved the thermal bottleneck and voltage drop issues, validated by a subsequent thermal imaging pass showing no anomalous hot spots.

Challenge 2: I2C Signal Corruption via Electromagnetic Interference (EMI)

•The Problem:

During early wet-testing, the ROV experienced random thruster stuttering,

and the pilot GUI began dropping high-resolution telemetry data from the ADS1115 depth sensor, causing erratic depth-hold behaviour.

•Root Cause Analysis:

Connecting a digital oscilloscope to the internal data bus revealed severe noise spikes on the I2C communication lines correlating exactly with PWM switching events. The high-frequency PWM switching of the RZ7886 motor drivers was generating Electromagnetic Interference (EMI). Because the 12 V power wires and 3.3 V data wires were bundled together inside the enclosure without physical separation, this EMI induced cross-talk and ground loops that corrupted the delicate I2C logic signals.

•Engineered Solution:

To resolve this without adding bulky shielded cables, the mechanical and electrical teams collaborated to redesign the internal layout of the SS304 enclosure. A custom 3-tier acrylic rack system was engineered to physically separate high-power and low-power components. High-current power distribution and motor switching were isolated on the bottom tier, while the sensitive Raspberry Pi 4 and all sensor logic were relocated to the top tier. A strict “cable halo” routing protocol was enforced, ensuring all 12 V power lines and 3.3 V data lines are physically separated by a minimum of 20 mm at every point within the enclosure. This air-gap isolation completely eliminated the EMI cross-talk, restoring perfect I2C signal integrity confirmed by a follow-up oscilloscope measurement.

6.0 Budget & Cost Accounting

Mind-Tech Robotics operates with strict adherence to commercial accounting principles. To comply with the 2026 MATE ROV international scoring requirements, all project expenses, travel projections, and component valuations — including donated and reused materials — are assessed at their Fair Market Value (FMV) in United States Dollars (USD). Items listed as “Reused (FMV)” reflect the current market replacement cost of the component, not its original purchase price.

6.1 Project Budget & Travel Estimates

MTR's operational budget was secured through a combination of university departmental funding (provided by Alexandria National University as an in-kind contribution valued at approximately \$400 USD covering laboratory access, and consumables sponsorship from Makers Electronics, who provided component discounts valued at approximately \$120 USD. The remaining costs were funded directly by team members. The total budget was divided into two phases: Research & Development (covering prototyping materials including PLA filament, test PCBs, and initial pool-test fasteners) and Final Manufacturing (covering all components listed in the FMV table below).

Table 3: Income Funding Table

Category	Source	Amount (USD)
Self-Funded	Employee Dues	\$1,950
Sponsorship	Makers Electronics (Discounts)	\$120
In-Kind Donation	Alexandria National University (Lab Fees)	\$400
Total Income		\$2,470

Table 4: Operating & Logistics Budget Table

Expense Category	Item Description	Cost (USD)
Competition Fees	Regional Registration	\$600
Logistics & Travel	Local Transit (Team & equipment to AAST Abu Qir)	\$20
Facilities	Pool Rental (Estimated 50 hours @ 30 EGP/hr)	\$30
Operations	Marketing & Team Branding	\$160
Support Equipment	Surface Power Supply	\$116
	Mechanical Manufacturing Tools	\$60
	Electrical Diagnostic Tools	\$30
Total Operating Budget		\$1,016

6.2 Fair Market Value (USD)

The hardware cost of MONA V2 reflects MTR's commitment to custom, in-house engineering. By designing proprietary printed circuit boards and modifying commercial bilge pumps, the team drastically reduced the financial overhead typically associated with marine robotics. The table below distinguishes between purchased, reused, and donated components as required by the scoring rubric.

Table 5: Fair Market Value Table

Category	Item Description	Type	Cost (USD)
Mechanical	HDPE Frame Material	Purchased	\$80.00
	Custom Machining & 3D Printed Parts	Purchased	\$60.00
	Marine Brass Cable Glands	Purchased	\$20.00
	Rubber, Sealant Glue, & Silicone	Purchased	\$20.00
	O-rings	Purchased	\$10.00
	Fasteners & Bolts	Purchased	\$10.00
	1100 GPH Bilge Pumps (x2)	Purchased	\$39.20
	1100 GPH Bilge Pumps (x6)	Re-used	\$117.60
	15-Metre Tether	Purchased	\$60.00
Hardware	Custom Motor Drivers	Purchased	\$100.00
	Sensors (Temperature, Current, Pressure)	Purchased	\$35.20
Software & Control	GXIVISION USB Cameras	Purchased	\$36.00
	Raspberry Pi 4	Re-used	\$55.00
	Surface Control Laptop	Re-used	\$1,000.00
Total Fair Market Value			\$1,643.00

7.0 Acknowledgements & References

7.1 Acknowledgements

Mind-Tech Robotics would like to extend sincere gratitude to the following individuals and organisations whose support was instrumental in bringing MONA V2 to life for the 2026 MATE ROV Pioneer class:

- Alexandria National University — for providing laboratory space, manufacturing equipment, and institutional support.
- Marine Advanced Technology Education (MATE) Center — for organising the competition and advancing STEM education.
- Arab Academy for Science, Technology and Maritime Transport (ROV Egypt) — for hosting the regional event.
- Prof. Dr. Tamer Helmy, Eng. Omar Al-Azab, Eng. Nour Eldin Sakr, and Eng. Ahmed Hossam — for their continuous technical mentorship and safety oversight.
- Makers Electronics — for generous discounts on electrical components and materials.
- Members from Robo-Tech — for peer support and knowledge exchange.
- Family and friends of all team members — for their encouragement throughout the season.



Table 13: Makers Electronics, MATE ROV Egypt and Alexandria National University Logos

7.2 References

The following technical documentation and datasheets were consulted during the development of MONA V2:

1. Open Robotics. ROS 2 Humble Hawksbill Documentation. Available: <https://docs.ros.org/en/humble>. (Used for establishing the publisher-subscriber node network between the surface laptop and the ROV.)
2. OpenCV. OpenCV-Python Tutorials & Documentation. Available: <https://docs.opencv.org>. (Consulted for developing the real-time stereo vision and depth-estimation pipeline.)
3. Texas Instruments. ADS1115 Ultra-Small, Low-Power, I²C-Compatible 16-Bit ADC Datasheet (SBAS444D). (Used for calculating the precise voltage resolution required for the analog pressure transducer reading in the depth-hold PID loop.)
4. Bosch Sensortec. BME280 Combined Humidity and Pressure Sensor Datasheet. (Referenced for operating temperature range and I²C address configuration for the internal enclosure environment monitor.)
5. Wuxi Wenkang. RZ7886 High Current DC Motor Drive IC Datasheet. (Referenced for thermal dissipation limits and continuous current ratings when designing the custom Power Distribution Board.)
6. Munson, B. R., Young, D. F., & Okiishi, T. H. Fundamentals of Fluid Mechanics. John Wiley & Sons. (Used as the reference for Annular Actuator Disk Theory and Screw Propeller Kinematics applied in the thruster trade study.)
7. MATE Center. 2026 MATE ROV Competition Pioneer Class Manual & Safety Rules. Available: <https://materovcompetition.org/pioneer>. (Utilised as the primary regulatory framework for all mechanical, electrical, and operational design constraints.)

8.0 Appendix A: System Integration Diagram (SID)

The System Integration Diagram below presents the complete topside and bottomside electrical architecture of MONA V2, including the 48V power tree, fuse placements, buck converter outputs, I2C data bus, PWM control lines, camera USB connections, and tether signal path. All signals are labelled using standard electrical schematic conventions.

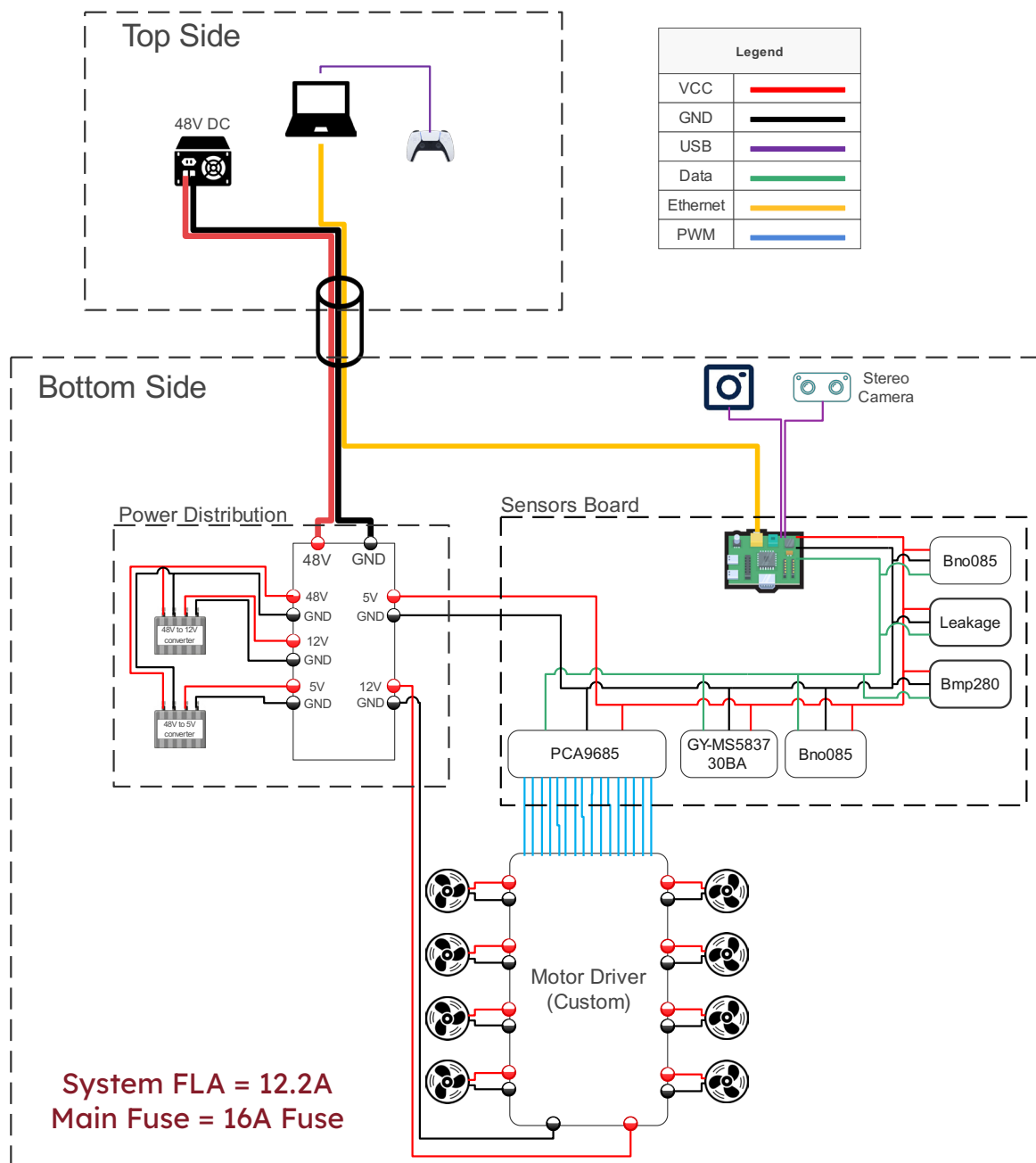


Figure 14: Full-page Electrical System Integration Diagram (SID) — Topside & Bottomside — showing the 48V to 12V / 5V power tree, 16A surface fuse, buck converters, Raspberry Pi 4 node, RZ7886 motor drivers, PWM lines to 8 thrusters, I2C sensor bus (ADS1115, BME280, moisture sensor), dual GXIVISION USB cameras, Ethernet-to-USB tether data path, and pneumatic solenoid valve 12V control lines.

The Fluid Power System Integration Diagram below presents the complete onboard pneumatic architecture of MONA V2, including the regulated 40 PSI air supply, 45 PSI pressure relief valve, 12V DC directional control solenoid valves, internal air routing lines, and the actuation paths for the dual-acting pneumatic gripper cylinder. All components and flow lines are labelled using standard fluid power schematic conventions.

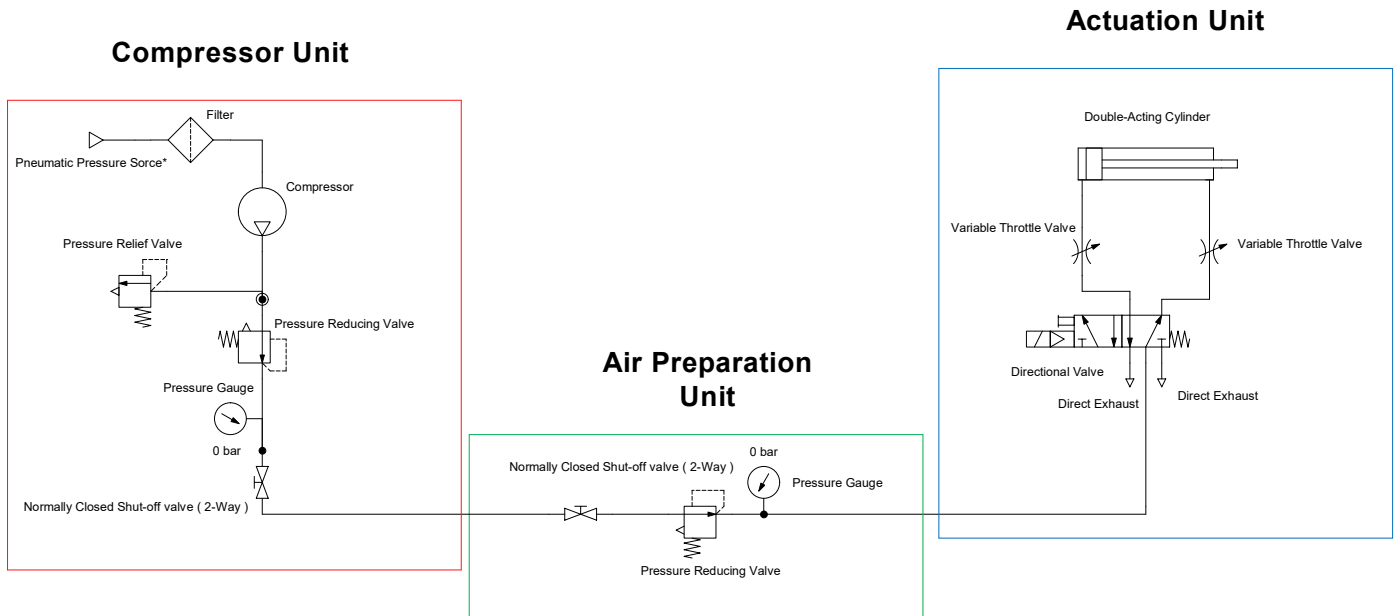


Figure 15: Fluid Power System Integration Diagram (SID) illustrating the pneumatic control circuit for the custom gripper. The schematic details the regulated air supply flow (restricted to a maximum operational pressure of 60 PSI), routing through the 12V DC directional control solenoid valves, and the actuation paths for the dual-acting pneumatic cylinder.