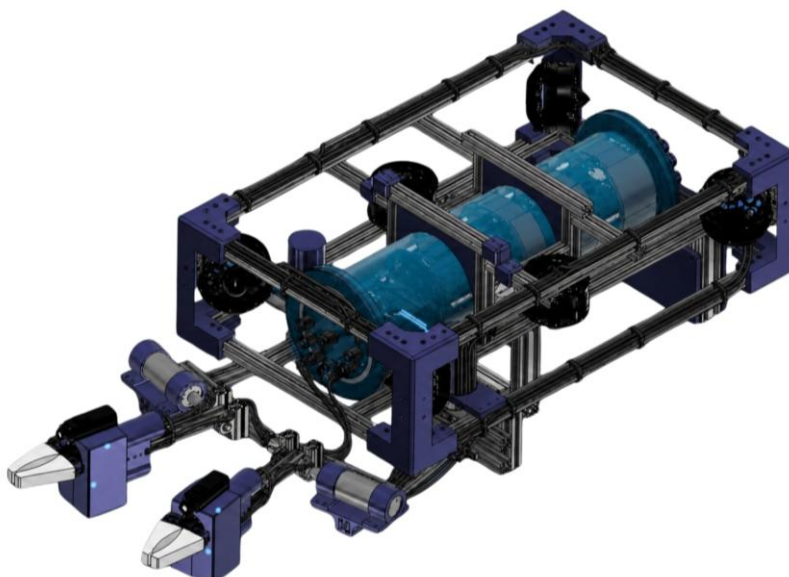




Technical Report

Manipal Academy of Higher Education, Dubai, UAE

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Abstract

Team Jalpari, an undergraduate engineering team from the Manipal Academy of Higher Education, Dubai, presents **Marine Conservation Pioneer**, a third-generation ROV developed for the 2026 MATE ROV Competition. Redesigned from Nautilus-X, the vehicle addresses the 2026 “Pushing Performance” mission through improved modularity, reliable subsea manipulation, and efficient operation in tasks such as coral garden modeling, biological sample recovery, and subsea observatory maintenance

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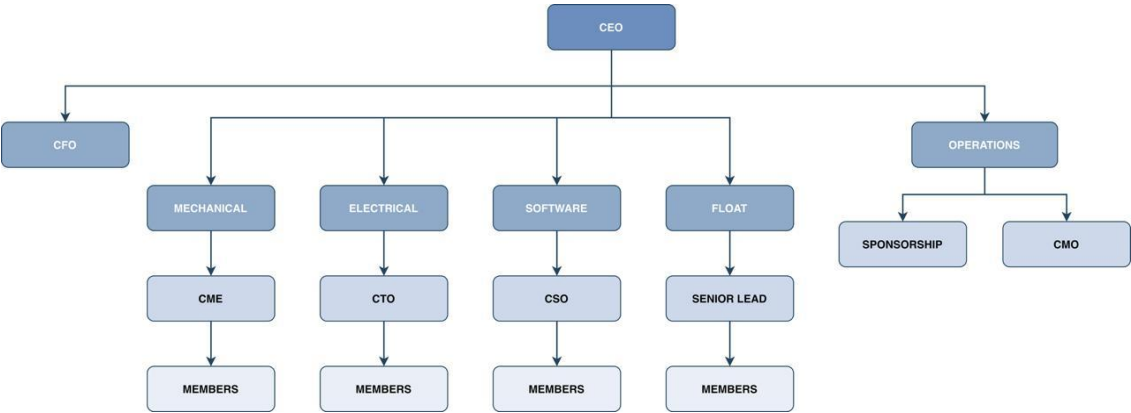
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1| TEAMWORK & PROJECT MANAGEMENT



Personnel Overview [Fig - 1.1 - JALPARI Org. Chart]

Jalpari Robotics operates on a Hierarchical Departmental Matrix. At the helm, the **CEO** provides unified strategic direction, supported by independent financial (**CFO**) and safety (**Safety Officer**) oversight. (Fig. 1.1)

The core engineering workforce is divided into four specialized pillars—Mechanical, Electrical, Software, and Float. Unlike traditional teams where one "Technical Director" manages everything, each of our pillars is commanded by a specialized Chief Officer (**CME**, **CTO**, **CSO**) or Senior Lead (Fig. 1.1). This ensures that every subsystem receives executive-level expertise and attention. To maintain this high level of operational oversight, Jalpari Robotics has defined specific leadership roles that bridge the gap between strategic planning and technical execution. Table 1.1 outlines the core responsibilities of each officer, ensuring clear accountability across the financial, safety, and engineering domains of the ‘MCP’ project.

Company Overview

Jalpari Robotics is a **marine technology enterprise** headquartered at Manipal Academy of Higher Education, Dubai. Established to bridge the gap between academic robotics and industrial application, we specialize in AI-driven solutions for automated coral restoration.

Our track record includes consistent podium finishes in regional competitions across the UAE. Our extensive competitive history has transitioned our operational model from a student club to Agile Engineering Startup, focused on reliability, scalability, and the long-term health of

the Persian Gulf's ecosystems.

Position	Responsibilities
CEO	Directs the strategic mission roadmap and manages external stakeholder relations.
CFO	Audits operational costs to ensure budget compliance and supply chain efficiency.
CTO	Engineers the custom avionics suite and power distribution network.
CME	Architects the composite pressure housings and 4-axis manipulation systems.
CSO	Develops autonomous navigation algorithms and real-time sensor fusion systems.
Senior Lead	Oversees teams and drives key project execution.
Safety Officer	Ensures regulatory compliance and operational safety.
Operations	Manages daily operations and logistical execution.

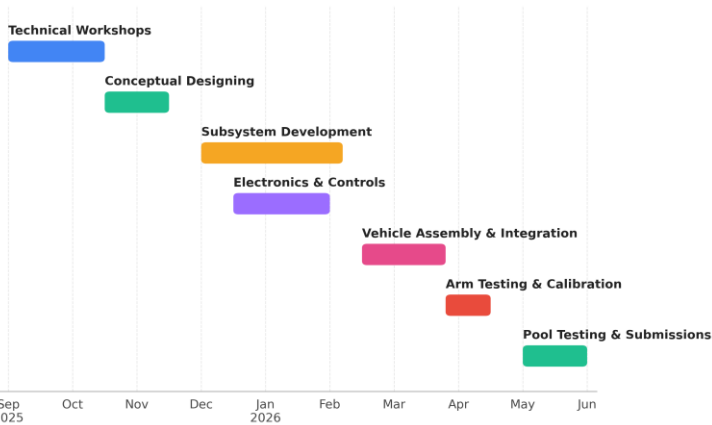
[Table 1.1 - JALPARI Position and Responsibilities]

PROJECT SCHEDULE

Team Jalpari’s development cycle is strategically divided into five major phases: **Onboarding, Conceptual Design, Subsystem Development, Integration & Testing, and Mission Readiness.** This staged approach ensures that new recruits are onboarded smoothly, ideas are developed systematically, and all systems are thoroughly tested before final deployment.

Onboarding Orientation (August -September): Welcomed new members through structured sessions and senior-led technical workshops to transfer domain knowledge from the previous Nautilus-X project.

Conceptual Design (Late September – October): Held brainstorming sessions to define goals for the new vehicle, focusing on design sketches and underwater strategies based on previous lessons.



[Fig. 1.2 - Project Management Scheduling and Breakdown]

Subsystem Development (November – January): Conducted parallel development on mechanical structures, electronics, and software, including CAD modeling and custom PCB design. (Fig. 1.2)

Integration & Testing (February – March): Assembled the system for regular pool testing, using feedback loops to drive iterative refinements in safety and redundancy.

Mission Readiness & Outreach (April – May): Final touches were made to the ROV, including waterproofing, sensor tuning, and field-testing. Simultaneously, STEM outreach plans were executed to promote underwater robotics in schools and universities through workshops and demos.

Project Management

Microsoft Teams	Central hub for meetings, updates, and asynchronous communication
Notion	Collaborative documentation for engineering logs, research, and brainstorming
Google Workspace	File storage and live collaboration on design documents and reports
Fusion Team Hub	Cloud-based sharing and review of 3D CAD designs and technical drawings
Excel Sheets (Shared)	Tracking project budget, inventory, and daily tasks.

[Table 1.2 - Project Management Tools and Platforms]

For Team **Jalpari**, the workflow starts with the weekly strategy meetings on **Microsoft Teams**, where the leads set the priorities and iron out any roadblocks for the **ROV**. This isn't just for talking; it's where the high-level decisions

are made before everyone dives into the shared **Microsoft Excel** sheets to track the nitty-gritty.

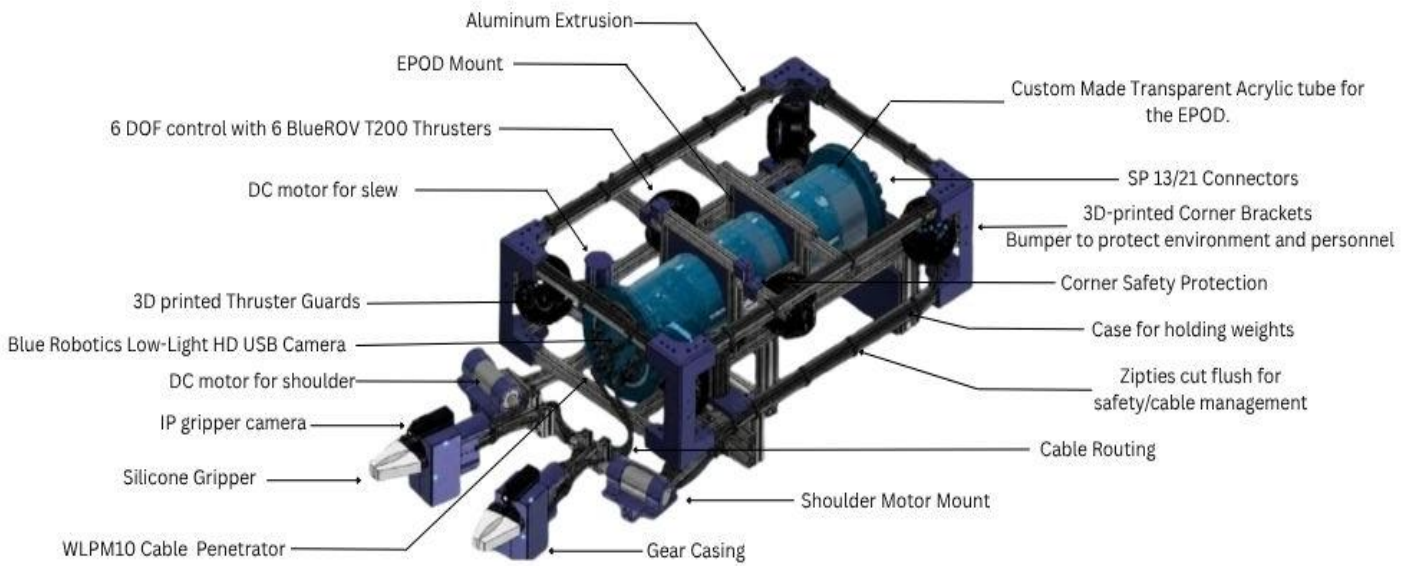
These sheets are the team's "checklist of truth," where we manage the project budget for every thruster and sensor while logging daily tasks to make sure the 15-person crew stays productive and actually hits the milestones for the 4-function arm and other components.

While Excel keeps the timeline straight, **Notion** serves as the actual "brain" of the operation, housing all the engineering logs, research, and technical brainstorming. Instead of losing hours of work in a chat thread, you're using Notion to document the software control logic, electrical layouts, and mechanical assemblies, ensuring that the design intent is preserved. This repository makes it easy to transition into the heavy design phase, where **Fusion Team Hub** takes over for cloud-based CAD sharing. Because the ROV has complex, detachable parts like the robotic arm, the mechanical team uses the Hub to review 3D designs and technical drawings in real-time, catching interferences digitally before anything ever touches a CNC machine or 3D printer.

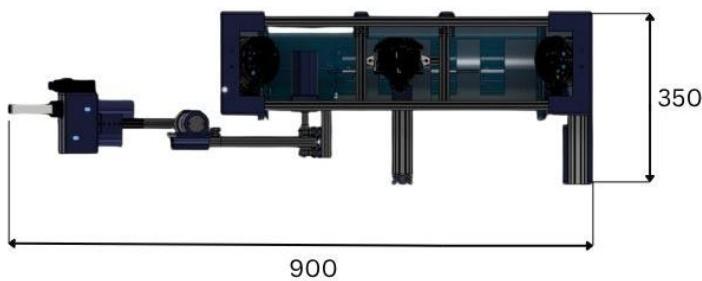
As the technical work solidifies, **Google Workspace** becomes the engine for the final deliverables like the Technical Design Report (TDR). Since we have already got the logs in Notion and the renders in Fusion, the team jumps into live **Google Docs** to collaboratively hammer out the reports and **STEM** outreach plans simultaneously. It's a closed loop where the communication happens in Teams, the logistics in Excel, the deep technical research in Notion, the physical design in Fusion, and the final documentation in Workspace, keeping the entire team in sync without everyone needing to be in the same room.

M.C.P Marine Conservation Pioneer

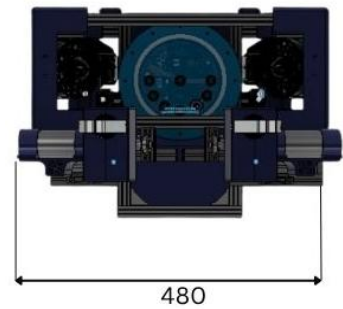
2| Design Rationale



[Fig 2.1 - Diagonal View]



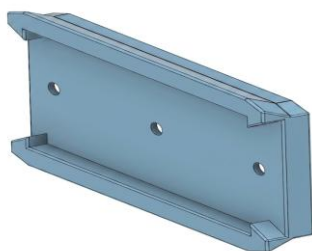
[Fig 2.2 - Side View]



[Fig 2.3 - Front View]

All dimensions are in "mm" unless mentioned otherwise

The **MCP ROV** (Marine Conservation Pioneer) features a fully decoupled architecture designed for rapid modifications. Its frame utilizes **T-slot aluminum extrusions** as a universal mounting grid, allowing tools, sensors, and payloads to be repositioned or scaled on the fly. Inside the pressure hull, a vertical **stacked PCB layout** separates core processing from the motor control layers. By using flexible board-to-wire connections instead of rigid plugs, individual boards—like its high-current **SmartElex ISMDHCX330** driver—can be extracted and serviced independently without a full system tear-down. This adaptable electronic backbone powers a **6-thruster vectored configuration** and a rugged, **DC-motor manipulator arm**, balancing strict power limits with multi-axis underwater maneuverability.



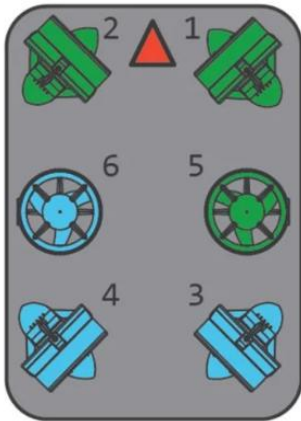
[Fig 2.4 - A specialized sonar attachment engineered to complete the World Championship collaborative bonus mission.]

2.1 Mechanical Design Overview

To meet the rigorous and dynamic operational requirements of the MATE ROV competition, the mechanical architecture of **MCP** was redesigned from the ground up. The design philosophy shifts away from the rigid, monolithic structures of previous iterations toward a highly modular, adaptive platform optimized for rapid maintenance, structural safety, and precise tool manipulation.

MCP replaces rigid claws with a **soft adaptive gripper**: a flexible skeleton in silicone whose fingers conform to different shapes, giving a high-friction grip without force-feedback sensors. This lets the vehicle securely handle delicate coral fragments in Task 1.3 and irregular observatory fixtures in Task 1.2 without damage or slippage. Dual 4-function arms position the gripper while the ROV stays mostly still, cutting thruster wash and camera shake and making connector insertion and valve work in Tasks 2.1 and 2.2 faster and more repeatable.

2.1.1 Propulsion and Thruster Configuration



[Fig. 2.1.1 - 6 Thruster Configuration]

To navigate precisely during competition tasks, **MCP** utilizes a standard **6-thruster layout** optimized for high maneuverability across 5 degrees of freedom, adopting the field-tested **BlueROV configuration**. This design features **four angled horizontal thrusters** mounted at 45 degree angles on the chassis corners to enable seamless, omnidirectional **strafing**, and **two vertical**

thrusters along the lateral centerline for precise **depth control**. Operating the vertical thrusters differentially provides **active stabilization** to counteract off-center payload loads from the gripper arm. While vectoring the horizontal thrusters reduces straight-line velocity, it provides the tight agility required for MATE mission spaces. A comprehensive comparative analysis of this layout against an omnidirectional alternative is detailed in **Table 2.1.1**

Movement	Controlled by
Surge	Thrusters 1 & 2 (front) + 3 & 4 (rear)
Sway	Thrusters 5 & 6 (side-facing center)
Heave	Vertical thrust from angled 1-4 + 5 & 6
Yaw	Differential between 1-2 and 3-4
Roll	Minor control via side counter-thrust

[Table 2.1.1 – ROV Degree of Freedom Control Allocation]

Described trade-offs to balance power consumption, cost, performance and mission requirements

To manage a strict total power limit and prevent overloading the surface system, the team intentionally restricted **MCP’s** motors to a **limited PWM duty cycle range** in software. This capped maximum current draw, preventing severe voltage drops over the tether. Furthermore, because the horizontal thrusters are angled at 45 degrees, the design naturally introduces vector-splitting losses. Adding two more thrusters to the system would have collapsed this tight **power, weight, and financial budget** by introducing unnecessary mass and additional hydrodynamic drag. By sticking to this optimized 6-thruster layout and managing it through software constraints, **MCP** achieves operational efficiency while maintaining the precise agility required for the competition.

6-Thruster Configuration	8-Thruster Configuration
Lower Power & Weight Draw: Requires fewer ESCs and channels, keeping current draw safely within strict power budgets and reducing tether voltage drops.	Severe Power Draw: Sucks significantly more current, easily overloading tightly capped power supplies if not heavily restricted in software.
Lower Cost & Complexity: Reduces financial overhead by eliminating the cost of two extra thrusters, while simplifying the control system wiring.	Increased Weight & Drag: Adds substantial dry mass and increases the vehicle's hydrodynamic footprint, requiring more buoyancy foam.
Coupled Degrees of Freedom: Cannot control all 6-DoF independently (typically lacks independent yaw/pitch control depending on orientation).	True 6-DoF Freedom: Grants complete, independent control over all linear and rotational axes (surge, sway, heave, roll, pitch, yaw) without coupling.

[Table 2.1.2 – Comparison 6-thruster and 8-thruster configurations]

2.1.2 Vehicle Structure

For **MCP**, the team pivoted from custom-machined aluminum sheets to standardized **T-slot aluminum extrusions** to optimize **cost, size, and weight**, as compared in **Table 2.1.3**. Utilizing off-the-shelf T-slot profiles minimized dry mass and eliminated custom CNC overhead, saving critical budget while maximizing the structural strength-to-weight ratio.

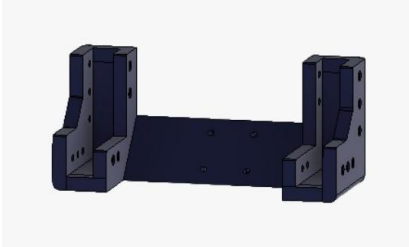
This reduced weight significantly slashes the volume of syntactic foam required for neutral buoyancy, keeping the ROV compact. While the tracks introduce minor hydrodynamic drag, the massive gains in modularity enable rapid field repairs and fluid, on-the-fly mechanical adjustments. The team can effortlessly alter vertical thruster heights, swap out electronic pods,

Aluminum Sheet	T-Slot Aluminum Extrusions
Zero Modularity: Once cut or bent, the structural layout is fixed; components cannot be easily shifted.	High Modularity: Allows components to slide and lock anywhere along the tracks.
High Manufacturing Overhead: Requires precision waterjet, laser cutting, or CNC machining.	No Machining Required: Off-the-shelf parts eliminate the need for CNC milling/cutting.
Difficult Maintenance: Restricted internal access makes on-the-fly field repairs incredibly slow.	Rapid Field Repairs: Easy to disassemble, adjust, or reconfigure between mission runs.
Compact Footprint: Can be bent or cut into tight, flush enclosures without track bulk.	Hydrodynamic Drag: Textured channels and corners create micro-turbulences underwater.
Higher (Frames): Intensive fabrication, bending, and labor drive up costs.	Lower (Frames): Saves significant money and time on machining labor.

[Table 2.1.3 - Difference between Aluminum Sheet and T-Slot Aluminum Extrusions]

2.1.3 Structural Safety

3D-Printed Custom Brackets: The vehicle utilizes custom-engineered, 3D-printed corner brackets. These components serve a dual purpose: they function as rigid structural mounts for the thruster assemblies and act as rounded safety fairings. By smoothing out sharp profile edges, these brackets protect underwater cables from abrasion and ensure compliance with strict MATE safety regulations regarding sharp-edge hazards.



[Fig. 2.1.3 -3D-Printed Custom Brackets]

2.1.4 Buoyancy and Ballast

Main Buoyancy System



[Fig. 2.1.2 - Buoyancy Foam]

To ensure optimal stability and hydroelastic control during high-precision manipulation tasks, **MCP** utilizes a custom-engineered buoyancy framework composed of high-density, offshore-grade **syntactic foam (rigid PVC subsea buoyancy foam)**. To achieve an ideal state of **neutral buoyancy** for the entire vehicle, a primary, contoured block of this high-visibility orange foam was strategically integrated into the **upper aft-center** of the aluminum extrusion frame. This placement directly aligns with the vehicle's transverse centerline, forcing the **Center of Buoyancy (CB)** to sit

perfectly in axis with the **Center of Gravity (CG)** to eliminate unwanted pitch and roll moments during sudden horizontal thrust transitions. Furthermore, to combat the destructive rotational torque and downward loading caused by expanding the vehicle's manipulator payload, separate custom-cut **syntactic foam modules** were directly attached to both links of the **4-axis robotic arm**. This localized flotation renders the mechanical arm completely **neutrally buoyant** in water, drastically reducing the structural load on the joint servos and allowing the pilot to execute fluid, micro-positioning adjustments without disrupting the stable horizontal trim of the main ROV chassis.

2.1.5 Payload and Tools

Cameras

To achieve maximum situational awareness and precise telemetry data collection during competition runs, **MCP** integrates an advanced **five-camera vision matrix** alongside a specialized sensor payload. This layout consists of **four 4MP PoE IP cameras** and one specialized **BlueRobotics Low-Light USB Camera**, all pressure-rated to function reliably **up to a depth of 5 meters**. The cameras are strategically deployed across the vehicle to optimize pilot efficiency and task execution:



[Fig. 2.1.3 – Cameras Used on the ROV]

Front-Facing Primary Navigation: The **Blue Robotics Low-Light USB Camera** is positioned at the front of the frame. Its superior light sensitivity and wide-angle view provide the pilot with an uncompromised, crisp view of the track ahead, even in shadowed or murky pool conditions

Manipulator Integration: Two 4MP PoE IP cameras are mounted at the endpoints of the manipulator arms, delivering close-up, high-definition visual feedback during delicate prop interactions.

Internal Diagnostics: One 4MP PoE IP camera is sealed directly inside the clear acrylic EPOD to act as a continuous, real-time diagnostic monitor for internal electronic components throughout the run.

Subsurface Tracking & Station-Keeping: The final **4MP PoE IP camera** is fixed beneath the chassis facing downward. This underneath camera is highly critical for executing **Task 1.3**, where **MCP** must successfully maintain its position directly over the **coral garden area**. It serves as the primary visual reference for station-keeping, allowing the pilot to closely track bottom features to lock the ROV's coordinates without drifting.

Sensors

Complementing this visual architecture, **MCP's** environmental and navigational tracking relies on a precise three-sensor suite:

Sensors	Description
Bar30 Pressure Sensor	Externally mounted to read ambient hydrostatic pressure, providing high-accuracy depth tracking and water temperature data to the surface GUI.
RM3100 Magnetometer	A high-performance, military-grade geomagnetic sensor that delivers incredibly accurate heading data, completely eliminating magnetic drift so the pilot maintains an exact orientation relative to the pool field.
SmartElex ISMDHCX330	Operates as the core motor driver interface, translating PWM commands from our processing system to smoothly regulate power distribution across the 6-thruster propulsion system while providing essential over-current and thermal safety diagnostics.

[Table 2.1.4 – Sensors Used in the ROV]

2.2 Electrical System Overview

Team Jalpari developed Marine Conservation Pioneer (MCP) as an incremental upgrade over previous ROVs, focusing on higher mission reliability, easier serviceability, and safer operation for the 2026 MATE ROV Competition. The design addresses the 2026 Request for Proposals by reducing wiring complexity, improving power distribution, and meeting strict limits on size, weight, and power. Development centered on a modular electrical architecture for power, control, and communications.

The EPOD's custom PCB stack and separated power/logic endcaps were introduced to isolate noisy loads, reduce failure points, and support rapid troubleshooting during competition, while the overall system was refined through iterative electrical prototyping and testing.

2.2.1 Electrical Architecture System Optimization

Electrical Architecture & System Optimization

Simultaneously, the electrical system adopted a "divide and conquer" strategy using task-specific custom PCBs. This modularity effectively mitigated Electromagnetic Interference (EMI) by isolating high-current motor drivers from sensitive logic circuits. This approach ensured the system remained scalable and field-serviceable, allowing for rapid troubleshooting and maintenance during competition without compromising the integrity of sensitive logic components.

Step-by-step planning :- Once the fundamental design requirements for the ROV, power circuitry, and internal electronics pod (EPOD) layout were established, the team transitioned into a parallelized development workflow. The mechanical department translated conceptual sketches into high-fidelity 3D models using **Autodesk Fusion**

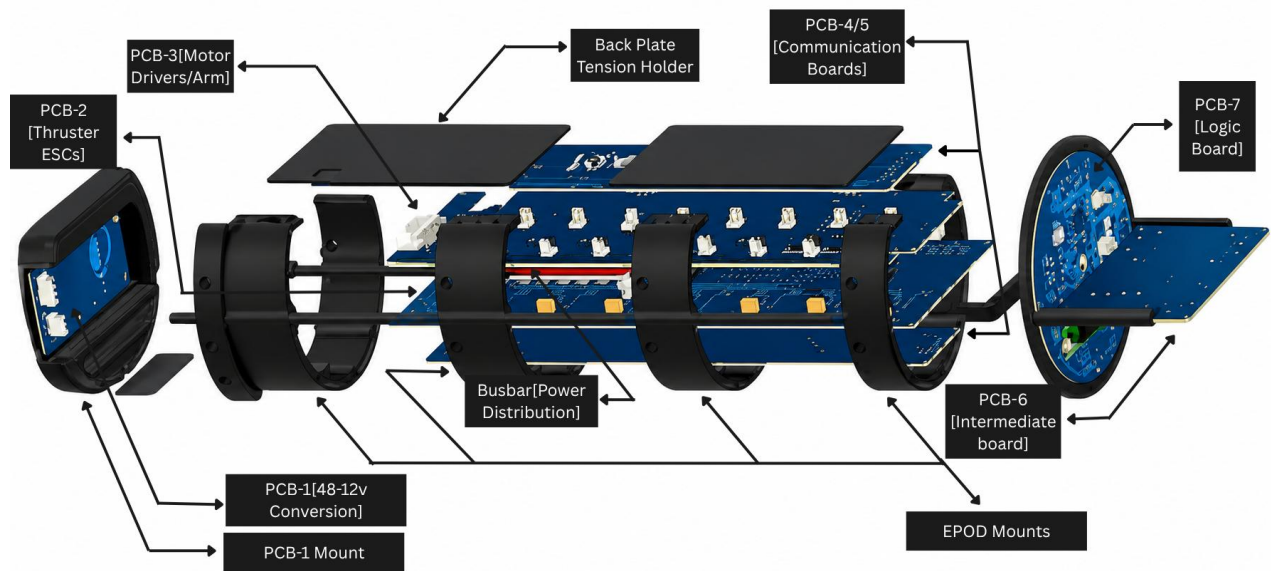
2.2.2 EPOD ARCHITECTURE OVERVIEW

The electrical system of MCP is centralized in a cylindrical electronics pod (E-Pod) with an internal diameter of 150 mm and a length of 600 mm, integrating power conversion, control, and communication into a single removable module

Region	Main Components	Purpose
Logic Cap (Low Noise)	Teensy,RM3100,PoE/PLC/Camera Switches	Control, sensing, networking
Central Section	Busbar, PCB, stack	Power Distribution, signal hub
Power Cap	48V input, BMR491, fuses, connectors	Power Entry and conversion

[Table 2.2.1 - EPOD Functional Split]



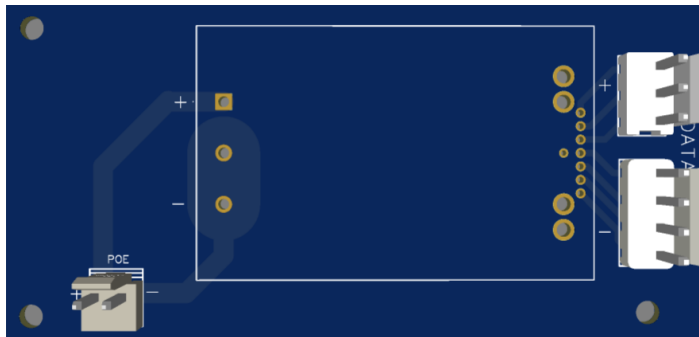


[Fig. 2.2.1— EPOD exploded view showing full PCB stack arrangement]

2.2.3 Custom PCB Architecture & Fault-Tolerant Motor Control

The stack anchors at both endcaps: the **power cap PCB** hosts the 48 V tether input and the **BDQ1300 48 V to 12 V converter** , while the **logic cap PCB** acts as the vertical backplane — the main signal and low-voltage power spine — integrating the Teensy 4.1, RM3100, ISM330DHCX, magnetic components, and communication modules.

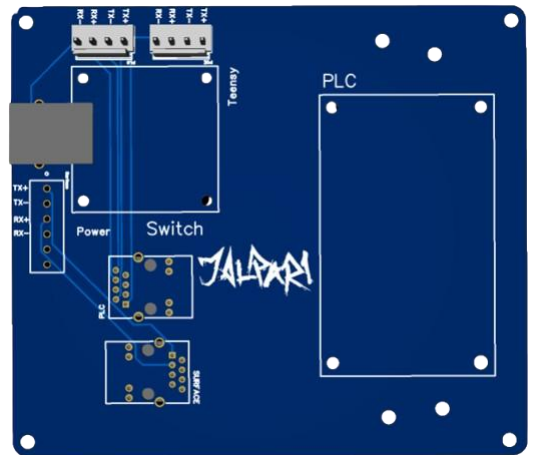
Two horizontal signal PCBs plug directly into the logic cap backplane via board-to-board connectors, breaking out headers to peripheral boards above and below. Mounted flush against the logic cap is the **intermediate communication PCB**, housing the Ethernet switch, PLC module, and RS-485 module.



[Fig. 2.2.2 — Power cap PCB: annotated schematic and assembled photo]



[Fig. 2.2.3 — Logic cap PCB: annotated schematic and assembled photo]



[Fig. 2.2.4 — Intermediate communication PCB: layout and photo]

The upper signal board distributes PWM, enable, and feedback lines to the ESC PCB carrying all 6 ESCs; the lower signal board interfaces with the motor driver PCB and the centrally seated 4-channel relay PCB. Busbars running through the geometric center distribute 12 V to every board, while trace routing on the logic cap separates

high-speed digital, analog sensor, and power regions — with twisted-pair routing reserved for the most noise-sensitive links to minimize EMI coupling from the switching ESCs.

2.2.4 Motor Driver and Gripper Control

During integration, a critical firmware constraint was identified: the Teensy's Servo.h library, used to generate PWM signals for the ESCs, occupies hardware timer resources that conflict with additional PWM channels required for motor driver control — effectively capping the total number of simultaneously addressable PWM-driven actuators. Attempts to introduce supplementary libraries or raw PWM generation for the gripper motors resulted in timing mismatches that destabilized ESC communication, rendering the approach unviable. Rather than compromising thruster control integrity, the team pivoted the gripper actuation strategy entirely: each gripper is now driven by **2 dedicated relays per gripper**, switching the polarity of current delivered through a **3-core SP13 waterproof connector** to the gripper motor — one relay energized for open, the other for close. This relay-based polarity switching requires no PWM channel allocation whatsoever, resolving the library conflict cleanly while maintaining full bidirectional motor control. The solution also inherits the same electromechanical robustness already present in the broader relay fallback architecture, keeping the gripper operational even in firmware-degraded conditions.



[Fig. 2.2.5 - Gripper Finger]

3| Tether Management System

3.1 Power Distribution, Protection, and Inrush Management

Bulk 48 V from the surface enters the power cap and feeds a **BDQ1300-48S12B-4L 48 V to 12 V** converter, which provides the main 12 V rail for propulsion and auxiliary systems. From the output, a central busbar rated for 150 A distributes 12 V to the ESCs, motor drivers, relay board, PoE switch, and other consumers. The 12 V bus is designed for a 108 A full-load current, with expected operational usage between 70–90 A based on the component power budget summarized in Table 3.1.

Equipment	Voltage (V)	Current (A)	Power (W)	Qty	Total Power (W)	Fuse (A)	Current at 48V (A)
Thruster	12	11	132	6	792	15	15.75
Slew Motor	12	9	108	2	216	10	4.5
Shoulder/Rotate Motor	12	9	108	2	216	10	4.5
Gripper Motor	12	0.5	6	2	12	4	0.25
POE Switch	48	0.2	9.6	1	9.6	4	0.125
Switch	12	0.3	3.6	1	3.6	4	0.075
Camera	48	0.3	14.4	4	57.6	4	1.2
Teensy	5	1	5	1	5	4	0.104
Total					1,311.8		26.5A

[Table 3.1 - Power Budget Table]

$FLA = 1.2 * \text{Total Current} = 31.8A$

Since 31.8A is our Full Load Current, we can decide that 30 A is suitable for our maximum operations at surface.

Provides margin for simultaneous thruster and manipulator peaks while staying within BMR and fuse ratings; each high-current branch is fuse-protected to localize faults. Custom E-pod PCBs include bulk electrolytics and local ceramic decoupling near ESCs and drivers, with ferrite beads on signal lines and TVS diodes on the 48 V and 12 V rails to suppress noise and protect against transients. Indicator LEDs on major rails speed bring-up and fault diagnosis.

3.2 Connectors, Sealing Integration

The EPOD uses a two-cap connector strategy, with each acrylic endcap dedicated to a distinct class of connection to keep power and signal lines separated. The power cap carries the 48 V bulk input from the surface through a single SP21 connector using 12 AWG tether power conductors, while 14 SP13 connectors handle all output connections, including the 6 T200 thrusters and 8 manipulator arm motors. SP13s were chosen over the originally planned LEMO series for major cost savings without compromising current handling or sealing performance. Each connector passes through a precision-drilled hole in the acrylic cap, is soldered directly to the pins, and is then fully resin-potted to create a continuous seal around the connector bodies, threads, and solder joints.

Option	Cost	Sealing Performance	Ease of use	Chosen
LEMO series	High	High	High	No
SP13 series	Low	High (with potting)	Medium	Yes

[Table 3.2 – LEMO vs SP Comparison]

The logic cap routes all signal and data lines through WLPM10 cable penetrators, with 6 penetrations for Ethernet, RS-485, PLC, and IP camera feeds. Each penetrator is resin-potted in its hole, forming a mechanically bonded barrier against hydrostatic pressure and vibration. Ethernet penetrators terminate at the internal network switch, RS-485 and PLC penetrators land on the power distribution board tether conductors, and the remaining penetrators carry IP camera signals back to the E-Pod switch for transmission to the surface station. Internally, board-to-board PCB connectors avoid extra bulkhead penetrations, minimizing acrylic cap holes and leak paths. Each connection class has a dedicated entry: SP21 for bulk power, SP13 for motor outputs, and WLPM10 for signal lines, so any single connector or penetrator failure affects only one subsystem.

3.3 Sensor Suite, Selection Fusion

Three sensors handle all onboard environmental and orientation data, each selected for a specific role within the EPOD's constrained architecture. Table 3.3.1 summarizes the selection rationale against evaluated alternatives.

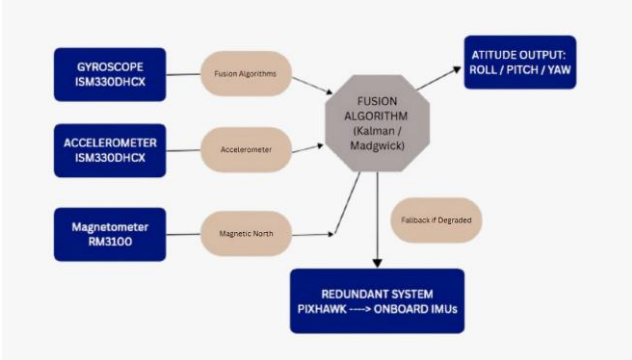
Parameter	Bar30	MS5837-30BA	Selected
Depth Resolution	2mm	2mm	Bar30
Additional Output	Depth + Temperature	Depth only	Bar30
Interface	I ² C	I ² C	—
Blue Robotics Integration	Native	Third-party	Bar30

[Table 3.3.1 - Sensors Used in the ROV]

Parameter	RM3100	HMC5883L	ISM330DHCX	MPU6050	Selected
Sensing Principle	Magnetoo-inductive	Magnetoresistive	MEMS Gyro/Accel	MEMS Gyro/Accel	Both
Noise Performance	13 nT RMS	200 nT RMS	4 mdps/√Hz	5 mdps/√Hz	Both
Vibration/Saturation Immunity	High	Low	Industrial-grade	Consumer	Both
Interface	SPI	I ² C	I ² C / SPI	I ² C	Both
Operating Temperature	-40°C to +85°C	-40°C to +85°C	-40°C to +105°C	-40°C to +85°C	Both

[Table 3.3.2 - Breakdown of Sensors]

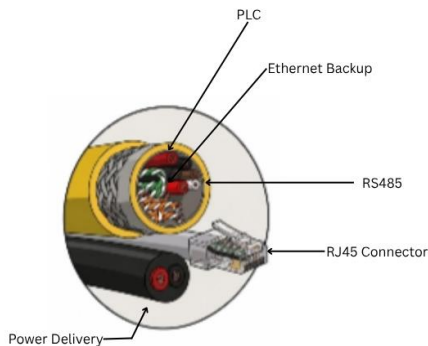
The orientation pipeline pairs the ISM330DHCX and RM3100 through a complementary fusion algorithm — Kalman or Madgwick filter — to produce a single stable 3-DOF orientation estimate. Fig. 3.3.1 illustrates the data flow through the fusion pipeline.



[Fig 3.3.1 Data Flow Pipeline]

The gyroscope tracks fast, high-rate angular motion with low latency but accumulates drift without an absolute reference. The fusion algorithm corrects this continuously using two independent physical anchors: the accelerometer's gravity vector locks pitch and roll to an absolute frame, while the RM3100's magnetic north measurement anchors yaw against heading drift. The result inherits the gyroscope's short-term responsiveness while remaining bounded by the long-term accuracy of both absolute references — eliminating the heading drift and nose-drop that would otherwise accumulate during extended manipulation tasks. Should either sensor produce degraded readings under electromagnetic interference from the switching ESCs or busbars, the system falls back passively to the **Pixhawk's onboard IMUs** without requiring firmware intervention.

3.4 Tether Breakdown



[Fig. 3.4.1 - Tether Breakdown Diagram]

Power Delivery 48 V AWG 8 Main Line

A dedicated 2-core AWG 8 copper cable supplies 48 V DC at up to 30 A from the surface PSU to the ROV. AWG 8 was selected for its low DC resistance and current capacity, keeping I^2R losses and conductor temperature rise within safe limits over the 20 m length. The 48 V distribution voltage reduces current for a given power level, which lowers voltage drop and allows the same tether to support simultaneous thruster peaks, manipulator loads, and auxiliary electronics without brown-outs on the 12 V subsea bus.

Multifunction Communication Tether – PLC, RS485, Backup Ethernet

A yellow multifunction tether integrates three distinct comms layers into a single cable for redundancy and noise robustness. Two dedicated conductors carry Power Line Communication (PLC), implemented on its own pair rather than on the main 48 V line to decouple data integrity from propulsion transients. A twisted brown-white pair carries RS-485, using differential signaling and a wide common-mode range to tolerate ESC switching noise and ground offsets over the full tether length. Two additional twisted pairs are reserved as backup Ethernet paths and can be promoted to primary use if the main Ethernet cable or its terminations are compromised during competition.

Primary Waterproof Ethernet High-Bandwidth Channel

A separate outdoor-rated, waterproof Ethernet cable provides the primary high-bandwidth link between the surface control station and the ROV. Shielded twisted pairs inside the cable carry all standard IP traffic: thruster and manipulator commands, IMU and depth telemetry, and multiple compressed video streams from the PoE camera network. The mechanical construction is abrasion-resistant and moisture-sealed to survive repeated deck handling, while the shielding reduces susceptibility to conducted and radiated EMI from the 48 V power line and ESCs.

Tether Length Calculation

Voltage (V)	Current (A)	Gauge (mm2)	Voltage Drop (V)	Voltage at Full Load (V)	Power (W)	Efficiency (%)
48V	30A	4mm2	2.52V	45.48V	1364.4W	94.8%
48V	30A	4mm2	3.78V	44.22V	1326.6W	92.1%
48V	30A	4mm2	5.04V	42.96V	1288.8W	89.5%
48V	30A	4mm2	5.30V	41.70V	1251.0W	86.9%
48V	30A	4mm2	7.56V	40.44V	1213.2W	84.3%

[Table 3.4.1 - Tether Length Breakdown]

According to the above table, the sweet spot that could be decided is to go with 20m as it gives enough length to prepare tasks and give enough efficiency. As is depicted in Table 3.4.1., The calculated length that would be required for the tasks is a minimum of 10m rounded off. We have decided to go with 20m as it gives enough slack for the tether handler to hand off tether during situations as well as the hanging of tether throughout the pool.

Tether Management

Tether Buoyancy

The tether has enough weight as it is carrying in essential, a 3 cable tether. Compounding on this, it tends to make the tether heavy and as the tether is entering from behind the ROV, it tends to weigh it down and cause a negative pitch. To avoid this, the tether has been strategically placed to point upwards and avoid pitch as much as possible. To add on, buoyancy foams have been kept to make the tether float and avoid being involved with the play area as much as possible.

Strain Relief

Here it is in clean, copyable plain text:
Pre-Run Inspection: Visually check the entire length of the tether for jacket cuts, exposed wiring, or kinks, ensuring both topside and ROV-side strain reliefs are completely secure.
The Figure-Eight Layout: Flake the tether onto the pool deck in a large figure-eight pattern instead of a standard circular coil to prevent the internal conductors from twisting mid-run.
Assign a Dedicated Handler: Appoint a Safety Officer whose sole responsibility is managing the tether, keeping constant eyes on the ROV's position and line tension.
Feed on Demand: Pay out the line only as the ROV advances; never throw excess slack into the water where it can sink, loop, or snag.
Maintain a Tension Buffer: Keep the line taut enough to prevent it from drifting into the thruster shrouds, but loose enough that it doesn't drag the vehicle or fight the pilot during precision tasks.

Monitor Pool Obstacles: Actively guide the line to ensure it doesn't scrape against sharp pool coping or get caught on ladders, lane lines, or underwater structures.

Track Pilot Rotation: Keep tabs on how many full rotations the pilot makes in one direction, and communicate when they need to counter-rotate to untwist the internal cables.

Hand-over-Hand Recovery: Retrieve the ROV using a gentle, hand-over-hand pulling motion, making sure the tether never rubs or grinds against the edge of the pool deck during extraction.

Post-Run Wipe and Log: Wipe down the tether jacket to remove chlorinated water, inspect the connectors for any signs of water ingress, and coil it neatly back into its storage configuration.

3.5 Waterproofing

For this generation, the team transitioned to a transparent acrylic tube rated for depths up to 15m, replacing the first-generation PVC pipe and last year's cramped NEMA 6P enclosure. Acrylic was selected for its immediate visual accessibility, allowing the team to inspect internal components and verify capacitor indicator lights without opening the pod. Furthermore, the increased volume eliminates the spatial constraints of the previous NEMA 6P housing, significantly improving physical access for hardware maintenance and debugging.

Feature	Gen I : PVC pipe	Gen II : Nema 6P	Gen III : Acrylic Tube
Visibility	None (Opaque)	Medium (only lid)	Excellent (Full Transparency)
Component Accessibility	Difficult/Narrow	Difficult /Very Cramped	Spacious & Accessible
Primary Benefit	Cheap & Accessible	High Industrial Protection	Real-time Visual Debugging
Depth Rating	50m	5m	20m

[Table 3.5.1. - Generations of EPOD]

4| Surface Control and Software

Control Station



[Fig. 4.1 – Control Station]

Housed within a rugged, impact-resistant Pelican case, this hard-shell Ground Control Station (GCS) securely protects the critical surface-level electronics from harsh environmental conditions. It consolidates all the essential hardware required to deliver surface power, process high-throughput data, and transmit real-time piloting commands to the ROV. The primary components integrated into this station and their specific functional roles are detailed in the table below:

Components	Role
Kill Switch	Instantly cuts off all hardware power for immediate safety in an emergency.
Dual Portable Screens	One screen displays live pilot controls; the other shows real-time camera feeds and sensor data.
48V Power Supply	Converts incoming power to a stable 48V DC output to run the vehicle's thrusters and subsystems.
Jetson AGX Orin	Serves as the main processing unit for AI tasks, video feeds, and navigation data.
Logitech Extreme 3D Controller	The primary joystick interface used by the pilot to steer and navigate the vehicle.
Potentiometer Arm Controls	Delivers analog precision tuning to allow meticulous micro-movements of the robotic manipulator arm.
Extension cord	Connects the main AC shore/lab power supply safely to the control station.

[Table 4.1 - Components of Control Station]

During initial pool testing with the standard Jetson Orin platform, the team encountered several critical hardware and communication bottlenecks that severely compromised vehicle reliability. Upgrading to the higher-tier **Jetson AGX Orin** provided the robust hardware architecture and stable driver support necessary to eliminate these failure points. The specific technical challenges faced during testing and how the AGX Orin resolves them are outlined in the Table 4.2.

Technical Issue Faced (Standard Jetson Orin)	Impact on ROV Operations	AGX Orin Resolution
Driver Incompatibility	Caused unstable peripheral recognition and software crashes.	Offers native, mature enterprise driver support for seamless component integration.
Arm Controller Latency	Created lag between pilot input and manipulator arm response.	Higher clock speeds and optimized bus routing ensure near-zero input latency.
Communication Losses	Led to sudden disconnections and telemetry drops between surface and ROV.	Superior PCIe/USB bandwidth and robust I/O handling maintain a stable tether link.
Thermal Overheating	Caused performance throttling and mid-operation system shutdowns.	Equipped with an advanced, heavy-duty cooling solution designed for sustained high workloads.

[Table 4.2 – AGX Vs Nano Comparison]

The ROV control system uses a decentralized architecture built around an NVIDIA Jetson AGX Orin running a localized Node.js GUI (localhost:3000) for telemetry visualization, gamepad parsing, and operator control, alongside a Python serial communication worker for tether communication. Subsea control is handled by a Teensy 4.1 microcontroller responsible for high-frequency sensor polling, deterministic thruster PWM generation, PID-based stabilization, and safety routines. Joystick inputs representing Surge, Sway, Heave, and Yaw are processed through a thruster mixing matrix to generate optimized motor outputs based on the ROV frame geometry. A secondary Arduino independently controls the manipulator arm using hardware timer-generated servo PWM signals. Orientation and heading estimation are achieved using a SmartElex ISM330DHCX IMU and RM3100 magnetometer housed inside the EPOD. The Teensy fuses sensor data using complementary filtering and transmits compact telemetry packets containing heading, pitch, roll, and thruster states to the surface GUI. An independent BlueOS-based video streaming system ensures camera processing remains isolated from propulsion and stabilization loops, improving reliability and eliminating computational bottlenecks. The Jetson AGX Orin also enables future AI-assisted autonomy, including real-time YOLO-based object detection and advanced navigation upgrades using industrial-grade AHRS systems.

5| Build vs. Buy and New vs. Reused

5.1| Build Vs Buy

The team adopted a build-first philosophy, designing and manufacturing all major PCBs in-house using EasyEDA and JLCPCB to optimize integration, compactness, and modularity within the EPOD. Custom-built components included the power and logic PCBs, communication boards, ESC and motor driver boards, relay systems, waterproof pressure chamber, and all 3D-printed structural mounts fabricated using PETG. This approach reduced cost, improved space utilization, and enabled rapid design iteration. Commercial components were used where reliable underwater performance or specialized functionality was required. These included the Blue Robotics T200 thrusters, Bar30 depth sensor, RM3100 magnetometer, ISM330DHCX IMU, Teensy 4.1, cameras, SP13 connectors, and manipulator motors. The BDQ1300-48S12B-4L DC-DC converter was selected for its compact high-power design and PMBus configurability.

5.2| New Vs Reused

Reusing well-maintained components from previous competitions directly reduced procurement costs and supported the team's commitment to sustainable engineering. The 6 T200 thrusters and ESCs from the MATE 2025 vehicle Nautilus-X were serviced and integrated, remaining fully compatible with the 2026 power budget of 30A at 48V. Following continuity, jacket integrity, and load testing, the reused MATE 2025 tether and surface 48V power supply unit were verified as fully adequate for the triple-redundant Ethernet/PLC/RS-485 architecture and output regulation specs. Additionally, the 2025 aluminum extrusions were re-cut for the new frame geometry, while the prior vehicle's Pixhawk flight controller was re-flashed and re-calibrated—its ArduSub firmware and onboard IMU redundancy meet all 2026 mission requirements.

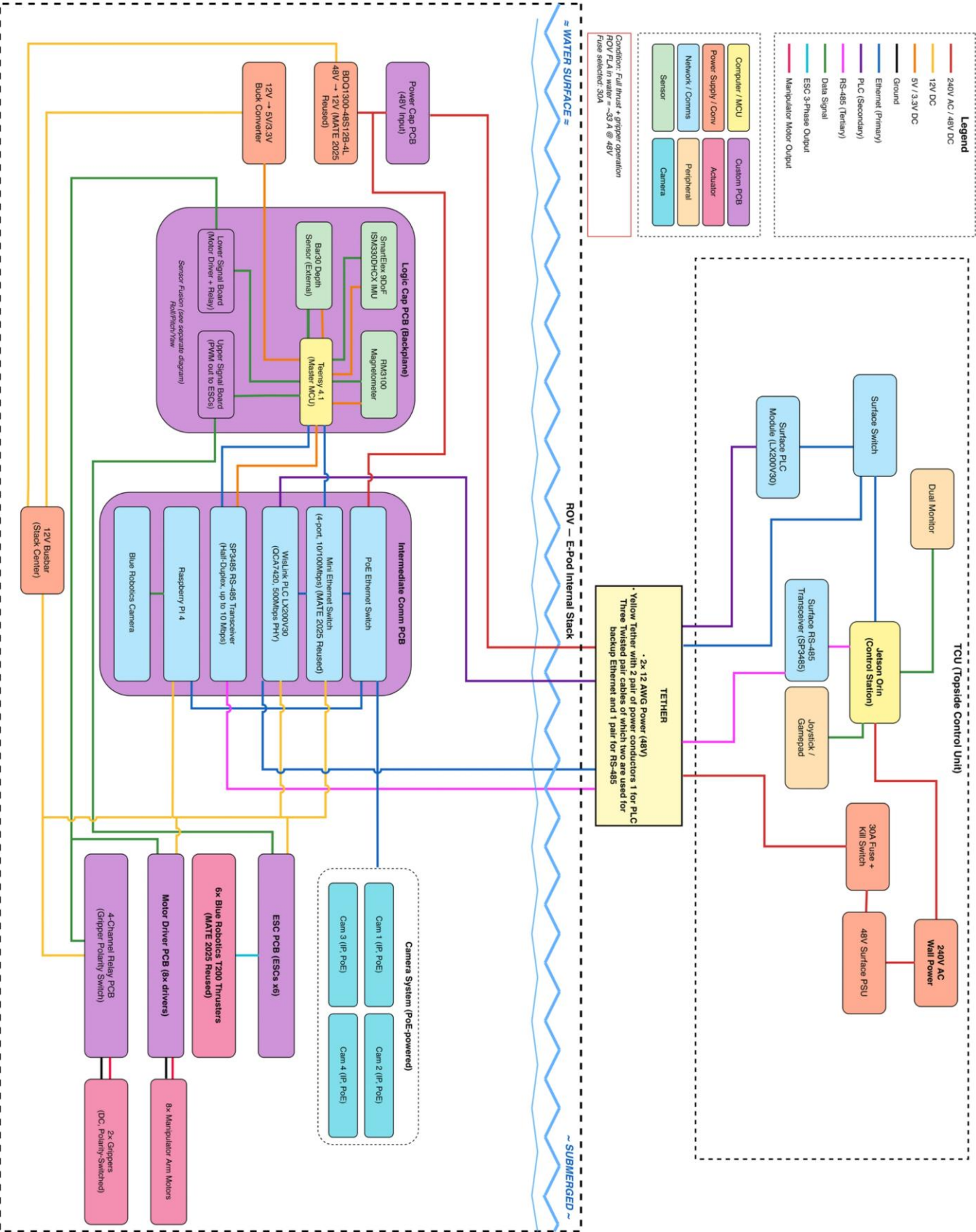
Component	Build / Buy	New / Reused	Justification
Custom PCBs (all)	Build	New	In-house EasyEDA design, JLCPCB manufacture — custom geometry required
6× T200 Thrusters	Buy	Reused (MATE 2025)	Inspected, cleaned; performance within 2026 power budget
T200 ESCs	Buy	Reused (MATE 2025)	Compatible with Teensy PWM output and 12V bus
Tether	Buy	Reused (MATE 2025)	Continuity tested; gauge supports Ethernet/PLC/RS-485
Aluminum Extrusions	Buy	Reused (MATE 2025)	Re-cut to new frame geometry
Pixhawk	Buy	Reused (other comp)	Re-flashed to ArduSub; onboard IMU meets 2026 requirements
48V PSU	Buy	Reused (MATE 2025)	Load-tested, output regulation verified within spec
Teensy 4.1	Buy	New	Required for Ethernet/PLC/RS-485 arbitration architecture
Bar30, RM3100, ISM330DHCX	Buy	New	Mission-specific sensor requirements
SP13 Connectors	Buy	New	Replaced LEMO series for cost saving without spec compromise
DC Motors (arms)	Buy	New	Replacing servo system following waterproofing pivot
Cameras	Buy	New	Mission imaging requirements
Polycarbonate panels	Buy	New	Frame panelling for EPOD and structural covers
3D Printed Parts	Build	New (PETG)	In-house fabrication, recycled PETG where possible
Pressure Chamber	Build	New	Custom transparent-window design; no commercial equivalent

[Table 5.1 – Build Vs Buy & New Vs Reused]



ROV SID

MCP System Interconnect Diagram (SID)

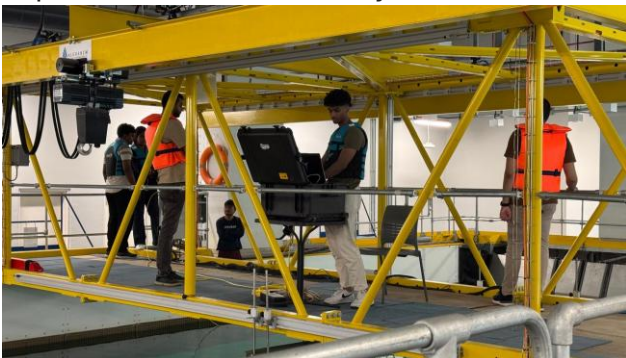


Jalpari's safety was prioritized throughout the design, assembly, testing, and operation of the ROV system. Operational procedures were developed to minimize electrical, mechanical, and handling hazards during launch, recovery, and maintenance activities. As many members of Team Jalpari were new to the field and had limited prior experience with ROV systems, additional precautions were taken to ensure a safe working environment during all stages of development and testing. Close supervision was maintained during poolside operations, equipment handling, and vehicle deployment to reduce the risk of accidents, improper handling, or damage to the system.

7.1 Safety Rationale

Personnel Safety

- **Mandatory Training:** Prior to any operational involvement, all new members must complete comprehensive training covering electrical hazards, pool-side protocols, proper ROV handling, tether management, and emergency response.
- **Designated Safety Officer:** All testing and operational activities are overseen by a dedicated Safety Officer strictly responsible for hazard identification, team movement control, and the enforcement of all safety protocols.
- **Mentorship & Supervision:** Experienced returning members actively supervise and guide newer recruits during all hands-on activities to ensure safe operational practices are consistently maintained.



[Fig 7.1 - Safety Training Session]

Equipment Safety

Mechanical Safeguards

- **Thruster Shrouds:** Installed on all thrusters to prevent accidental contact with moving propellers.
- **Deburred Edges:** All sharp edges on the frame and custom mounts are smoothed to prevent personnel injury and cable abrasion.
- **Cable Management:** Strain relief mechanisms secure all entry and exit points. Internal wiring is tightly routed to prevent snagging or interference with moving parts.

Electrical Safeguards

- **Circuit Protection:** Fused power distribution isolates the main high-power system from lower-power subsystems, preventing cascading electrical faults.
- **Kill Switch:** A readily accessible emergency cutoff switch allows the pilot to immediately power down the vehicle in abnormal situations.
- **Waterproofed Connections:** Electrical connections are kept strictly internal where possible. Necessary external connections (e.g., manipulator arm motors) are directly soldered and thoroughly sealed against water intrusion.

Operational Safety

- **Pre-Dive Inspections:** Mandatory visual and functional checks are conducted before every dive to verify seal integrity, tether connections, communication, and thruster operation.
- **Handling Protocols:** Launch and recovery operations are highly coordinated among team members to prevent tether entanglement, accidental drops, or sudden mechanical stress on the vehicle.

7.2 Safety Procedures and Checklists

Team Jalpari's Safety Checklists are detailed in **Appendix C**. All pool-side members are trained on these documents. During operations, the designated Safety Officer strictly dictates the step-by-step checklist and must issue a final clearance signal before the ROV is authorized for

8 | CRITICAL ANALYSIS



8.1 Testing and Troubleshooting Methodology

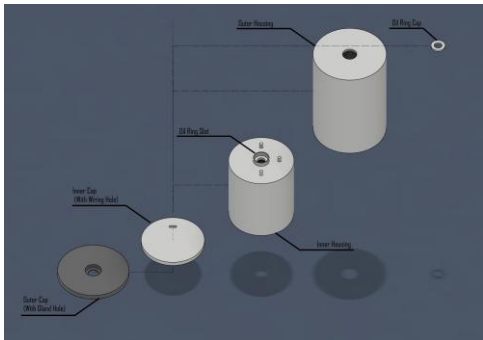
The team adopts a rigorous, hardware-in-the-loop (HIL) testing methodology to validate subsystem reliability prior to full-scale deployment.

- All components were pressure tested in our custom-built pressure chamber.
- Prior to water submersion, the full electronics stack was assembled and stability and communication was tested.
- Finally, The entire system is tested in water to ensure sealing is perfect and our thruster dynamics and control loops were working as intended

8.2 Prototyping, Design Evaluation, and Troubleshooting

Waterproofed Servo Enclosure

The initial plan was to use high torque servos with a custom made waterproof housing. The housing was designed to be a resin filled, double walled, oil filled housing featuring an internal pressure compensation mechanism. However, after studying the tradeoffs we decided to switch to DC motors for its simplicity, compactness and ease of the waterproof housing design. This was vital for the hydrodynamic profile and the enhancing operational agility of the ROV.



[Fig 8.1: Servo Waterproof Housing]

Spatial Re-alignment of the Gripper and Rotation Motors

The initial plan was to place the gripper actuation after the rotational actuation. This was a very straightforward idea. However, we decided that this would be prone to cable entanglement during operation



[Fig 8.2: Gripper/Rotation Actuation]

Compute Platform Upgrade

During initial pool trials utilizing a standard Jetson Orin platform, the vehicle experienced severe hardware bottlenecks. To ensure we wouldn't have any input delay or telemetry dropouts, we decided to upgrade to the NVIDIA Jetson AGX Orin.

Navigation Sensor Fusion Architecture Transition

The IMU and heading data was initially planned to be from the RM3100 and SmartElex ISMDHCX330. Due to the tight competition submission timelines and software integration hurdles, the team temporarily regressed to a Pixhawk flight controller from our previous iteration of the ROV. The team then transitioned back to the initially planned sensor suite because it can be directly be integrated to the Teensy microcontroller via I2C/SPI, dramatically shrinking the physical footprint and unlocking advanced, low-latency sensor fusion capabilities for precise dead reckoning.

9 | ACCOUNTING

9.1 Financial Management & Strategy

Team Jalpari operates on a meticulously managed budget, separating massive logistical expenses from direct ROV research and development. To fund the initial prototyping phase, we bootstrapped a working capital pool of \$3,849.13 through member base dues. Being a team that heavily relies on self-funding, it is important that we focus heavily on resourcefulness and sustainability to keep our actual ROV build costs extremely low. By reclaiming, testing, and integrating major systems from previous competition iterations (like our thrusters and tether), we drastically reduced our environmental footprint and financial overhead. This allowed us to reallocate our primary funds toward international travel, custom tooling, and competition logistics.

9.2 Total Team Operational Budget

Transporting a 10-member engineering team to the competition requires the bulk of our funding. Personal daily sustenance is excluded from this budget per standard guidelines.

Team Name	Team Jalpari	
Institution	Manipal Academy of Higher Education, Dubai	
Competition Year	MATE ROV 2026	
Document Type	Project Budget Projection	
Expenses		
Category		Description / Key Components Included
Mechanical & Structural Systems	\$1,824.37	ROV chassis, Blue Robotics penetrators/hardware, acrylic enclosures, motors, thruster mounts, and raw building materials (PVC, aluminum).
Electrical & Control Systems	\$1,143.64	Custom PCBs, Teensy microcontrollers, power distribution systems, actuators, IMUs, magnetometers, and connectors.
Administrative & Competition Fees	\$680.74	Official MATE ROV 2026 team registration and initial corporate documentation/logistics.
Travel & Logistics: Logistics & Transport	\$11,082.37	Round-trip international flights for 10 traveling team members and vehicle rentals
Travel & Logistics: Lodging & Visas	\$4,884.96	Estimated Airbnb costs and visa application processing fees for 10 team members
Project Contingency Fund	\$136.15	Emergency allocation reserved for last-minute hardware replacements, shipping/import duties, or rapid prototyping adjustments.
TOTAL PROJECTED BUDGET	\$19,752.21	Total estimated financial layout for the MATE ROV 2026 campaign.
Notes: Personal daily sustenance (food and beverage) is excluded from the team operational budget per standard guidelines, handled via individual personal expenses.		

[Table 9.1: Project Budget Projection]

8.3 ROV Component Accounting

The Project Costing table represents the comprehensive accounting of all components onboard the 2026 vehicle. To demonstrate our commitment to budget management and sustainability, we have listed the commercial retail value of every part alongside the actual cost incurred by the team this season. The table can be found in **APPENDIX C**

10 | ACKNOWLEDGEMENT

Here is the updated acknowledgements section, including a dedicated and formalized mention for your father to fit the professional tone of the document.

Acknowledgements

Our operations would not be possible without the support of our sponsors, university, and families. We are incredibly grateful for the help and support we have received this year, and thank the following organizations and people for their contributions:

- Many thanks to MATE II for the organization of the MATE ROV competition and the creation of opportunities for students to learn, design, and build ocean technologies.
- Professor Suresh Balakrishnan and Dr. Vyshak Sureshkumar for their invaluable mentorship and guidance of Team Jalpari.
- The Manipal Academy of Higher Education Dubai and the Centre for Robotics and AI lab for providing essential laboratory and classroom space.
- Our alumni, Bilal Baslar and Jerin Jose, for their continued guidance, advice, and support.
- Bambu Lab for their exceptional 3D printing technology, which was heavily utilized and instrumental to our manufacturing process.
- Mr. Sasikiran for generously providing us with an alternative workspace and facility when the university was temporarily closed due to the regional situation.
- A special thank you to Mr. Sajan Phillip Mathew for his generous and vital monetary support.
- And the parents and families of all our team members for their financial support and continuous encouragement throughout the project.

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12 | APPENDICES

APPENDIX A

ROV Construction

Workspace Preparation:

- Cleaning of debris and all sharp items to avoid damaging of components.
- Placement of silicon grease bucket to hold O-rings during maintenance.
- Correct placement of components according to predefined Electrical layout.

Closing:

- Check resistance of 48 V line and 12 V lines to avoid shorts and resistance across it.
- Open pressure release valve to avoid pressure buildup during enclosure close.
- During insertion of tube towards main structure, ensure wires are tucked in.
- O Ring has to be held onto groove.
- Ensure tightening of tube to both caps in star pattern to avoid over strain of acrylic.
- Make sure tether is placed in right orientation to avoid strain to the tether and directly on strain relief.

After Closing:

- Check for any resistance between the 48 V line as well as the dedicated SP connector connected to 5V line.
- Tighten the pressure release valve to avoid all leaks.
- Ensure the cylinder is horizontally placed and aligned EPOD to the ROV.
- Ensure both o rings are tightened onto groove.
- Ensure all Blue Robotics Penetrators are gripped properly onto cables.

ROV Runs

Pre-Deployment Checks

- Confirm that sufficient team members are present for safe ROV operation, including the pilot, tether manager, safety officer, and deployment personnel.
- Inspect the ROV frame, enclosure, and external components for visible damage, loose mounts, cracks, or structural weaknesses.
- Check that the power supply and surface-side electrical systems are dry and positioned safely away from the edge of the pool.
- Ensure tether strain relief points are securely attached to prevent accidental stress on connectors or internal wiring.
- Verify successful communication between the surface station and onboard systems before deployment.
- Ensure all personnel are equipped with appropriate safety gear and avoid loose clothing or unsecured accessories near moving equipment.
- Confirm stable power delivery and communication before enabling thruster systems.
- Ensure all team members are clear of moving components before vehicle activation.
- The pilot and co-pilot do a system health check and confirm with each other before confirming with Tether Manager as the ROV is placed into the water.
- Deployment personnel handle the vehicle using designated lifting points on the frame to avoid damage to sensitive components.
- The ROV is gradually lowered into the deployment zone while maintaining tether control and vehicle stability.

During Operation

- The tether manager continuously monitors tether movement and slack to reduce the risk of entanglement or excessive strain.
- The pilot remains prepared to activate the emergency kill switch if abnormal vehicle behavior or electrical issues are observed.

Recovery Procedures

- The pilot carefully navigates the ROV back to the designated recovery area before retrieval.
- The vehicle is removed from the water in a controlled manner to prevent sudden loading on the tether or mounted components.
- Electrical systems are powered down before post-operation handling or maintenance begins.

Post-Deployment Procedures

- The ROV is visually inspected for signs of damage, loose components, or water ingress after operation.
- Batteries and electrical systems are disconnected and secured before transportation or maintenance activities.

APPENDIX B – Lab Safety Policy

I. General Lab Conduct & Accountability

- **Supervision Required:** Never work in the lab without Lead supervision or a designated supervisor present.
- **Stay Focused:** Concentrate on the task at hand. Do not talk to, distract, or be distracted by others while operating equipment.
- **Keep it Clean:** Watch for tripping hazards. Never place materials, stock, or objects in thoroughfares or passageways.
- **No Food or Drink:** Eating and drinking are strictly prohibited in all lab spaces.

II. Personal Protective Equipment (PPE) & Attire

- **Standard Attire:** You must wear lab-appropriate clothing at all times. This includes:
 - Safety glasses or side-shields.
 - Closed-toe, non-slip shoes.
 - No loose clothing, rings, watches, or bracelets.
 - Long hair must be securely tied back.
- **Glove Protocol:** Wear gloves when appropriate for chemical or heat protection but **never** wear gloves when working with rotating or moving machinery.
- **Respiratory Safety:** Use appropriate masks or respiratory protection when working with dust, mists, fumes, or vapors.
- **Safe Lifting:** Use proper techniques and always obtain assistance when lifting, moving, or carrying heavy loads.

III. Machine & Tool Operation

- **Know Your Equipment:** Be thoroughly knowledgeable about the equipment you are using. If you don't know, ask.
- **Proper Use:** Use tools strictly for their intended purposes. Always clamp or secure the workpiece properly before beginning.
- **Hands Off Moving Parts:** Do not use fingers or hands to remove chips or debris from moving or stationary machines. Never attempt to slow down or stop rotating equipment with your hands or tools.
- **Adjustments:** Never adjust a moving or rotating machine (unless motion is necessary to make the adjustment). Always allow the machine to come to a complete standstill before making repairs or tweaks.

- **Unattended Operation:** Never leave a machine running while unattended, unless the machinery is specifically designed to do so (e.g., 3D printers).
- **Post-Machining:** File and deburr all machined parts or raw stock to eliminate sharp edges.

IV. Hazard Management & Emergency Response

- **When in Doubt, Stop:** If you are ever unsure about a proper or safe procedure, halt your work immediately and ask for guidance.
- **Chemical Awareness:** Read the Safety Data Sheet (SDS) for all lubricants, resins, adhesives, or other chemicals before working with them.
- **Report Hazards:** Report unsafe or hazardous conditions wherever noted. Correct them immediately if it is safe to do so.
- **Report Injuries:** All injuries or accidents, no matter how minor, must be reported immediately to the Shop Supervisor.
- **Emergency Preparedness:** Know the exact locations of fire extinguishers, fire exits, eye wash stations, and first aid kits before you begin work.

APPENDIX C – Cost Accounting

Institution:		Manipal Academy of Higher Education, Dubai				
Team Name:		Team Jalpari				
Competition Year:		MATE ROV 2026				
Document Type:		Project Costing & Income Sheet				
Date	Type / Method	Category	Item / Description	Expense / Outflow (USD)	Income / Credit (USD)	Running Balance (USD)
12/05/2025	Cash Pool	Revenue	Total Member Base Dues & Top-ups	\$0.00	\$3,849.13	\$3,849.13
15/05/2025	Reused	Mechanical	6x Blue Robotics T200 Thrusters	\$1,170.86	\$1,170.86	\$3,849.13
15/05/2025	Reused	Electrical	ROV Tether Cable (Neutrally Buoyant)	\$299.52	\$299.52	\$3,849.13
15/05/2025	Reused	Electrical	Custom Power Cap & Log Boards	\$40.84	\$40.84	\$3,849.13
30/07/2025	Cash Pool	Electrical	SmartElex Micro 6DoF IMU – ISM330DHCX	\$5.86	\$0.00	\$3,843.27
30/07/2025	Cash Pool	Electrical	RM3100 Magnetometer	\$25.38	\$0.00	\$3,817.90
02/08/2025	Cash Pool	Electrical	Header pins, Teensy 4.1, Ethernet kit, USB	\$58.96	\$0.00	\$3,758.94
17/12/2025	Cash Pool	Electrical	2xPLC, 1xPOE, 1xMotorDriver, 1xPOECamera	\$155.48	\$0.00	\$3,603.46
17/12/2025	Cash Pool	Electrical	Import Fee for AliExpress Electricals	\$10.89	\$0.00	\$3,592.57
30/12/2025	Cash Pool	Mechanical	Access & End cap	\$17.15	\$0.00	\$3,575.41
30/12/2025	Cash Pool	Mechanical	PVC Pipe (Altos Trading)	\$10.29	\$0.00	\$3,565.12
30/12/2025	Cash Pool	Mechanical	VC Pipe	\$8.58	\$0.00	\$3,556.54
30/12/2025	Cash Pool	Mechanical	PVC galon	\$1.72	\$0.00	\$3,554.83
30/12/2025	Cash Pool	Mechanical	Duct tape	\$4.49	\$0.00	\$3,550.34
30/12/2025	Cash Pool	Mechanical	Adaptor	\$2.74	\$0.00	\$3,547.59
30/12/2025	Cash Pool	Mechanical	M Seal (Agkuja)	\$4.90	\$0.00	\$3,542.69
30/12/2025	Cash Pool	Mechanical	O-ring (Power Seals)	\$6.81	\$0.00	\$3,535.88
30/12/2025	Cash Pool	Mechanical	Glue and access cap	\$13.44	\$0.00	\$3,522.45
30/12/2025	Cash Pool	Mechanical	Resin (Amazon)	\$17.15	\$0.00	\$3,505.29
30/12/2025	Cash Pool	Mechanical	Vernier	\$5.31	\$0.00	\$3,499.98
05/01/2026	Cash Pool	Mechanical	PVC Glue	\$0.86	\$0.00	\$3,499.13
05/01/2026	Cash Pool	Mechanical	Battery spring and Duckbill valve	\$6.38	\$0.00	\$3,492.75
05/01/2026	Cash Pool	Electrical	Fuse, Diode, Mosfet, etc (DigiKey)	\$93.29	\$0.00	\$3,399.46
05/01/2026	Cash Pool	Electrical	Jumper Wires	\$4.08	\$0.00	\$3,395.37
05/01/2026	Cash Pool	Mechanical	M Seal (Calicut)	\$1.09	\$0.00	\$3,394.28
06/01/2026	Cash Pool	Mechanical	Threaded Bar, Dome Nut	\$2.04	\$0.00	\$3,392.24
06/01/2026	Cash Pool	Mechanical	Cable Gland, Clear Epoxy	\$5.45	\$0.00	\$3,386.79
06/01/2026	Cash Pool	Mechanical	M Seal (Techno King)	\$1.36	\$0.00	\$3,385.43
06/01/2026	Cash Pool	Mechanical	Oil Seal	\$1.36	\$0.00	\$3,384.07
06/01/2026	Cash Pool	Electrical	Desoldering wick	\$1.67	\$0.00	\$3,382.40
07/01/2026	Float Fund	Electrical	Battery, Reed switch, Fuse, Charger, Light	\$49.02	\$0.00	\$3,333.38
07/01/2026	Cash Pool	Mechanical	PVC Glue, Mask, Gloves	\$5.17	\$0.00	\$3,328.21
09/01/2026	Cash Pool	Electrical	Import/Shipping DigiKey (Aramex)	\$14.49	\$0.00	\$3,313.72
09/01/2026	Cash Pool	Mechanical	Teflon Tape	\$0.82	\$0.00	\$3,312.90
09/01/2026	Cash Pool	Mechanical	M Seal	\$1.36	\$0.00	\$3,311.54
09/01/2026	Cash Pool	Mechanical	Oil Seal	\$1.36	\$0.00	\$3,310.18
17/01/2026	Cash Pool	Mechanical	PVC welding (Falcon Engineering)	\$11.44	\$0.00	\$3,298.74
17/01/2026	Cash Pool	Electrical	Pumps	\$11.01	\$0.00	\$3,287.74
01/02/2026	Cash Pool	Mechanical	PVC welding (Dar Al Barakah)	\$14.30	\$0.00	\$3,273.44

18/02/2026	Cash Pool	Mechanical	Filament (Printify3D)	\$8.17	\$0.00	\$3,265.27
26/02/2026	Cash Pool	Electrical	Resistor/ Capacitor	\$13.41	\$0.00	\$3,251.86
27/02/2026	Cash Pool	Mechanical	Pressure Valve connector	\$2.72	\$0.00	\$3,249.14
02/03/2026	Cash Pool	Electrical	Custom PCB Manufacturing (JLCPCB)	\$237.24	\$0.00	\$3,011.90
02/03/2026	Cash Pool	Electrical	Converter, Fuse (DigiKey)	\$161.65	\$0.00	\$2,850.25
16/03/2026	Cash Pool	Mechanical	Import for Motor Driver (iMile)	\$2.23	\$0.00	\$2,848.02
17/03/2026	Cash Pool	Mechanical	Acrylic Tube (Blue Rhine)	\$45.75	\$0.00	\$2,802.28
19/03/2026	Cash Pool	Mechanical	O-Ring (Golden Seal)	\$10.89	\$0.00	\$2,791.38
21/03/2026	Cash Pool	Mechanical	Motor, Relay, Thread Inserts, Wire, etc.	\$238.01	\$0.00	\$2,553.38
22/03/2026	Cash Pool	Electrical	Import/shipping DigiKey (Shop & Ship)	\$31.10	\$0.00	\$2,522.27
24/03/2026	Cash Pool	Electrical	Waterproof Conn, Silicon wire, Bearing, U-Bolt	\$198.81	\$0.00	\$2,323.46
28/03/2026	Cash Pool	Electrical	Import and shipping for PCBs (Aramex)	\$96.39	\$0.00	\$2,227.07
10/04/2026	Cash Pool	Electrical	Resin, Soldering station, Soldering tool	\$76.24	\$0.00	\$2,150.84
10/04/2026	Cash Pool	Electrical	Import Fee (iMile)	\$1.64	\$0.00	\$2,149.20
18/04/2026	Cash Pool	Mechanical	ROV Acrylic welding (Pleasant Acrylics)	\$71.48	\$0.00	\$2,077.72
18/04/2026	Cash Pool	Electrical	Ethernet Kit for Teensy	\$4.95	\$0.00	\$2,072.77
18/04/2026	Cash Pool	Electrical	Capacitors	\$2.72	\$0.00	\$2,070.04
18/04/2026	Cash Pool	Electrical	Solder Paste, Male Header, Female Header	\$11.44	\$0.00	\$2,058.61
20/04/2026	Cash Pool	Electrical	Penetrators, Vent Plug (Blue Robotics)	\$129.04	\$0.00	\$1,929.56
20/04/2026	Cash Pool	Electrical	Import for Flux and Lead	\$1.09	\$0.00	\$1,928.47
20/04/2026	Cash Pool	Mechanical	Angle Grinder Blade, Glue	\$1.09	\$0.00	\$1,927.38
20/04/2026	Cash Pool	Admin	Petrol Logistics Fuel	\$35.40	\$0.00	\$1,891.99
21/04/2026	Cash Pool	Mechanical	M4 Screws, Measuring Tape	\$4.57	\$0.00	\$1,887.41
21/04/2026	Cash Pool	Electrical	Teensy USB Board, Male Header, Lug	\$54.89	\$0.00	\$1,832.52
21/04/2026	Cash Pool	Electrical	Import for Penetrators (DHL)	\$9.67	\$0.00	\$1,822.85
21/04/2026	Cash Pool	Mechanical	Machine screw, Angle, spring	\$12.60	\$0.00	\$1,810.25
21/04/2026	Cash Pool	Mechanical	Extrusions (Dazzle Robotics)	\$19.40	\$0.00	\$1,790.85
21/04/2026	Cash Pool	Mechanical	Bearings, Angle connector, Pneumatics	\$123.78	\$0.00	\$1,667.06
23/04/2026	Cash Pool	Mechanical	Filament (Amazon)	\$40.02	\$0.00	\$1,627.04
23/04/2026	Cash Pool	Mechanical	Acrylic Cutting (Dar Al Barakah)	\$4.29	\$0.00	\$1,622.75
27/04/2026	Cash Pool	Mechanical	Pipe Connectors, Clamps	\$6.80	\$0.00	\$1,615.95
27/04/2026	Cash Pool	Mechanical	Import charges for AliExpress	\$2.78	\$0.00	\$1,613.17
27/04/2026	Cash Pool	Mechanical	Screws, Threaded Rod	\$6.00	\$0.00	\$1,607.17
27/04/2026	Cash Pool	Admin	STEM Outreach Activities	\$11.03	\$0.00	\$1,596.14
27/04/2026	Cash Pool	Mechanical	Spray Paint (Ace)	\$13.07	\$0.00	\$1,583.07
04/05/2026	Cash Pool	Mechanical	Lights	\$3.87	\$0.00	\$1,579.19
04/05/2026	Cash Pool	Mechanical	Screws, Clip	\$10.81	\$0.00	\$1,568.39
04/05/2026	Cash Pool	Mechanical	Cable	\$27.45	\$0.00	\$1,540.94
04/05/2026	Cash Pool	Mechanical	Bar 30, Penetrators (Blue Robotics)	\$215.96	\$0.00	\$1,324.98
04/05/2026	Cash Pool	Mechanical	Socket Set	\$13.61	\$0.00	\$1,311.37
05/05/2026	Cash Pool	Mechanical	Tool Box set	\$10.89	\$0.00	\$1,300.47
05/05/2026	Cash Pool	Mechanical	Mseal (AATCO Trading)	\$4.29	\$0.00	\$1,296.19
05/05/2026	Cash Pool	Electrical	PLC Switch, Pitch Plug	\$44.48	\$0.00	\$1,251.71
05/05/2026	Cash Pool	Electrical	DC Converter, Fuse Board (DigiKey)	\$243.20	\$0.00	\$1,008.51
05/05/2026	Cash Pool	Electrical	DigiKey Import (DHL)	\$11.03	\$0.00	\$997.48
07/05/2026	Cash Pool	Mechanical	Extrusions (Dazzle Robotics)	\$12.80	\$0.00	\$984.68
07/05/2026	Cash Pool	Electrical	Transceiver Breakout Module	\$1.91	\$0.00	\$982.78
10/05/2026	Cash Pool	Admin	Official MATE Team Registration Fee	\$674.74	\$0.00	\$308.04
11/05/2026	Cash Pool	Electrical	Resistor Kit	\$2.86	\$0.00	\$305.18
11/05/2026	Cash Pool	Mechanical	Drill Bits	\$2.72	\$0.00	\$302.46
11/05/2026	Cash Pool	Mechanical	AliExpress Import (EMX)	\$1.41	\$0.00	\$301.05
13/05/2026	Cash Pool	Mechanical	Resin (Amazon)	\$27.23	\$0.00	\$273.82
13/05/2026	Cash Pool	Mechanical	Silicon Sock for 3D printer	\$2.12	\$0.00	\$271.70
13/05/2026	Cash Pool	Mechanical	Clamps, PU Pneumatic tube, Hose Fittings	\$6.08	\$0.00	\$265.62
14/05/2026	Cash Pool	Mechanical	Brass Mini Brush	\$0.82	\$0.00	\$264.80
14/05/2026	Cash Pool	Mechanical	Silicon Brush	\$1.96	\$0.00	\$262.85
17/05/2026	Cash Pool	Mechanical	O-rings (Power Seals)	\$8.17	\$0.00	\$254.68
17/05/2026	Cash Pool	Mechanical	Aluminium Tape	\$2.86	\$0.00	\$251.82
17/05/2026	Cash Pool	Mechanical	Braid sleeve, Duct tape, Mseal	\$11.44	\$0.00	\$240.38
17/05/2026	Cash Pool	Mechanical	Snap Hook	\$3.77	\$0.00	\$236.61
17/05/2026	Cash Pool	Mechanical	Complete PVC Tube & Structural Fitting Pack	\$21.78	\$0.00	\$214.82
17/05/2026	Cash Pool	Mechanical	Cable Tie	\$11.72	\$0.00	\$203.10
17/05/2026	Cash Pool	Mechanical	Bond MDF Kit, Mseal, Spray Paint	\$7.08	\$0.00	\$196.02
19/05/2026	Cash Pool	Mechanical	M-seal, WD 40	\$8.58	\$0.00	\$187.44
19/05/2026	Cash Pool	Mechanical	Screw	\$2.52	\$0.00	\$184.93
20/05/2026	Cash Pool	Travel	Airfare/Accommodation/Visa/Rental Contributions	\$0.00	\$15,755.03	\$15,939.96
Pending	Projected	Travel	International Airfare (10 Pax)	\$10,401.63	\$0.00	\$5,538.33
Pending	Projected	Travel	Group Accommodation (Airbnb)	\$3,539.82	\$0.00	\$1,998.50
Pending	Projected	Travel	Visa Processing (10 Pax)	\$1,345.13	\$0.00	\$653.37
Pending	Projected	Travel	Vehicle Rental	\$653.37	\$0.00	\$0.00
TOTALS				\$21,088.16	\$5,333.13	\$0.00