

RedSea Rovers

Technical Documentation – PIONEER Class (2025 - 2026)

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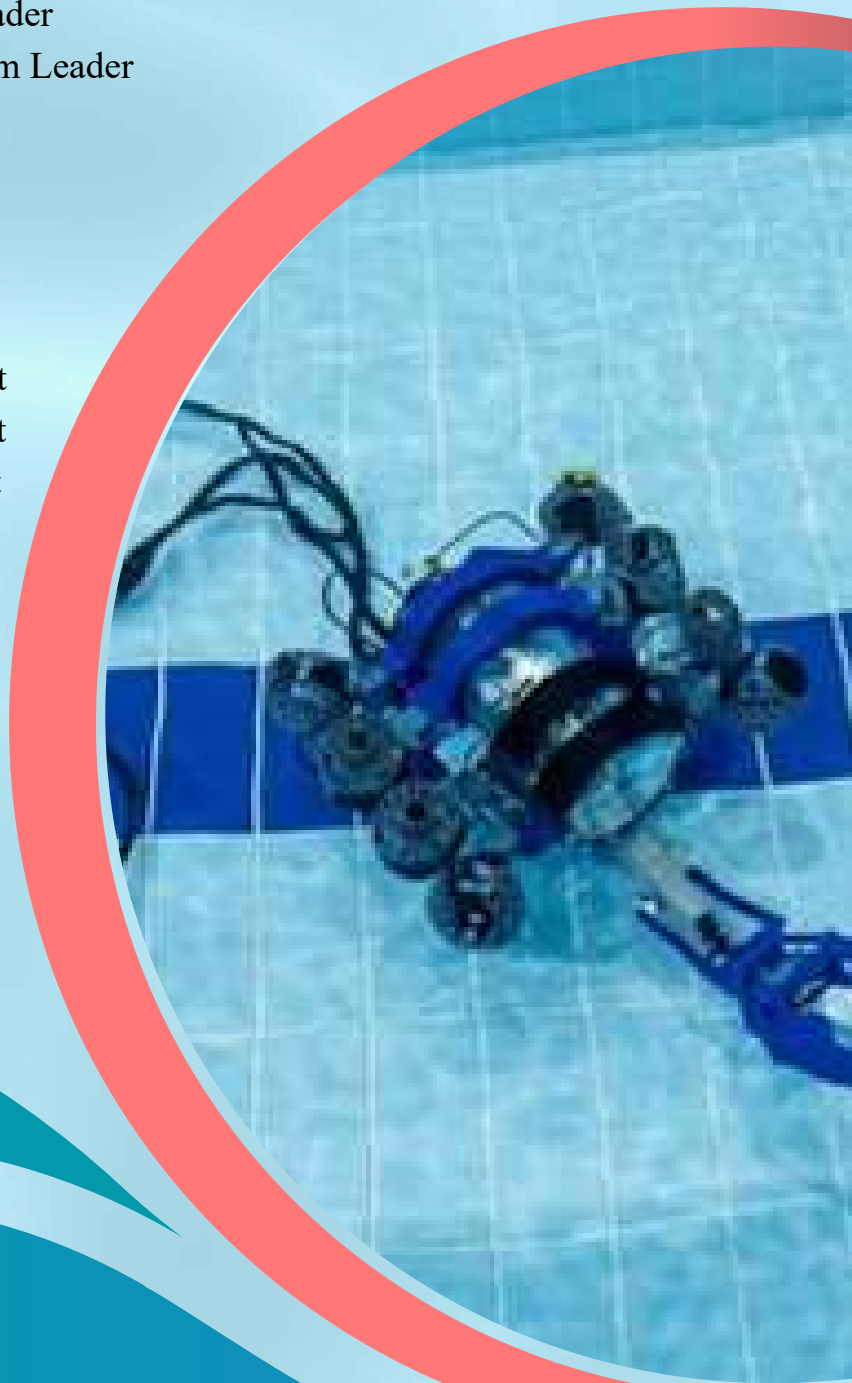


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EXECUTIVE ABSTRACT

RedSea Rovers presents its advanced electro-mechanical marine architecture engineered specifically to address the complex marine challenges outlined in the 2026 MATE PIONEER Request for Proposals (RFP). Driven by a philosophy that prioritizes rigorous hands-on practical experience and data-driven empirical testing, our engineering company developed a highly robust, multi-tiered robotic solution.

The primary platform features an 8-thruster vectored Remotely Operated Vehicle (ROV) built on a modular 3D-printed PETG structural chassis. The vehicle is equipped with a stable 48V DC surface-to-vehicle power distribution architecture, a Pixhawk flight controller executing ArduSub firmware, and a Raspberry Pi 4 edge-processing computing platform running BlueOS. For complex underwater identification, a computer vision pipeline utilizing a fine-tuned YOLOv8 object-detection model is deployed to deliver high-confidence real-time telemetry.

To fully satisfy the autonomous under-ice profiling requirements of Task 4, RedSea Rovers engineered an independent, non-ROV Autonomous Profiling Float Subsystem. Operating completely decoupled from the main vehicle via a dedicated battery bank and an ESP32 microcontroller, this float features a custom syringe-based Mechanical Buoyancy Engine. By implementing a closed-loop control loop paired with precise hydrostatic pressure sensor feedback, the float achieves highly accurate vertical depth-profiling and stabilization capabilities.



Figure 1: RedSea Rovers core engineering and operational team

1 TEAMWORK & PROJECT MANAGEMENT

1.1 Company Profile

RedSea Rovers operates as an agile engineering company driven by individuals with deep foundational expertise in Electrical Engineering, mechanical design, and autonomous systems. The team prioritizes empirical data-driven decision making, hands-on practical experience, and rapid hardware prototyping over purely theoretical design. To optimize cross-functional efficiency, maintain strict financial accountability, and deliver complex underwater technologies on time, RedSea Rovers establishes two distinct organizational structures: an Administrative & Operational Management Hierarchy and a Technical Engineering Breakdown.

Corporate & Operational Management Structure

To manage administrative workflows, resource tracking, financial documentation, and external stakeholder relations, our operational structure is organized as follows:

Chief Executive Officer (CEO): **Roba Alnushayri**

Responsible for primary cross-functional alignment, strategic project direction, and ensuring compliance with the MATE RFP guidelines.

Chief Operating Officer (COO): **Abdullah BinSalman, Ammar ALAhmadi**

Manages laboratory scheduling, material tracking, workflow logistics, and milestone enforcement protocols.

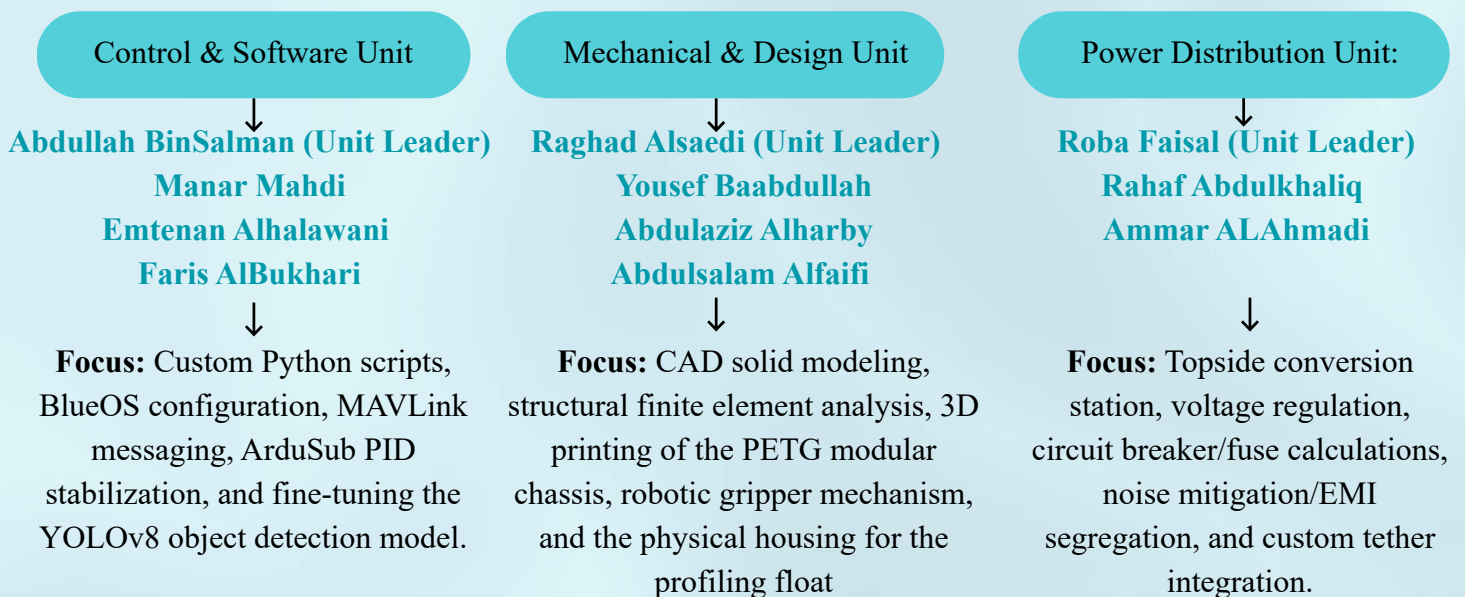
Chief Financial Officer (CFO): **Raghad Alsaedi, Yousef Baabdullah**

Oversees university grant distribution, industry sponsorship allocation, procurement costing, and travel budgeting.

Chief Marketing Officer (CMO): **Rahaf Abdulkhaliq, Emtenan Alhalawani, Manar Mahdi**
Handles external technical communication, corporate branding, media documentation, and marketing display logistics.

Technical Engineering Structure

To facilitate parallel development and seamless integration of the vehicle's hardware and software components, the practical assembly work is divided into technical units:



1.2 Project Timeline

A comprehensive Gantt-style build schedule was established at the project's inception to guide the engineering phases, ensuring all systems were rigorously tested prior to the May 2026 deadlines:

MATE ROV COMPETITION

PROJECT GANTT CHART | Oct 2024 – Jun 2026

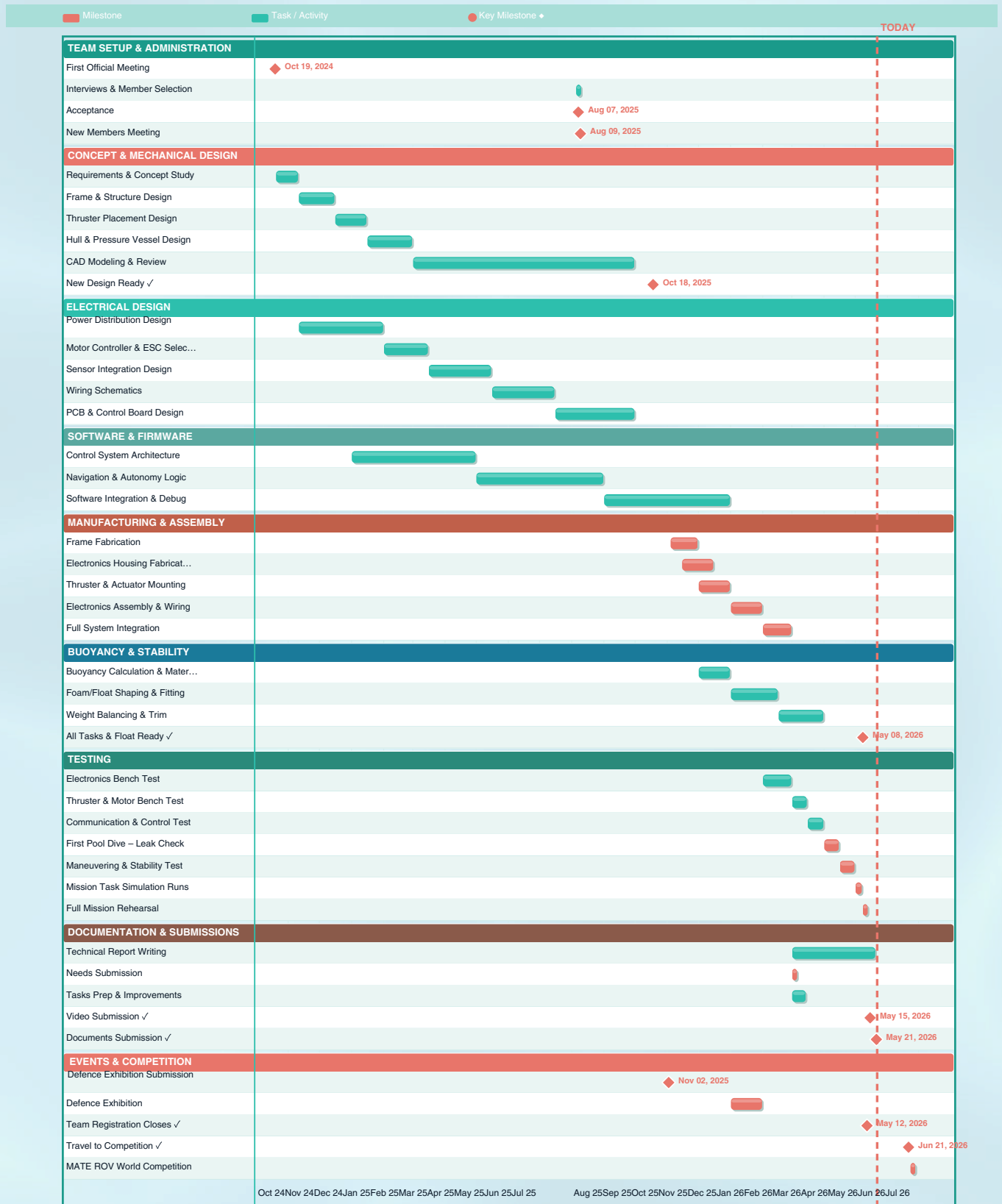


Figure 2: Project development timeline and Gantt chart

2 SYSTEM & MECHANICAL DESIGN RATIONALE

From the earliest stages of development, the RedSea Rovers team transformed conceptual engineering ideas into a fully developed product design. To meet the demanding requirements of the MATE Pioneer-class ROV competition, the design process required addressing numerous technical challenges through continuous evaluation and iterative improvement. One of the most critical challenges was determining the most effective and practical design configuration. Multiple concepts were analyzed and compared based on their structural performance, operational efficiency, advantages, and design limitations before selecting the final configuration.

2.1 Chassis Engineering, Material Selection & Structural Trade-offs

The chassis plays a fundamental role in the overall structural integrity, stability, and operational performance of the ROV. During the early stages of development, the primary design objective was to create a compact, modular, and highly serviceable frame capable of supporting rapid integration, maintenance, and replacement of critical subsystems such as tooling modules, buoyancy elements, and electronic components. To achieve these goals, the team focused on optimizing structural efficiency while maintaining durability and maneuverability in underwater environments.

The frame was manufactured entirely using 3D-printed Polyethylene Terephthalate Glycol (PETG), selected for its excellent balance between mechanical strength, corrosion resistance, dimensional stability, and lightweight characteristics. Compared to conventional materials, PETG provided enhanced rigidity and impact resistance while remaining highly suitable for long-duration underwater operations and rapid prototyping applications.

Structurally, the chassis is composed of four curved structural ribs that form the primary load-bearing architecture of the vehicle. These ribs provide secure mounting interfaces for the propulsion system while maintaining a symmetrical and balanced configuration. The frame supports a total of eight Blue Robotics T200 thrusters strategically distributed to achieve stable six-degree-of-freedom maneuverability, precise motion control, and efficient thrust allocation during operation.

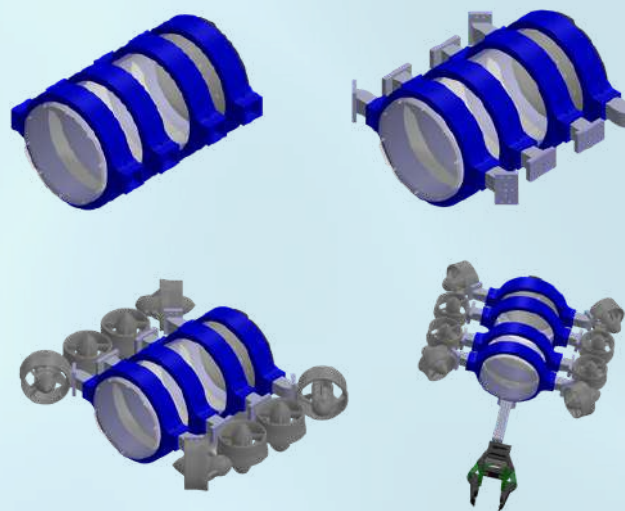


Figure 3: 3D CAD modeling of the modular PETG chassis

To optimize the strength-to-weight ratio, the chassis components were manufactured using a gyroid infill pattern with a 50% infill density. This configuration significantly reduced unnecessary mass while preserving structural stiffness and load-bearing capability. The gyroid geometry also improved internal stress distribution throughout the printed structure, resulting in a durable yet lightweight frame capable of withstanding demanding underwater conditions.

At the center of the chassis, a watertight cylindrical electronics enclosure is securely mounted between the structural ribs. This enclosure protects sensitive onboard electronics, control systems, and power distribution components from water ingress, pressure exposure, and external impacts. The enclosure mounting system was designed to minimize vibration transmission while simplifying assembly and maintenance procedures.

To further enhance the ROV's mission capabilities and operational flexibility, the vehicle incorporates a servo-actuated robotic manipulator mounted at the front section of the chassis. The manipulator enables the ROV to perform complex underwater interaction tasks, object retrieval and handling operations, and mission-specific activities required for MATE Pioneer-class challenges.

Additionally, the ROV is equipped with two structural landing skids mounted symmetrically on both sides of the chassis. These skids were specifically designed to provide stable ground support during deployment, maintenance, and recovery operations. In addition to improving overall stability, they serve as protective structural elements for the front-mounted robotic manipulator, reducing the risk of damage caused by impact or surface contact during operation. Structural simulations and load analysis confirmed that the landing skid assembly is capable of safely supporting the full operational mass of the ROV, approximately 15 kg, while maintaining structural integrity and minimizing deformation under loading conditions.



Figure 4: 3D-printed PETG structural landing skids integrated for ground stability and manipulator protection.

2.2 Buoyancy & Ballast Principles (Stability & CG/CB Calculations)

The ROV was designed to operate under near-neutral buoyancy conditions with a slightly negative buoyancy configuration. This design approach allows the vehicle to descend naturally in water when the thrusters are inactive, causing the ROV to behave similarly to a controlled falling body. Maintaining slight negative buoyancy improves operational safety and stability by preventing unintended ascent and reducing the continuous thrust required to maintain depth.

The buoyancy and ballast system were carefully optimized to achieve a balanced relationship between the Center of Gravity (CG) and the Center of Buoyancy (CB). Positioning the CB slightly above the CG enhances the static stability of the vehicle, allowing the ROV to maintain a stable orientation during underwater maneuvering and task execution.

To control vertical motion, the ROV utilizes four vertically oriented Z-axis thrusters that generate precise upward and downward thrust forces. This configuration enables stable depth control and omnidirectional maneuverability in

a manner similar to the flight behavior of a quadcopter drone in air. Additional horizontal thrusters mounted at the front and rear sections of the vehicle provide efficient surge, sway, and yaw control, allowing the ROV to maneuver freely in all directions while maintaining a fixed operating depth. This propulsion arrangement is particularly important during mission operations near the pool floor, where precise positioning and stable movement are required for task execution and manipulator operation.

2.3 Autonomous Profiling Float Subsystem (Task 4: MATE Floats Under the Ice)

Developed independently for Task 4, this float simulates under-ice environmental data collection using a "Mechanical Buoyancy Engine" for automated vertical profiling without traditional thrusters.

Mechanical Buoyancy Engine: Housed in a watertight acrylic cylinder, a high-torque stepper motor drives a lead screw to actuate a 550 mL syringe. This dynamically alters the float's specific gravity:

- **Descent (Negative Buoyancy):** Retracting the syringe plunger draws ambient water in, increasing the float's overall density to initiate a controlled descent.
- **Ascent (Positive Buoyancy):** Extending the plunger expels the water payload, decreasing density and increasing the net buoyant force to return to the surface.

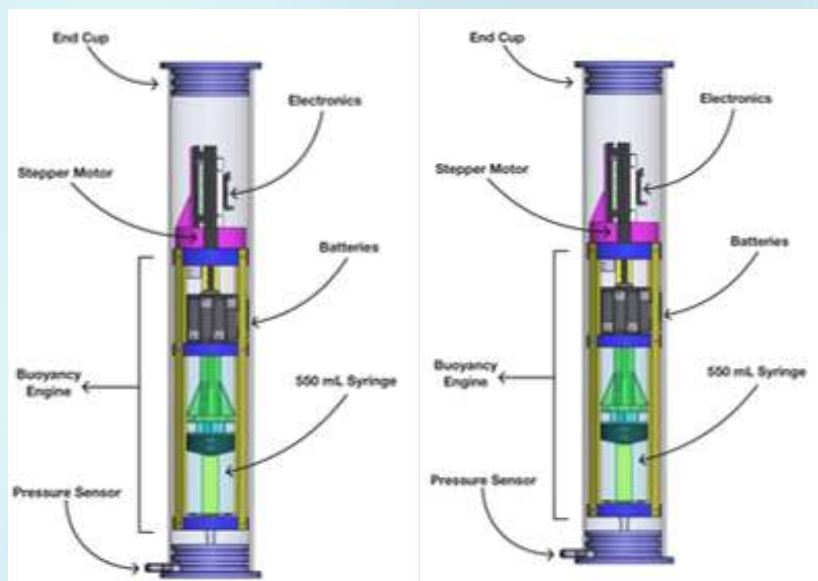


Figure 5: Syringe-based Mechanical Buoyancy Engine for the autonomous float

2.4 Vectored Thruster Configuration & Propulsion Power Trade-offs

The ROV propulsion system was developed using a vectored thruster configuration to achieve high maneuverability, precise motion control, and stable underwater operation. The propulsion layout enables full six-degree-of-freedom (6-DOF) movement, allowing the vehicle to perform complex translational and rotational maneuvers required for MATE Pioneer-class missions.

The thruster arrangement was carefully optimized to improve thrust distribution and minimize hydrodynamic interference between propulsion units. Four vertically oriented thrusters provide accurate depth and attitude control, while the remaining horizontal thrusters generate multidirectional forces for efficient surge, sway, and yaw motion. This vectored configuration allows the ROV to maintain stable positioning and precise maneuverability during underwater manipulation and task execution.

Several propulsion power trade-offs were evaluated throughout the design process to balance maneuverability, electrical power consumption, system weight, and operational efficiency. Increasing the number of thrusters improved vehicle control authority and redundancy; however, it also increased energy demand, system complexity, and overall mass. The final eight-thruster configuration was selected as the optimal compromise between propulsion performance and power efficiency within the available power budget.

To enhance operational safety and improve component protection, custom 3D-printed protective guards were integrated around each thruster. These guards reduce the risk of accidental contact with rotating propellers during handling and operation while also protecting the thrusters from debris and external impacts. The guard geometry was designed to preserve smooth water flow and minimize reductions in propulsion efficiency.

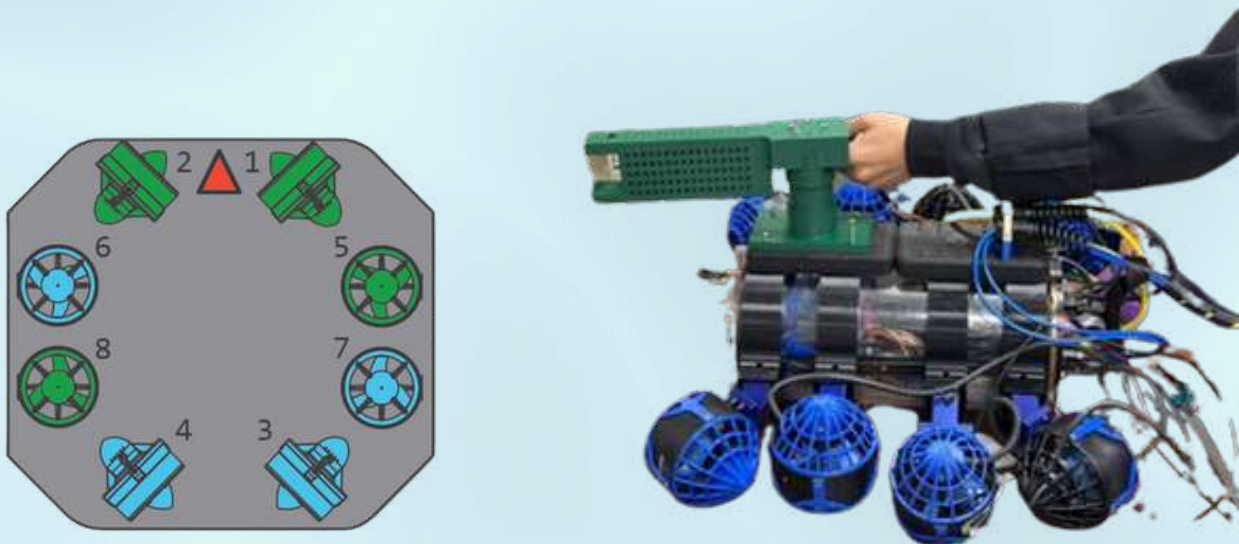


Figure 6: 8-Vectored thruster configuration for 6-DOF maneuverability

2.5 Custom Mission Tools, Payload, & Sensor Integration

The primary manipulator (gripper) was custom-designed using CAD and manufactured in-house through 3D printing using PETG filament, selected for its high strength, durability, and excellent water resistance in underwater environments. The gripper was specifically developed to provide reliable object handling capabilities while maintaining a lightweight and compact structure compatible with the ROV chassis.

The gripping mechanism operates using a lead screw actuation system, which converts rotational motion into precise linear motion. This mechanism was selected due to its simplicity, positional accuracy, high mechanical advantage, and ability to generate controlled gripping forces while minimizing unwanted backlash. The linear actuation system enables smooth opening and closing motion of the gripper jaws, allowing the manipulator to securely handle delicate mission objects without causing damage.

A high-torque waterproof servo motor was integrated into the mechanism to drive the lead screw assembly and provide sufficient gripping force under underwater operating conditions. The servo-based actuation system offers accurate motion control, repeatability, and responsive operation during manipulation tasks.

The gripper structure was designed with multiple linkage elements to distribute loads efficiently across the mechanism while improving structural rigidity during operation. In addition, the jaw geometry was optimized to improve object contact stability and enhance gripping performance for objects with varying shapes and sizes encountered during mission tasks.

To ensure operational reliability, the manipulator design also considered manufacturability, ease of assembly, maintenance accessibility, and weight reduction. The use of 3D-printed components enabled rapid prototyping and iterative design improvements throughout the development process, allowing the team to refine the mechanism efficiently while minimizing manufacturing cost and production time.

Sensor Integration: To minimize system complexity and optimize the power budget, the external sensor payload is strictly streamlined to two essential devices:

- **Pressure Sensor:** Feeds real-time depth data to the flight controller, enabling stable automatic depth-holding during precise manipulator operations.
- **Underwater Camera:** Provides the live feed for piloting and serves as the sole visual input for our fine-tuned YOLOv8 object detection model.

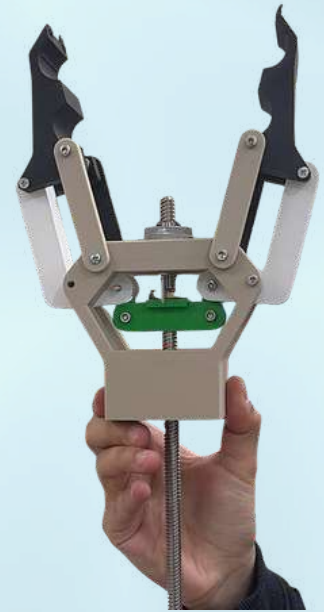
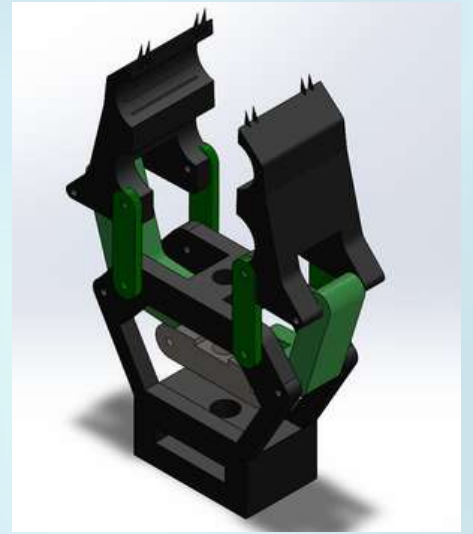


Figure 7: Custom 3D-Printed PETG manipulator gripper

2.6 Engineering Decision Analysis: Build vs. Buy & New vs. Reused

A core aspect of our agile engineering approach is maximizing resource efficiency through strategic sourcing:

Table 1: Engineering Decision Analysis: Build vs. Buy & New vs. Reused

Component / System	Sourcing Decision (Build vs. Buy)	Lifecycle Decision (New vs. Reused)	Engineering Rationale & Mission Trade-offs
Propulsion System (Thrusters)	Buy(Blue Robotics)	Reused	Reusing the high-efficiency thrusters from the 2025 vehicle ensures strict budget compliance and sustainable engineering.
Flight Controller (Pixhawk Unit)	Buy	Reused	Utilizing a commercial off-the-shelf flight controller provides proven hardware reliability and robust sensor integration.
Processing Unit (Raspberry Pi)	Buy	New	Selected to handle the intensive computational loads required for running the fine-tuned YOLOv8 object detection model. Purchasing an industry-standard Single-Board Computer (SBC) ensures reliable processing power and seamless communication with the flight controller.
Depth / Pressure Sensor	Buy	Reused	Reusing the high-precision pressure sensor from the previous season provides reliable telemetry for depth calculations. This commercial sensor is essential for the Pixhawk to maintain stable depth holding (heave control) during delicate payload operations.
Power Distribution & Signal Routing	Build (In-House)	New	Custom routing and manual integration of the power architecture allows for precise space optimization inside the electronics enclosure. It guarantees physical isolation between high-current lines and sensitive signal wires to prevent electromagnetic
ROV Structural Chassis	Build (In-House)	New	The main frame was completely redesigned and fabricated in-house for the 2026 season.
Main Electronics Enclosure	Buy	Reused	The watertight acrylic cylinder from the 2025 vehicle was reused. It maintained a zero-failure rate during previous underwater pressure testing, allowing us to safely protect the new electronics while allocating financial resources elsewhere.
Vision Sensors (Cameras)	Buy	Reused	Reusing the cameras from the 2025 vehicle proved highly efficient. Testing confirmed that their existing resolution was fully capable of providing the clear visual streams required for our YOLOv8 model.
Manipulator Gripper	Build (In-House)	New	Custom CAD modeled and 3D-printed using PETG filament to meet the precise dimensions of the 2026 mission props. This custom fabrication minimizes payload weight compared to heavy commercial alternatives.

3 ELECTRICAL SYSTEMS & POWER DISTRIBUTION

3.1 Power Architecture & Surface-to-Vehicle Voltage Regulation

Operating in the MATE PIONEER class requires a highly reliable power architecture capable of delivering sustained energy over a long distance without significant voltage drop under heavy dynamic loads. To achieve this, we engineered a custom topside power station utilizing four heavy-duty AC-to-DC converters plugged directly into the surface mains (wall power). These four external converters work in tandem to generate a highly stable, high-capacity 48V DC supply. Transmitting the power at 48V DC through the tether minimizes the current required, effectively reducing voltage drop and allowing for a thinner, more hydrodynamic cable profile. Once inside the main watertight electronics cylinder, the 48V supply is carefully managed by two internal step-down converters to safely power the onboard electronics without overloading any single circuit.



Figure 8: Topside power station featuring 48V DC conversion

3.2 Power Distribution Integration & Signal Routing

Inside the enclosure, a primary heavy-duty buck converter steps the 48V down to supply the 12V Bus Bar. This high-current bus directly powers the Electronic Speed Controllers (ESCs) for the vectored thrusters and the manipulator servo. A secondary internal step-down converter lowers the voltage further to 5V, providing a clean, isolated power line dedicated to the sensitive logic components, including the Raspberry Pi, the Pixhawk flight controller, and the pressure sensor. To manage the thermal output of housing both converters inside a sealed tube, we optimized their placement to allow for maximum passive heat dissipation. Furthermore, to guarantee signal integrity, the internal wiring was strictly routed based on current levels. The 48V and 12V high-current lines were physically segregated from the 5V logic lines and communication cables, preventing electromagnetic interference (EMI) from disrupting the I2C telemetry and PWM motor signals.



Figure 9: Internal electronics enclosure demonstrating strict wire segregation

3.3 Power Budget Analysis & Maximum Consumption

A rigorous power budget analysis is critical to ensure the ROV operates reliably without exceeding the 48V, 30A (1440W) surface power supply limit stipulated by MATE safety regulations. The table below details the absolute maximum theoretical current draw for all integrated components.

Table 2: System Power Budget Analysis and Maximum Current Draw

Component / System	Qty	Operating Voltage	Max Current per Unit (A)	Total Max Current (A)	Total Theoretical Power (W)
Blue Robotics T200 Thrusters	8	12V DC	25.6	204.8	2,457.60
35KG Manipulator Servo	1	5V DC	2.1	2.1	10.5
Raspberry Pi 4	1	5V DC	3	3	15
Pixhawk Flight Controller	1	5V DC	3	3	15
Underwater Camera	1	5V DC	0.3	0.3	1.5
Pressure Sensor	1	5V DC	0.00125	0.00125	< 0.1

As calculated, running all eight T200 thrusters at 100% maximum output simultaneously would theoretically demand over 2,450W, safely exceeding our surface supply capacity. To mitigate this without sacrificing the 6 Degrees of Freedom (DoF) provided by the 8-thruster configuration, we implemented a strict software-level throttle cap within the ArduSub parameters on the Pixhawk. The thrusters are hard-coded to operate at a maximum of 50% PWM output. This software limitation acts as a primary safety mechanism, keeping the actual maximum power draw well under the 1440W threshold, while still providing ample thrust for precise maneuverability.

3.4 Circuit Protection, Fuse Ratings, & Wiring Standards

Safety and circuit integrity are paramount. Our circuit protection strategy is implemented in stages, preventing catastrophic failures and localized component damage.

- **Topside Primary Protection:** A fast-acting 30A inline fuse is integrated directly at the surface power station output. This acts as the ultimate fail-safe to immediately cut 48V power if a severe short circuit occurs within the tether or the main enclosure.
- **Internal Branch Protection:** Inside the enclosure, power distribution branches are individually fused before connecting to the 12V and 5V bus bars.
- **Wiring Standards:** To handle the varying current densities safely, we utilized specific American Wire Gauge (AWG) standards based on ampacity tables. High-current lines connecting the 12V bus to the ESCs utilize 12 AWG stranded copper wire to prevent overheating and voltage drop. Conversely, the 5V logic lines utilizing lower currents (under 3A) are wired with 20 AWG, minimizing internal clutter while safely sustaining the current required for the Raspberry Pi and Pixhawk.

3.5 Tether Design Requirements & Tether Management Protocol

Tether Design & Integration: The tether is essentially the lifeline of our ROV. During our early design discussions, we realized that a thick, unorganized bunch of cables would create massive underwater drag and completely throw off the vehicle's balance. To solve this, we used a spiral cable wrap to neatly bundle the heavy-gauge 48V power lines and the shielded twisted-pair signal cables (Cat5e) into a single, streamlined tether. This spiral wrap not only keeps the tether organized but also provides crucial mechanical protection against abrasion.

Because we used shielded Cat5e, we could safely run power and data in the same external bundle without EMI issues. However, right at the ROV's bulkhead entrance, we deliberately split the bundle. Power and signal lines enter the main enclosure through completely separate penetrators, allowing us to maintain the strict internal physical segregation we established for noise reduction. Finally, to prevent the tether from sinking and dragging on the pool floor, we attached small, bright foam floats along the spiral wrap, keeping the entire line slightly buoyant.



Figure 10: The spiral cable wrap bundling the tether

Tether Management Protocol: We learned very quickly during our early pool tests that having a great ROV doesn't matter if the tether gets tangled in the thrusters. Because of this, tether management became a dedicated, active role on our team. During every wet test and official run, one team member is assigned exclusively as the "Tether Manager." Their workflow includes:

1. **Active Feeding:** The manager constantly watches the ROV's movement, feeding out just enough slack so the ROV can move freely, but pulling it taut when necessary so it doesn't loop into the thruster guards.
2. **Deck Safety (Manual Spool):** Instead of letting the cable pile up chaotically on the pool deck, we use a manual cable spool. Winding the tether by hand onto the spool prevents the internal wires from twisting or snapping, allows for rapid deployment, and keeps our surface workspace completely clear of tripping hazards.
3. **Pilot Communication:** The tether manager and the pilot are in constant verbal contact. If the pilot is about to reverse or make a sharp turn, they call it out so the tether manager can react immediately.



Figure 11: Manual Tether Management Spool.

4 SOFTWARE, CONTROL & VISION SYSTEMS

4.1 Software Architecture & BlueOS Integration

When designing the software architecture, our primary goal was to eliminate any processing bottlenecks that could cause latency between the pilot's joystick input and the ROV's movement. To achieve this, we implemented a dual-processor system. At the surface, the pilot uses QGroundControl (QGC) as the primary ground control station to send commands and monitor the vehicle's telemetry in real time.



Figure 12: Control Station Setup

These signals travel down the tether's Cat5e cable via UDP and interface with our companion computer, a Raspberry Pi 4 running BlueOS. Transitioning to BlueOS was a major operational upgrade for our team. It provides a highly stable, web-based interface for system diagnostics, effortlessly manages the network bridging, and routes our camera feeds without forcing the Pi to compute complex low-level motor algorithms. This OS choice streamlined our development process significantly, allowing us to deploy updates rapidly poolside.

4.2 Flight Control & ArduSub Integration

For the actual movement and stabilization of the vehicle, BlueOS passes the MAVLink commands directly down to the Pixhawk flight controller via a serial connection. The Pixhawk is flashed with the open-source ArduSub firmware. Relying on ArduSub was a strategic decision; it natively handles the complex motor mixing required for our 8-vector thruster configuration. More importantly, it continuously reads data from the onboard pressure sensor to run an internal PID control loop. This allows the Pixhawk to maintain incredibly stable automatic depth-holding (heave control) without any manual input from the pilot. By offloading this critical stabilization task entirely to the Pixhawk, our software team could focus the bulk of the Raspberry Pi's processing power on running our custom computer vision models.

4.3 Computer Vision & YOLOv8 Integration

One of our major software milestones for the 2026 season was implementing a robust Computer Vision (CV) system to assist the pilot in identifying mission-critical objects in challenging underwater environments. After evaluating several object-detection architectures, we selected the YOLOv8 (You Only Look Once) model. YOLOv8 provides an exceptional balance between high detection accuracy and low inference latency, making it perfectly suited to run natively on our Raspberry Pi 4 edge device without severe frame-rate drops.

To integrate this into our workflow, the live video feed from the underwater camera is routed through the BlueOS network bridge. We developed a custom Python script utilizing the OpenCV library to capture this UDP video stream frame-by-frame and feed it directly into our deployed YOLOv8 model.

Rather than training a model from scratch, we utilized Transfer Learning. We took a pre-trained YOLOv8 model and fine-tuned it specifically for our underwater environment. This strategic engineering decision saved significant computational resources while leveraging the model's existing feature-extraction capabilities. We compiled a custom dataset featuring the specific 2026 mission props—focusing on identifying specific benthic species (such as crabs), locating coral fragments for the habitat assessment task, and recognizing visual markers on the underwater infrastructure.

Because underwater lighting and turbidity change drastically depending on the pool environment, we applied heavy data augmentations during the fine-tuning phase. By synthetically adding color shifting, blur, and low-light simulations to our custom dataset, we ensured the fine-tuned model wouldn't fail or produce false positives under actual competition conditions. During operations, the system successfully overlays bounding boxes and confidence scores over the identified targets on the pilot's screen, drastically reducing pilot fatigue during delicate manipulation tasks.

4.4 Float Software Architecture & Autonomy

The float is managed by an ESP32 microcontroller powered by a dedicated 8AA battery bank, ensuring complete operational autonomy from the main ROV system.

- **Telemetry & Depth Sensing:** A high-precision pressure sensor interfaces via I2C, delivering real-time depth feedback to the microcontroller.
- **Closed-Loop Control:** The ESP32 implements a closed-loop algorithm, comparing target and actual depths to output precise step signals to the stepper driver, dynamically adjusting the syringe plunger to maintain or change depth.
- **Time-Scheduled Profiling:** An integrated Real-Time Clock (RTC) allows the float to execute pre-programmed mission schedules (e.g., automated dive cycles at set intervals), simulating real-world oceanographic deployment.

SYSTEM INTERCONNECTION DIAGRAMS (SIDs)

5.1 Primary Electrical System Interconnection Diagram (Single Page)

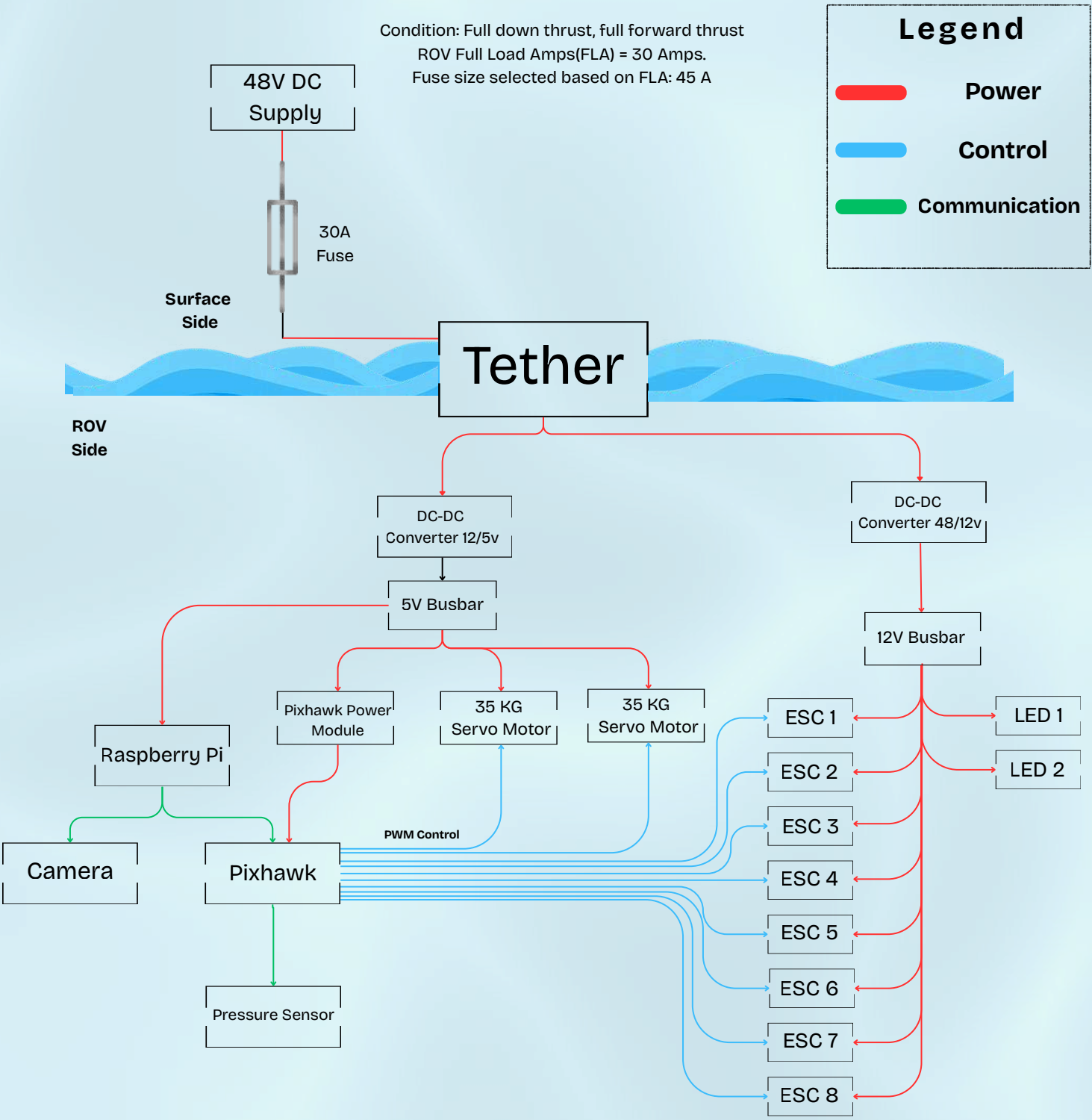


Figure 13 : Primary Electrical SID.

This comprehensive diagram details the complete electro-mechanical architecture of the RedSea Rovers 2026 vehicle. It maps the 48V DC power transmission from the surface station through the tether, the internal power distribution via 48V-to-12V step-down converters, and the signal routing. Key subsystems illustrated include the Raspberry Pi 4 running BlueOS for network management, the Pixhawk flight controller handling ArduSub motor mixing, the 8-vectored thruster array, the IP68 waterproof manipulator servos, and the camera vision system. All wire gauges (AWG) and fuse ratings are specified to industrial standards.

5.2 Autonomous Profiling Float Subsystem SID

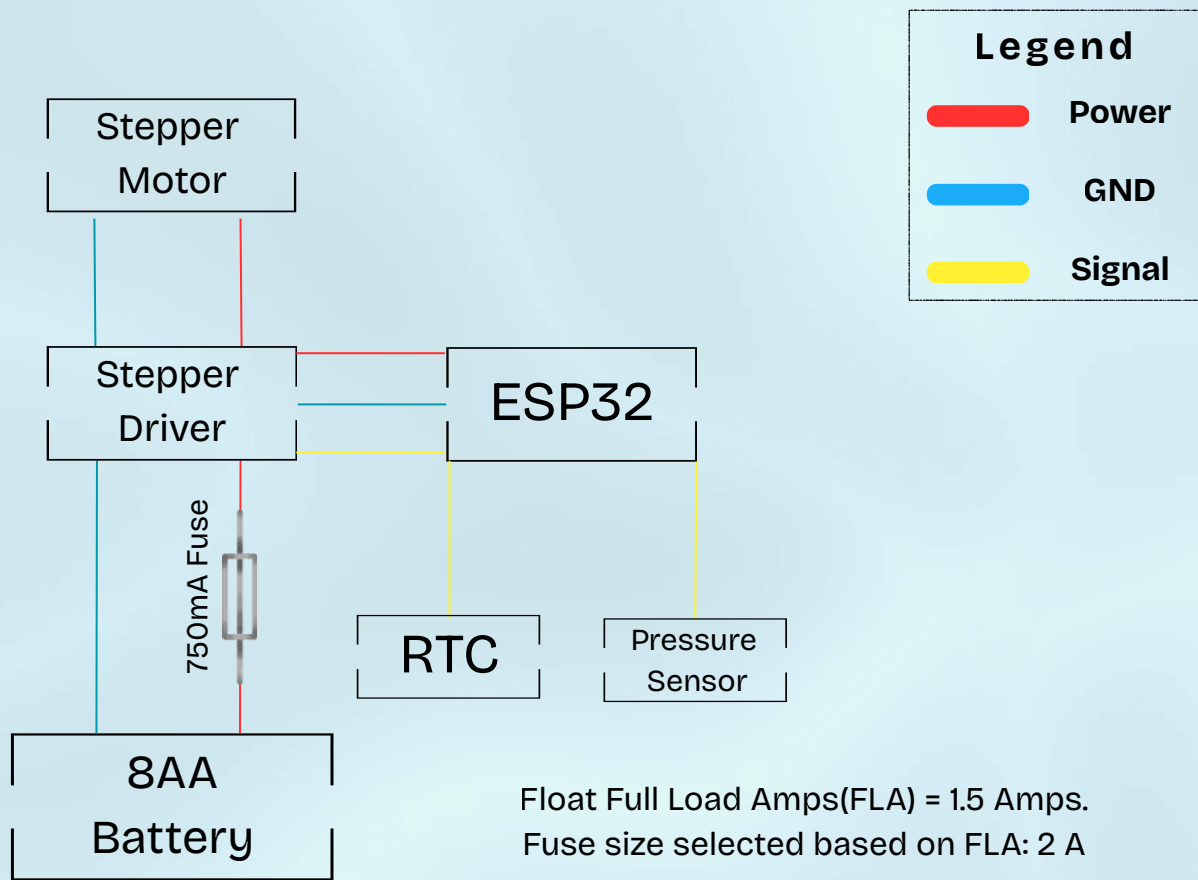


Figure 14: Autonomous Profiling Float Subsystem SID.

This diagram details the internal architecture of our independent autonomous float. The system utilizes a mechanical Buoyancy Engine driven by a high-torque stepper motor, which linearly actuates a 550 mL syringe to displace water and regulate buoyancy. The device operates independently from the main ROV using its own dedicated battery bank and control board. A pressure sensor provides real-time depth feedback to the onboard microcontroller, allowing the system to autonomously execute precise depth-profiling maneuvers.

6 SAFETY

6.1 Safety Rationale (Personnel, Equipment, & Operational)

For RedSea Rovers, safety is not an afterthought or a mere compliance checklist; it is a fundamental design constraint integrated into every phase of our engineering and operational workflow. We categorized our safety rationale into three core pillars:

- **Personnel Safety:** The physical well-being of our team and bystanders is our highest priority. All poolside and workshop operations strictly mandate Personal Protective Equipment (PPE), including safety glasses and closed-toe footwear. To prevent physical injuries, we meticulously sanded all structural chassis components to eliminate sharp edges, and all moving parts are properly shielded.
- **Equipment Safety:** To protect our mechanical and electronic investments, our system incorporates multiple fail-safes. Electrically, we enforce strict AWG wire sizing standards and utilize a 30A fast-acting inline fuse as the primary defense against overcurrent conditions. Mechanically, the 8 vectored thrusters are fully enclosed within custom 3D-printed shrouds to prevent debris ingestion and accidental contact.
- **Operational Safety:** Our Tether Manager strictly enforces a deck protocol to keep the operational area clear of tripping hazards using a manual spooling technique. Furthermore, highly visible warning labels (e.g., "Pinch Point," "High Voltage 48V") are strategically placed on the ROV and the surface power station to maintain constant situational awareness.

6.2 Job Site Safety Analysis (JSA Hazards Matrix)

To systematically identify and mitigate risks, we developed a comprehensive Job Site Safety Analysis (JSA). The following matrix highlights our most critical operational hazards and the engineered controls implemented to minimize their impact:

Table 3: Job Site Safety Analysis (JSA) and Mitigation Matrix

Task / Activity	Potential Hazard	Risk Level	Mitigation / Control Measure	Residual Risk
Topside Power Setup	Electrical shock or short circuit from 48V power supply.	High	Inline 30A fast-acting fuse; Anderson connectors; marine-grade heat shrink; dry deck protocol.	Low
ROV Deployment & Retrieval	Slips, trips, or falls poolside; heavy lifting strains.	Medium	2-person lift protocol; mandatory closed-toe shoes; keeping tether neatly spooled.	Low
Thruster Operation	Lacerations or finger injuries from rotating propellers.	Medium	Custom 3D-printed thruster shrouds; "Pinch Point" warning labels; strict "power-off before handling" rule.	Low
Soldering & Fabrication	Burns, eye injuries, or inhalation of toxic fumes.	Medium	Mandatory safety glasses; well-ventilated workspace (fume extractors); soldering iron holsters.	Low

6.3 Construction & Operational Safety Checklists

Pre-Dive Operational Checklist:

- [] Verify 30A main inline fuse is securely seated and intact.
- [] Inspect tether for any cuts, abrasions, or exposed internal wires.
- [] Verify the mechanical Strain Relief is securely anchored to the ROV chassis and test tension to ensure zero load is transferred to the electrical penetrators.
- [] Confirm all bulkhead penetrators and enclosures are properly sealed and locked.
- [] Ensure deck area is dry and completely free of tripping hazards.
- [] Conduct communication and telemetry check via QGroundControl before applying thruster power.

Post-Dive / Retrieval Checklist:

- [] Immediately disconnect the main 48V power supply at the surface station.
- [] Retrieve the ROV by applying tension strictly to the tether's Strain Relief, safely transferring the vehicle's wet weight to the chassis.
- [] Inspect the Strain Relief connection point on the chassis for any signs of material fatigue, bending, or loosening.
- [] Rinse the vehicle with fresh water to prevent chlorine/saltwater corrosion.
- [] Inspect 3D-printed shrouds and enclosures for any micro-cracks or water ingress.

7 CRITICAL ANALYSIS: TESTING & TROUBLESHOOTING

7.1 Multi-Phase Prototyping & Wet/Dry Testing Methodology

Our testing methodology was deeply rooted in applied electrical engineering principles, prioritizing isolated subsystem validation before full-scale integration. To minimize risks to our expensive electronics, we structured our prototyping and testing into three distinct, chronological phases:

- Phase 1: Dry Testing & Bench Diagnostics: Before exposing any component to water, we rigorously verified our electrical architecture. We conducted extensive continuity checks on all custom power distribution boards and soldered joints. Utilizing lab power supplies, we bench-tested the Pixhawk motor mixing signals and BlueOS telemetry, ensuring our software architecture was perfectly communicating without the variables introduced by a wet environment.
- Phase 2: Watertight Integrity (Static Hydrostatic Testing): To validate our mechanical seals without risking the internal electronics, we performed a practical static hydrostatic test. We fully assembled the empty main acrylic enclosure, ensuring all radial O-rings and penetrators were firmly seated. We then fully submerged the empty cylinder in the pool for an extended period. A thorough visual inspection confirmed absolutely no water ingress, practically validating our mechanical seals under real hydrostatic pressure.
- Phase 3: Wet Testing & Buoyancy Trim: Once watertight integrity was proven, we integrated the electronics and moved to wet testing. Our initial focus was entirely on static stability. We iteratively adjusted the placement of our closed-cell foam floats and internal ballast weights until the ROV achieved perfect neutral buoyancy and a stabilized center of gravity (CoG). This critical step prevents the vectored thrusters from overworking simply to maintain depth.

7.2 Critical Troubleshooting Log & Engineering Solutions

Troubleshooting is an inherent part of the engineering process. Rather than relying on guesswork, we implemented a systematic Root Cause Analysis (RCA) approach to diagnose and resolve anomalies effectively. The following log details our most critical challenges and the practical engineering solutions we implemented:

Table 4: Critical Troubleshooting Log and Root Cause Analysis (RCA)

Subsystem	Observed Issue (Symptom)	Root Cause Analysis (RCA)	Implemented Engineering Solution
Power Distribution	Initial calculations showed all 8 thrusters operating at max capacity could exceed the 30A surface power limit.	Simultaneous max PWM signals from the Pixhawk demanded higher peak current than the tether/fuse could safely supply.	We implemented a software-level PWM throttle cap within the ArduSub parameters, mechanically limiting the maximum thrust output to stay strictly within our power budget.
Software / Vision	YOLOv8 object detection experienced severe frame-rate drops (lag) when running simultaneously with the BlueOS video stream.	The Raspberry Pi 4 CPU was thermal-throttling and bottlenecking due to processing high-resolution video frames through the neural network.	We aggressively downscaled the input frame resolution for the OpenCV script before feeding it to the YOLOv8 model, drastically improving FPS without sacrificing detection accuracy.
Manipulator / Tooling	Standard servos used for the robotic arm consistently short-circuited during depth testing.	Custom waterproofing attempts using various epoxy resins failed. Microscopic voids in the potting compound allowed water ingress under hydrostatic pressure.	Applying the "Build vs. Buy" rationale, we abandoned custom-potting and procured a factory-rated IP68 waterproof servo, ensuring mechanical reliability and eliminating continuous maintenance downtime.
Vision / Operations	The pilot experienced a significant "blind spot" beneath the robotic arm, making manipulation tasks extremely difficult.	The primary camera's fixed Field of View (FOV) was physically obstructed by the manipulator's geometry, preventing direct line-of-sight to the mission props.	We integrated a secondary, downward-facing auxiliary camera specifically mounted to monitor the manipulator's workspace. This provided the pilot with a dedicated feed for precise tool alignment.

8. ACCOUNTING & FINANCIALS

8.1 Budget Planning Strategy

RedSea Rovers operates with a strict corporate financial mentality. Our project is currently supported by university grants and a strategic sponsorship from Johnson Controls, totaling SAR 85,000 (~\$22,666 USD). We utilize a "Reuse and Re-engineer" strategy to optimize our hardware costs, allowing us to focus our financial resources on the international expedition to Canada.

Note: While our current budget secures the participation of a core technical delegation of six members, we are actively pursuing additional sponsorships to broaden our financial capacity. Our objective remains to increase our funding to support the attendance of our entire team, ensuring all core technical and operational roles are fully represented at the competition.

8.2 Budget Overview

The following table outlines our current projected costs for the 2026 ROV development and competition cycle.

Table 5: Budget Planning, Income, and Actual Expenditures

Category	Description	Budgeted Value (USD)
Technical Development	ROV components & upgrades	\$3,515.98
Logistics & Travel	Flights, accommodation, & freight for 6 members	\$19,150.00
Total Secured Funding	University & Johnson Controls	\$22,666.00

8.3 Project Costing Sheet (Actual Expenditures)

This section provides an accounting of our income, donations, and actual expenditures.

Date	Type	Category	Description	Amount (USD)	Running Balance
01/2026	Income	Grant	University Grant	\$9,333.00	\$9,333.00
05/2026	Income	Sponsorship	Johnson Controls	\$13,333.00	\$22,666.00
2 - 5/2026	Re-used/Purchased	Tech	Propulsion, Power, Vision, Structure	(\$3,515.98)	\$19,150.02
06/2026	Purchased	Travel	Flights, Accommodation, Shipping	(\$19,150.00)	\$0.02

8.4 Fundraising Status & Contingency

To realize our goal of full team participation, we have established the following financial roadmap.

Financial Status	Goal	Action
Secured	\$22,666	Fully allocated for core team (6 members)
Target Gap	~\$17,000	Additional funding required for 4 remaining members
Strategy	Expansion	Ongoing outreach to industry partners for sponsorship

REFERENCES & ACKNOWLEDGEMENTS

9.1 Technical References & Datasheets

The engineering, software, and mechanical development of the RedSea Rovers 2026 vehicle relied on the following technical documentation, open-source frameworks, and component datasheets:

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9.2 Acknowledgements

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Furthermore, we extend our sincere appreciation to the Manufacturing Community for their collaborative spirit, which fostered an environment of shared tools and hands-on manufacturing expertise. Their support was instrumental in successfully transitioning this vehicle from a CAD concept to a fully operational ROV.

