

ATLANTIS



VORTEX ACADEMY
THE ART OF THINKING

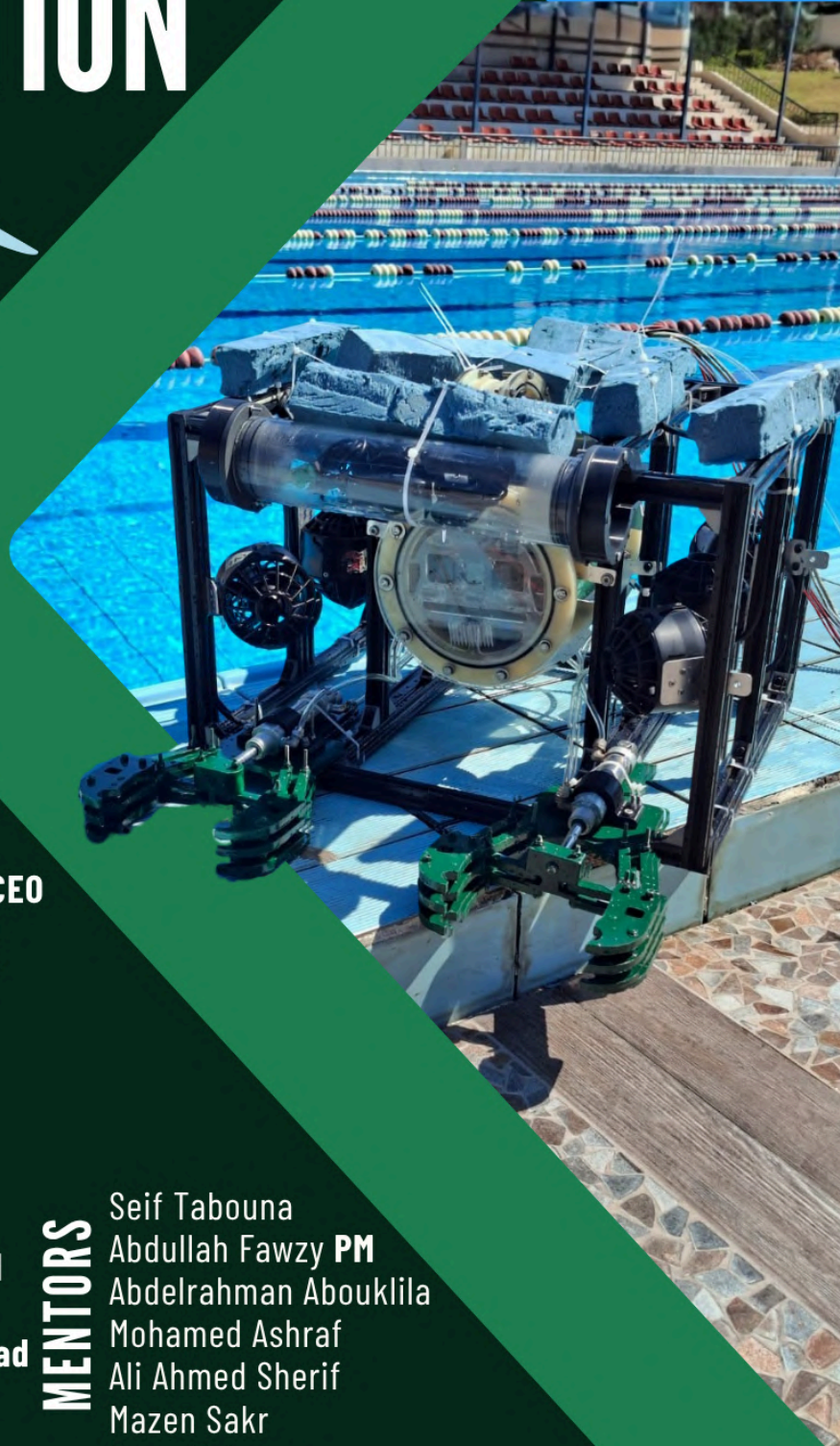
MATE ROV
COMPETITION

TECHNICAL DOCUMENTATION

MateROV 2026

Alexandria, Egypt 

Vortex Academy



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PM: Project Manager
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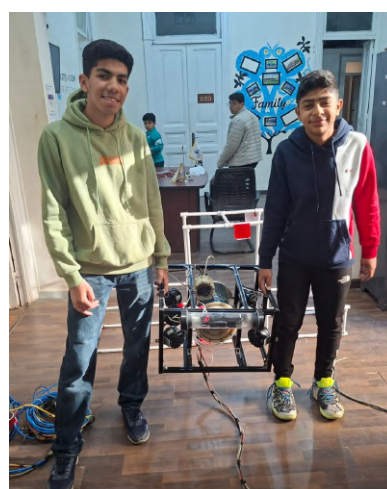
Table of Contents

1.0 Abstract.....	3
2.0 Teamwork and Organization.....	4
2.1 Company Overview:.....	4
2.2 Personnel & Organizational Structure:.....	4
2.3 Schedule & Workflow Management:.....	4
2.4 Procedures, Resources, & Task Management:.....	5
3.0 Engineering Design Rationale.....	6
3.1 Overall Vehicle Design:.....	6
3.2 Step-by-Step Planning & Design:.....	6
3.3 Design Decisions & Trade-offs:.....	6
3.4 Innovation.....	7
3.5 Problem Solving.....	8
3.6 Systems Approach & Integration:	8
3.7 Vehicle Structure:.....	9
3.8 Vehicle Systems:.....	10
3.9 Electrical System:.....	11
3.9.1 Internal Enclosure Layering & Cabling Layout:.....	11
3.9.2 Custom Main Control PCB & Signal Architecture:.....	11
3.9.3 Equipment Safety Circuitry:.....	11
3.9.4 Tether Design & Specifications:.....	12
3.9.5 Tether Management Protocol:.....	12
3.10 Control System Architecture: 13	
3.10.1 Computing Hardware & "Build vs. Buy" Justification:.....	13
3.10.2 Software Architecture & Development Process:.....	13
3.11 Custom Graphical User Interface(GUI):.....	14
3.12 Computer Vision & Software:.....	14
3.13 Propulsion:.....	15
3.14 Buoyancy and Ballast:.....	16
3.15 Payload and Tools:.....	16
3.16 Build vs. Buy & Component Lifecycle:.....	17
3.17 Autonomous Float System "Crystal":.....	17

4.0 Safety.....	18
4.1 Safety Philosophy & Culture:.....	18
4.2 Training & Lab Protocols:.....	18
4.3 Physical Vehicle Safety Features:	18
4.4 Warning Labels & Operational Protocols:...	18
4.5 Harsh Environment Personnel Safety.....	19
5.0 Critical Analysis: Testing & Troubleshooting: 19	
5.1 Testing Methodology & Prototyping:.....	19
5.2 Troubleshooting Protocol:	19
5.3 Practical Application:	20
6.0 Budget & Cost Accounting.....	20
6.1 Financial Planning & Travel Budget:.....	20
6.2 Cashbook Accounting & Resource Management: 20	
7.0 References:.....	21
8.0 Acknowledgements:.....	21
9.0 Appendices:.....	22



1



1.0 Abstract

The 2026 MATE ROV Competition challenges teams to address real-world marine conservation and energy infrastructure needs across four mission areas: mapping cold-water coral ecosystems for the Seabed 2030 initiative, supporting the SmartAtlantic Alliance through invasive species monitoring and offshore asset management, enabling wind-powered energy solutions for global scalability, and deploying autonomous profiling floats beneath Arctic ice.

Atlantis is a 30-member marine technology company from Alexandria, Egypt. Our primary ROV, Leviathon, is a 15 kg aluminum-framed vehicle featuring six Blue Robotics T200 thrusters in a 45-degree vectored configuration, delivering balanced omnidirectional thrust for station-keeping in flume tank currents and multi-directional waves. A custom Dynamic Power Allocation algorithm manages the strict 300W budget by isolating motion axes, yielding a 92.2% increase in per-motor vertical lift to 24.12N without exceeding the 25 A limit. Four near-zero-latency USB cameras (<40 ms) feed a Raspberry Pi 5 paired with a Pixhawk flight controller, running a custom YOLO object-detection model (0.937 mAP) for European Green Crab identification and a TripoSR pipeline for 3D coral garden reconstruction. Pneumatic HDPE dual grippers, a motorized rotary biofouling tool, and passive snap-clip mechanisms address manipulation tasks across all three pool-based missions.

Our autonomous float, Crystal, uses a dual-pump bladder system controlled by an ESP32 and Bar30 pressure sensor to execute vertical profiles and maintain depth holds within 66 cm tolerance beneath the ice. This report details how Leviathon and Crystal integrate mechanical, electrical, and software systems to accomplish all 2026 mission objectives.



Fig. 1. The members of Atlantis gathered at the Arab Academy for Science, Technology, and Maritime Transport (AAST) in Alexandria, Egypt, for the 2026 MATE ROV season. Photograph retrieved from the MATE ROV Egypt Regional Competition Facebook page, 2026.

2.0 Teamwork Project Management

2.1 Company Overview:

Atlantis is a student-led engineering organization mentored by Vortex Academy. Formed to push the boundaries of underwater robotics, our company operates on a foundation of cross-disciplinary integration and collaborative teamwork. By pairing the hands-on experience of returning veterans with the fresh perspectives of recruits, we establish a rigorous mentorship environment.

Purpose: The explicit purpose of this organizational structure is to ensure rapid knowledge transfer and seamless day-to-day operations. This enables our sub-teams to work in parallel to meet the strict demands of the 2026 competition theme and successfully deliver both our primary ROV (Leviathon) and autonomous Float (Crystal).

2.2 Personnel & Organizational Structure:

To execute our mission objectives efficiently, the 30 members of Atlantis operate under a clear corporate hierarchy. The purpose of this structure is to ensure absolute accountability, prevent siloed engineering, and streamline task execution across all vehicle mechanisms. **(Detailed Leadership Structure in Appendix A):**

Chief Executive Officer (CEO) & Chief Financial Officer (CFO): The CEO defines the strategic vision, directs overall operations, and enforces safety protocols. The CFO strictly manages the project budget, utilizing weekly financial reports to track expenditures for all consumables, assets, and logistics.

Chief Technology Officer (CTO) & Technical Leads: The CTO serves as the central integration node, making high-level engineering decisions to ensure parallel development between the ROV and the Float. Technical Leads direct the core sub-teams (Mechanical, Electrical, Software, and Float). Their primary responsibility is to delegate daily tasks, conduct rigorous CAD and code reviews, and resolve technical roadblocks.

Project Managers (PMs) & Committee Leads: PMs oversee the day-to-day execution of the physical build, tracking the supply chain and resolving operational delays to keep engineering efforts aligned with mission constraints. Committee Leads drive business operations, secure necessary funding, and execute community outreach to fulfill our real-world impact objectives.

The Rest of the members: Any other member belongs to a technical subteam (Electrical, Mechanical, or Software) and receives tasks.

2.3 Schedule & Workflow Management:

Initial Planning: At the very beginning of the 2026 development phase, Atlantis established a comprehensive project schedule utilizing a Gantt chart **(Figure 2)**. The purpose of this initial schedule was to formally divide the workload into core, manageable stages: new member training, concurrent design of Leviathon and Crystal, physical manufacturing, rigorous testing, and final documentation.

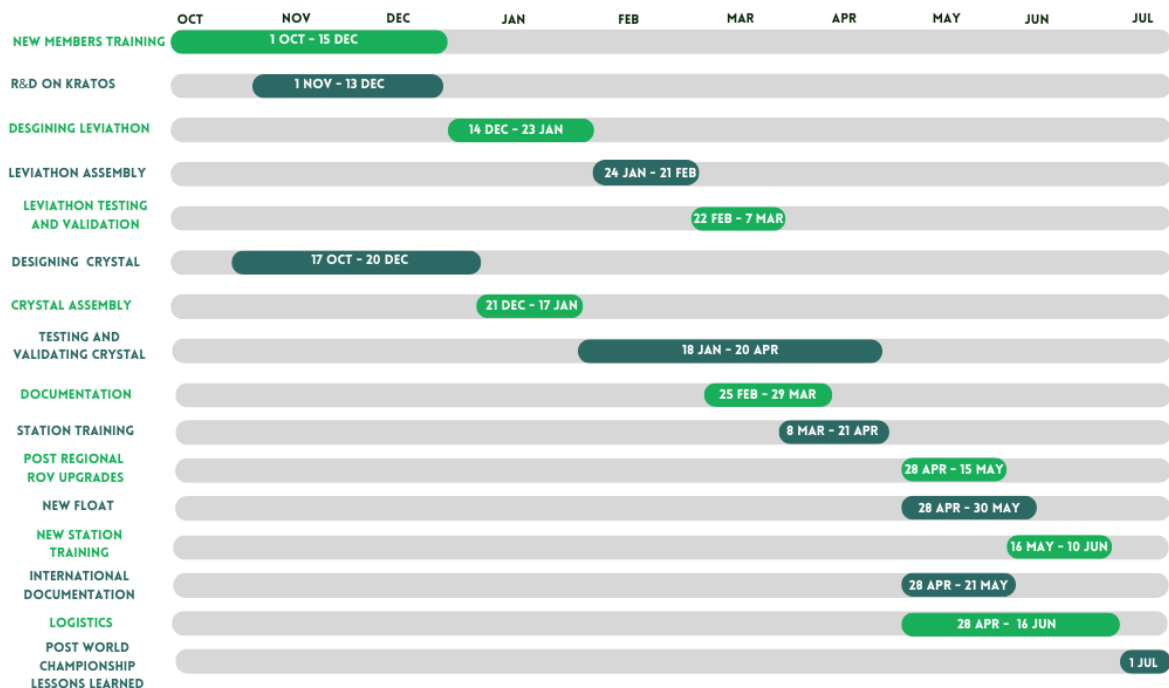


Fig. 2. Comprehensive project timeline and Gantt chart detailing the 2026 development phases for Leviathon and Crystal. Created by Rodayna Mohamed, Software Team.

Schedule Deviations and Team Adjustments: While our initial Gantt chart provided a vital roadmap, real-world constraints required our team to remain agile. During mid-January, academic final exams caused a severe, unforeseen two-week delay in the mechanical assembly of the Leviathon frame. To adjust to this deviation and recover critical lost time, the CTO utilized [our task-tracking software](#) to temporarily reallocate three idle members from the Software team to assist the Mechanical team with frame deburring and assembly.

The purpose of this cross-training adjustment was to bypass a major bottleneck; it successfully recovered 10 days of the schedule and kept our critical path to the testing phase intact.

2.4 Procedures, Resources, & Task Management:

Managing Atlantis and the Vortex Rangers Workspace

To efficiently manage our 30-member team and handle daily operations, Atlantis relies on strict protocols centered around our custom virtual hub, the Vortex Rangers Workspace ([Figure 3](#)). Functioning much like Jira or Confluence, this platform centralizes all task tracking, internal communication, and schedule management. It features a custom reservation system for our physical workspace and hardware, while also integrating daily progress updates. The main goal of this hub is to prevent miscommunication and give leadership real-time visibility into the team's progress.

Day-to-Day Agile Operations

We tackle daily engineering challenges using an Agile methodology. Our weekly all-hands meetings always begin with a mandatory standup, where sub-teams report on their progress and highlight any major blockers. The Workspace also acts as our living engineering notebook. We log all meeting minutes, CAD iterations, and test footage directly into the hub, keeping everything connected with our technical tools like SolidWorks, KiCad, and GitHub. To keep motivation high and clear minor bottlenecks, we gamify our workflow. Members earn points for completing tasks and are heavily encouraged to take on cross-departmental assignments.

Resource Management and Procurement

To avoid delays during the physical building phase, our Project Managers take direct ownership of the supply chain. They proactively anticipate hardware needs, such as specific microcontrollers or manipulators, and submit purchase requests directly through the Workspace. These requests go through a fast, streamlined approval process managed by the CFO. This ensures that critical components arrive exactly when they are needed for assembly.

Reactive Problem Solving in Action

When unexpected issues arise, our protocols help us pivot quickly. For example, during the final assembly phase in February, customs delayed a critical shipment of Agro cable glands by two weeks. This threatened our watertight enclosure timeline. The Tools Project Manager immediately flagged the issue in the Workspace, which triggered our escalation protocol. Within 24 hours, the CFO authorized an emergency purchase, and the Mechanical lead found a compatible local supplier right here in Alexandria. We instantly updated the Workspace schedule to postpone the enclosure sealing. This quick shift prevented any lost build days and ensured we used verified components rather than compromised substitutes. ([check Figure 4 for some projects](#))

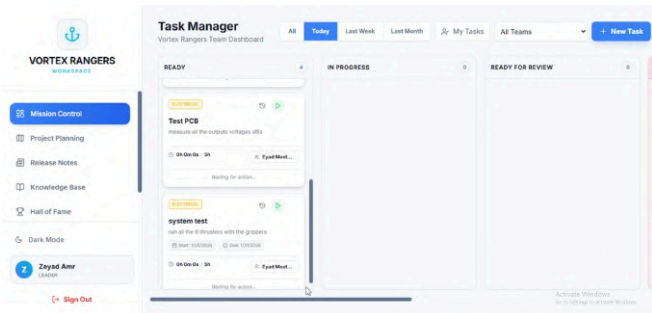


Fig. 3. The Vortex Rangers Workspace interface, Screenshot captured by Eyad Ashraf.

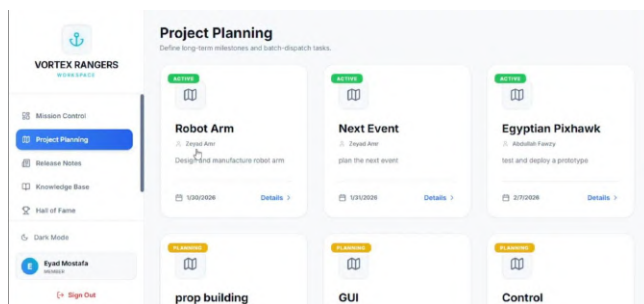


Fig. 4. Vortex Rangers Workspace project tracking interface. Screenshot captured by Eyad Ashraf.



3.0 Engineering Design Rationale

3.1 Overall Vehicle Design:

Atlantis presents Leviathon ([Figure 6](#)), a highly maneuverable 15 kg ROV engineered specifically to conquer the harsh, dynamic environments of this year's competition. To counteract fierce flume tank currents and multi-directional waves, we shifted from the compact geometry of our previous model, Kratos ([Figure 5](#)), to a wider, heavier aluminum extrusion frame. This increased mass and wide-stance footprint maximize hydrodynamic stability. To ensure reliable, sustained propulsion against these intense water currents, we selected six Blue Robotics T200 thrusters mounted on impact-resistant, 45-degree custom aluminum brackets.

Leviathon's front chassis is meticulously designed to house a versatile payload that directly addresses the mission tasks:

Task 1.1 Static O-ball Clips: Two custom-designed static clips allow the ROV to snap the O-balls into the basket stars in seconds.

Task 2.4 Buoy Anchor Hook: A purpose-built hook designed to securely capture and recover the buoy anchor, securing 15 points.

Task 2.5 Biofouling Rotary Tool: A specialized rotary tool engineered to safely remove biofouling from the observatory camera.

Dual Horizontal Grippers: Designed for core manipulation tasks, including retrieving the EDNA sensor, power connectors, caps, and coral species. These grippers can also be magnetized to efficiently extract the micropile installation pin in Task 3.1.



Fig. 5. SolidWorks CAD render of Kratos, our previous ROV.
Render created by Hour Ahmed.

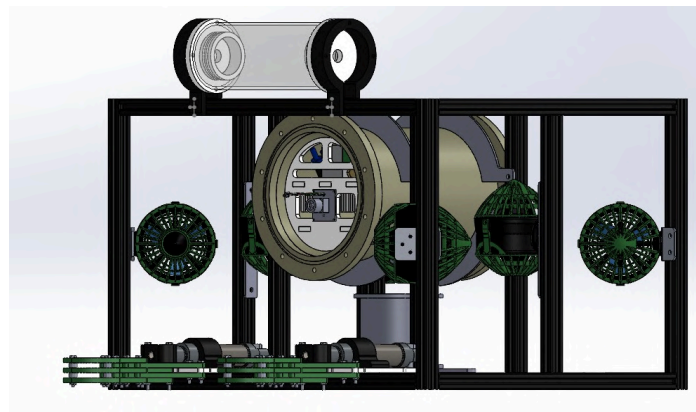


Fig. 6. SolidWorks CAD render of Leviathon. Render created by Habiba Gaber.

3.2 Step-by-Step Planning & Design:

To maximize scoring potential, Atlantis executes a rigorous, iterative design cycle tailored to specific mission requirements. We apply this process to every component, as demonstrated by the development of our [Task 2.5 Biofouling Rotary Tool](#):

Task Analysis & Research: We break down the task constraints. For the rotary tool, this required defining the exact prop dimensions, handle size, necessary rotational speed, and material limitations.

Brainstorming & Mechanism Selection: We ideate mechanical solutions, determining the optimal gear ratios and driving mechanisms required to clean the observatory camera without damaging it.

Virtual Validation: We draft a CAD prototype and validate structural integrity via simulation, evaluating mechanical trade-offs cost-effectively.

Fabrication & Initial Testing: We manufacture the prototype and conduct dry operational tests. If a mechanism fails at this stage, we return to **Step 2: Brainstorming & Mechanism Selection**.

Subsea Stress Testing: Validated designs undergo intense underwater stress testing with our primary pilot to simulate competition conditions.

Design Cycle Result: During the underwater stress testing of the rotary tool (Step 5), we discovered that the initial motor lacked sufficient torque when fighting water resistance. Following our process, we returned to Step 2, recalculated our torque requirements, upgraded to a higher-torque motor, and successfully resolved the issue prior to competition.

3.3 Design Decisions & Trade-offs:

Operating in a high-current flume tank demands hardware that has zero response time. A trade study dictated a massive shift to Leviathon's wide-stance geometry to support simultaneous multi-manipulation under multidirectional wave stress. Furthermore, we conducted a rigorous evaluation of our telemetry architecture to ensure our pilot could navigate these harsh conditions effectively.

Table 1: Frame Design Trade-off Analysis:

Feature	Compact Frame (Kratos)	Wide-Stance Frame (Leviathon)
Footprint	Agile, but inherently unstable when operating multiple large tools. (Base Area: ~900 cm ²)	A massive increase in Hydrodynamic stability. (Base Area: 2000 cm ² , increasing roll-stability moment by 35%).
Thrusters	Outside perimeter. Highly vulnerable to direct pool-wall impacts.	Inside the perimeter. The aluminum extrusion frame acts as a protective roll-cage.
Payload	Lacked lateral space for simultaneous tool operation. Weight: ~12 kg. Max Capacity: 2 Tools.	Accommodates dual horizontal grippers, a central rotary tool, and task hooks. Weight: 15 kg. Max Capacity: 4+Tools.

Table 2: Camera System Trade-off Analysis:

Feature	IP Cameras	USB Cameras
Latency	Noticeable delay due to network encoding/decoding. (Average Latency: 150ms – 250ms).	Near-zero latency is crucial for precise, instantaneous reaction times. (Average Latency: <40ms).
Network Architecture	4 independent IP cameras compete for tether bandwidth, requiring complex subsea IP routing and a switch.	The Raspberry Pi 5 acts as a central hub, efficiently multiplexing the 4 video streams alongside telemetry
Hardware Footprint	Requires an additional subsea networking switch and manual IP configuration. (Added ~150g weight & \$45 cost).	Plug-and-play simplicity. Eliminates the Ethernet switch, reducing the electronics' internal space requirement by 10%.

Decision: We ultimately selected the USB cameras. While the 150-ms to 250-ms latency of IP cameras is often considered acceptable for manipulation in calm waters, it becomes a critical liability in a highly dynamic flume tank. When combating multi-directional waves and high currents, the pilot requires near-zero latency to make instantaneous micro-corrections. The USB cameras provide the real-time responsiveness essential for this year's harsh environment while streamlining the internal system architecture.

3.4 Innovation

High Functionality at Reduced Cost: The "Crystal" Magnetic Reed Switch: During our regional preparation, we faced a critical setback: our autonomous float, Crystal, was lost, and we lacked a replacement waterproof power switch. A standard Blue Robotics subsea switch costs \$28 and had a two-month shipping/customs lead time, which would have entirely stopped our autonomous task testing. To solve this, we engineered a clever, out-of-the-box alternative, using cheap, locally sourced components. We designed a custom solid-state power circuit relying on a simple 3\$ magnetic reed switch (**Figure 8**). The mechanism is brilliantly simple: Placing a magnet on the outside of the hull opens the circuit (turning the float OFF). To deploy the float for its mission, the pilot simply removes the magnet, closing the circuit and powering the system ON.



Fig. 8. Reed Switch.

The Advantage: This solution reduced our component cost by nearly 90% while providing a highly reliable, waterproof seal without any external moving parts. Unlike mechanical switches that can physically fail or disconnect under pressure, our magnetic switch ensured that Crystal could be tested continuously and deployed reliably for its autonomous tasks.

Vehicle Design Innovation:

Dynamic Power Allocation for Deep-Water Heavy Lift Ranger-class vehicles is strictly capped at 300W. Operating six T200 thrusters concurrently easily exceeds this limit, presenting a massive vulnerability when navigating the currents of the flume tank or executing rapid vertical ascents from the 5-meter pool bottom. Historically, ROVs rely on a hard, global power cap across all motors, which severely restricts vertical lifting force to just 12.55 Newtons per motor. To overcome this, we engineered a custom Dynamic Power Allocation algorithm. The software locks in a strict 60W baseline for logic systems, leaving 240W dedicated entirely to propulsion. Rather than throttling the whole vehicle, the algorithm monitors pilot inputs and instantly funnels the full 240W *exclusively* to the active thrusters.

The Advantage: By isolating the heave axis during vertical payload operations, we can safely push the vertical thrusters to 1820 PWM. As demonstrated in (**Figure 9.1**), this produces 24.6 Newtons per motor, a massive 92.2% increase in lifting capacity without tripping the 25A breaker. This targeted power allocation is the definitive factor that allows Leviathon to execute rapid, 5-meter vertical transits to the surface to deposit time-sensitive items like the Basket Stars (Task 1.1). Furthermore, it provides the sheer brute force necessary to haul massive, high-drag payloads from the pool floor, such as the waterlogged Lobster Pot (Task 2.3) and the dense eDNA sensor (Task 2.5).

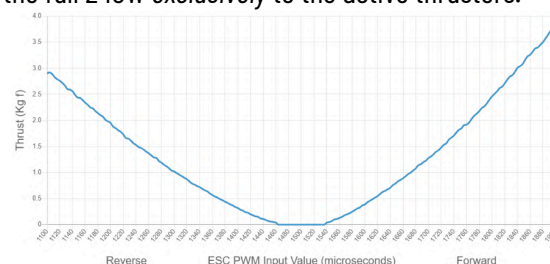


Fig. 9.1 T200 thruster force vs. ESC PWM. Graph retrieved from Blue Robotics.

3.5 Problem Solving

Brainstorming Process & Cross-Industry Integration

To tackle complex design challenges, Atlantis employs a structured, three-step brainstorming process:

Define Constraints: We outline the exact physical and financial limitations of the problem.

Cross-Industry Research: We actively look outside the marine engineering field for existing, proven mechanisms that solve similar mechanical issues.

Whiteboard Evaluation: The team openly debates how to adapt these external solutions for subsea use.

Example Application: We applied this exact process when struggling to design a low-profile bladder for our retrieval autonomous float's (Crystal's) variable-buoyancy system. Standard marine bladders were too bulky. During our cross-industry research phase, we looked to the medical field and discovered that a standard leg-mounted urine collection bag provided the exact properties we required (**Figure 9.2**). Constructed from durable, high-frequency welded PVC, it offered a fully sealed, vacuumable internal capacity with pre-integrated dual ports (an anti-reflux inlet and a drainage spigot). By applying minor modifications to the tubing interfaces, we repurposed this highly reliable, cost-effective medical device into the core of Crystal's active ballast system.

Rational Evaluation of Alternatives: Hydrodynamic Trade Study

During our retrospective analysis of our previous ROV, we identified that standard 2D flat-plate thruster guards severely restricted volumetric flow and bottlenecked our total thrust. To find the optimal solution, we used a data-driven trade study to evaluate design alternatives based on fluid dynamics.

The Problem: Pushing fluid through a sharp, non-profiled 2D mesh produces a "vena contracta" and massive boundary-layer separation, resulting in a turbulent wake that chokes the inflow.

The Alternatives & Data: We evaluated the Drag Coefficient (C_d) of two distinct geometries. We compared standard flat-plate designs (high drag, $C_d \approx 2.0$) against custom hydrofoil cross-sections (low drag, $C_d \approx 0.04$).

The Decision: The mathematical data heavily favored the hydrofoil geometry. Based on this rational evaluation, we manufactured custom 3D-printed guards featuring contoured meshes with precisely radiused leading and trailing edges.

The Result: Applying this scientific approach effectively delays boundary layer separation and ensures attached flow. This minimizes thrust loss from turbulent wakes, maximizing our propulsion efficiency while remaining strictly compliant with MATE IP20 finger-safety regulations (*Reference: Munson, Fundamentals of Fluid Mechanics*).

3.6 Systems Approach & Integration:

This year, the primary challenge is not the complexity of the tasks themselves, but the harsh environment. Actions that take seconds in a calm pool, such as inserting the power connector into the port (Task 3.2), become incredibly difficult when fighting the flume tank's multi-directional waves. To address this, Atlantis adopted a holistic systems approach, ensuring our mechanical, electronic, and software designs work in unison to create a highly maneuverable and hyper-stable ROV. Integrating Mechanics and Electronics for Extreme Stability. Mechanical weight alone cannot conquer multi-directional waves; true stability requires a unified system.

Mechanical Baseline: We designed a wider frame and maximized the distance between our vertical thrusters. Following the same physics principles used in multi-rotor drones, which drastically improves the vehicle's natural roll and pitch stability.

Active Electronic Stabilization: To complement the mechanical frame, we integrated a Pixhawk flight controller (**Figure 10**). While originally designed for the drone industry, we selected the Pixhawk based on commercial marine standards (it serves as the core architecture for industrial vehicles like the BlueROV2). Because we lacked access to a wave pool for testing, attempting to build a flight controller from scratch was an unacceptable risk. The Pixhawk provides reliable, commercially proven hardware and software integration.

Task-Specific Application of Stability Systems. This tight integration between the frame and the flight controller is exactly how we address this year's hardest tasks:

Active Stabilization (Task 2.5): Inserting the PC02 PVC fork into slightly larger couplings requires extreme precision. When multi-directional waves hit the ROV, the Pixhawk detects the tilt and instantly fires the widened thrusters to counteract the current, keeping the vehicle perfectly still so the pilot can complete the delicate insertion. **Depth Hold (Task 1.3):** During the transect task, the ROV must hold a precise position over the square. By activating the Pixhawk's "Depth Hold" mode, the software takes complete control of the vertical axis. The pilot no longer has to fight the waves pushing the ROV up, and down; they can focus 100% of their attention on horizontal alignment.

Cross-Disciplinary Synergies Instead of isolating our engineering departments, we made calculated, system-wide decisions to maximize total vehicle performance:



Fig. 9.2 Urine bag image
retrieved from [Euromed](https://www.euromed.com).



Fig. 10 Pixhawk flight controller; Image
retrieved from <https://pixhawk.org/>.



Virtual Integration for Vision & Grippers: We modeled Leviathon alongside the actual MATE competition props in SolidWorks. By virtually simulating the 2-inch PVC coral species props (task 1.1), we accurately scaled our physical horizontal grippers. Furthermore, we added an acrylic faceplate to guarantee a distortion-free pixel ratio, ensuring our software's algorithms would measure accurately.

Solving Hardware Limits with Software: The strict 25A current limit is a system-wide bottleneck. Instead of downsizing our thrusters (a mechanical compromise that would lose lifting power), we solved the problem with software. Our Dynamic Power Allocation algorithm actively manages the electrical budget, allowing us to safely push the hardware to its maximum limit during heavy payload operations without blowing fuses, giving Leviathon the brute strength and stability required to perform reliably in heavy underwater currents.

Mechanical Efficiency Aids Software Control: Replacing standard flat thruster guards with 3D-printed hydrofoils did more than improve mechanical fluid dynamics. By smoothing the water flow, we directly lowered the electrical current drawn by the motors. This power savings gives more electrical "overhead" to aggressively fire the thrusters and maintain depth hold in turbulent conditions

3.7 Vehicle Structure:

When designing Leviathon, every structural decision was driven by the need to survive the flume tank's turbulent environment while carrying a heavy payload. To achieve this, we fundamentally evaluated the trade-offs between size, weight, and cost, resulting in several critical design shifts from our previous ROV, Kratos.

Size Trade-off: Low Drag vs. Hydrodynamic Stability

The Trade-off: A compact frame (like Kratos) produces low drag and high agility, but lacks the internal space for multiple tools and acts like a pendulum in rough water.

Final Design Influence: We accepted the penalty of a larger drag profile and expanded to a 50x40x35 cm wide-stance geometry. This massive footprint increases our roll-stability moment by 35% and provides the necessary lateral space to securely house our dual horizontal grippers and central rotary tool across the front chassis.

Weight Trade-off: Handling vs. Subsea Mass

The Trade-off: A lightweight ROV is easy to carry but gets easily tossed around by multi-directional waves and flume tank currents.

Final Design Influence: We deliberately increased the vehicle's weight from 12 kg to 15 kg. While this requires more thrust to accelerate, the added mass acts as a physical anchor against wave disturbances. Despite this increase, it remains safely under the manual handling limits, allowing for smooth, two-person poolside deployment without requiring a crane.

Cost Trade-off: Custom HDPE Fabrication vs. Modular Reuse

The Trade-off: HDPE frames are incredibly lightweight but exhaust the team's financial budget, leaving little room for upgrades.

Final Design Influence: We chose to use heavier, Commercial-Off-The-Shelf (COTS) aluminum extrusions for our frame and rigorously reused 70% of Kratos's structural hardware. This highly efficient cost-saving measure funded our critical upgrades.

Final Structural Implementation

Modular Chassis: The aluminum extrusion frame (**Figures 11 & 12**) acts as a rugged, protective roll cage. The profiles are rigidly assembled using 90-degree aluminum angle brackets and T-nuts. This fastening method allows for rapid, drill-free component repositioning, ensuring we can adjust tool placement poolside if needed.

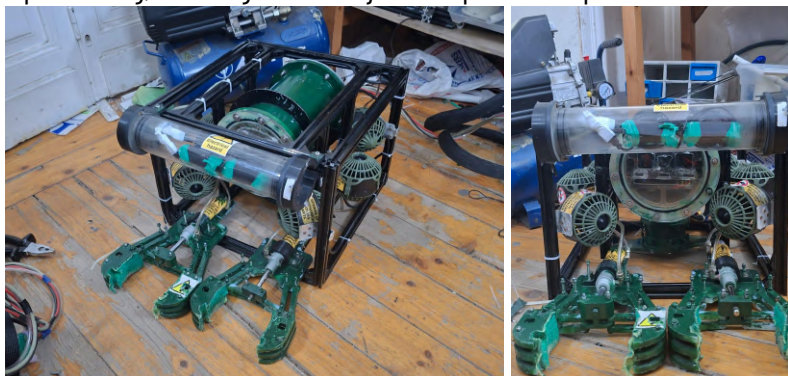


Fig. 11 and 12. Physical assembly of Leviathon's modular aluminum extrusion frame. Photographs by Ahmed Rezk.

Watertight Enclosures & Sealing: To protect our core electronics from hydrostatic pressure, Leviathon utilizes three watertight housings. The main cylinder relies on a highly rigid, custom-machined aluminum rear faceplate (**Figure 13**) fitted with Agro cable glands to prevent flexing. To ensure absolute watertight integrity, we designed an industry-standard static axial seal. The custom aluminum faceplate mechanically compresses an O-ring seated securely within a groove on the HDPE cylinder, strictly adhering to the tolerances defined in the [Parker Hannifin O-Ring Handbook](#).



Fig. 13. Custom laser-machined rear aluminum face. Photograph by Eyad Wagdy.



Propulsion Mounting: We mount our six T200 thrusters using custom-bent, 45-degree aluminum brackets. While 3D-printed mounts are cheaper and easier to produce, we traded that convenience for the vastly superior durability and impact resistance of solid aluminum.

3.8 Vehicle Systems:

For the 2026 season, we deliberately evolved Leviathon's systems from our previous ROV, Kratos, to meet a harsher mission profile that requires simultaneous manipulation, stable station-keeping in waves, and strict electrical budgeting. We evaluated every component iteratively based on testing data, preserving proven hardware while redesigning systems that failed or limited us last year.

Payload Systems & Gripper Evolution: The most significant evolution was our payload architecture. Kratos used a horizontal and a vertical manipulator layout. While effective last year, testing proved it was inadequate for 2026's multi-step tasks that require handling props horizontally only in front of the ROV. We evolved to a dual-horizontal layout to give the pilot a more intuitive working envelope for simultaneous grabbing and stabilizing. We also overhauled our materials based on direct failure analysis. Kratos used laser-cut acrylic grippers. While easy to manufacture, testing showed acrylic was too brittle, often cracking under stress or accidental pool-wall impacts. To evolve, we machined Leviathon's manipulators from 9mm High-Density Polyethylene (HDPE), which is highly impact-tolerant.

Gripper Mechanism & Task Integration: Our grippers ([Figure 14](#)) are actuated by pneumatic pistons. Direction Control Valves (DCVs), which are triggered by MOSFETs on our custom PCB, instantly route air to open or close the pistons. To ensure the ROV can securely hold heavy, smooth props like the Coral Species or the power port cap without them slipping, we lined the inner jaws with a high-friction abrasive material. This low-cost, clever pneumatic integration provides immense gripping force without the complexity or cost of commercial electronic actuators. ([See Appendix C for the complete pneumatic system](#)).

Rotary Tool Design & Mechanics: The central rotary tool ([Figure 15](#)) was engineered specifically to solve Task 2.5 (observatory biofouling) at a highly efficient cost. **Mechanism:** The tool consists of a high-torque DC motor. The motor's metal shaft is securely linked via a copper coupler to a custom-built, two-pronged fork made from standard PVC pipes and elbow fittings.

Task Integration: To complete the task, the pilot navigates the ROV until the PVC fork slides over the observatory's handle. The pilot then powers the DC motor, which smoothly spins the fork to perform the required three full rotations. By using a wide PVC fork, we ensure the tool engages the handle securely without slipping, distributing the contact load so the ROV is not pushed backward by the rotational force.

Cameras & Tether Optimization: The USB vs. IP Trade-off

Leviathon features four HD USB cameras: a front camera for navigation, a gripper camera for manipulation, a top camera for spatial awareness, and a benthic camera for transect observation and YOLO-based crab detection.

Solving the Latency Problem: Last year, we used IP cameras. While IP cameras work well in calm waters, they suffer from encoding delays, resulting in an average latency of 150–250 ms. In a static pool, this is manageable. However, **in this year's flume tank with multi-directional waves, IP cameras are a massive liability**. A quarter-second delay means that by the time the pilot sees the target on their screen, the waves have already pushed the ROV out of alignment. To successfully grab objects or insert pins while fighting currents, the pilot requires instant visual feedback.

The USB Evolution: We evolved to a full USB architecture because USB cameras offer near-zero latency (<40 ms). This allows the pilot to make instantaneous micro-corrections during delicate payload tasks. Furthermore, wiring all cameras directly to the onboard Raspberry Pi 5 eliminated the need for a bulky subsea network switch, saving \$45, removing weight, and freeing up 10% of our enclosure space.

Control System Evolution & Cost-Effective Reuse: We further simplified the logic architecture by removing anything that did not directly increase mission performance. We replaced our old Arduino-based signal translators with low-cost industrial optocouplers. This heavily reduced our PCB footprint and wiring complexity while fully protecting our logic boards from motor voltage spikes. At the sensing level, we intentionally kept the stack minimal. We exclusively use the Bar30 pressure sensor and the Pixhawk IMU to manage depth stability and pitch/roll awareness, the only two behaviors that genuinely matter when fighting wave currents. We inherited the six Blue Robotics T200 thrusters, the Pixhawk controller, major enclosures, and aluminum stock from Kratos. Reusing the six thrusters alone saved \$1,380 USD. By carrying over 70% of last year's hardware, we freed up the necessary budget to invest in our critical new upgrades: the Pi 5, the custom pneumatic manipulators, and our hydrodynamically improved 3D-printed thruster guards.



Fig. 14. Leviathon's pneumatic HDPE gripper in an open position. Photograph by Hour Ahmed.



Fig. 15. The custom rotary tool. Photograph by Omar Masry.

3.9 Electrical System & Workmanship:

Leviathon's electrical system is engineered for absolute reliability under the heavy turbulence of the flume tank. We eliminated disorganized point-to-point wiring to ensure the ROV never disconnects or loses power while fighting multi-directional waves. By prioritizing immaculate workmanship, we guarantee a neat, professionally installed system with zero tangled "spaghetti" wiring. This not only secures full marks in the safety and workmanship inspection but also ensures uninterrupted control when executing high-precision operations, such as aligning the PC02 connector in Task 2.5. **(A complete schematic is provided in "SID" (Check Appendix D), and a detailed power calculation table is provided in Table 3).**

Table 3 "Power Calculation Table":

Component	Qty	Operating Voltage (V)	Max Current(A)	Max Power (W)	Total Power (W)	Equivalent Current at 12V Main (A)
Raspberry Pi 5	1	5V	5.00 A	25.00 W	25.00 W	2.08 A
Pixhawk Flight Controller	1	5V	6.00 A	30.00 W	30.00 W	2.50 A
HD USB Cameras	4	5V	0.12 A	0.60 W	2.40 W	0.20 A
Directional MOSFETs	3	12V	0.12 A	1.44 W	4.32 W	0.36 A
Rotary DC Motor (Task 2.5)	1	12V	0.80 A	9.60 W	9.60 W	0.80 A
T200 Thrusters	6	12V	Variable	Variable	220.32 W	18.36 A (Total Allocated)
- Horizontal Vectoring Load	4	12V	4.59 A	55.08 W	220.32 W	18.36 A
- Vertical Heave Load	2	12V	9.18 A	110.16 W	220.32 W	18.36 A
Total System Draw	-	-	-	-	291.64 W	24.30 A

3.9.1 Internal Enclosure Layering & Cabling Layout:

To maximize both electromagnetic interference (EMI) isolation and physical water-ingress protection, the internal components of our main cylindrical enclosure (**Figure 15**) are strictly divided into three physical tiers:

Bottom Layer (High-Noise/Low-Cost): Houses the 12V-to-5V buck converters and the Directional Control Valve (DCV) solenoids for our pneumatic grippers. If a micro-leak occurs, water naturally pools at the bottom. Placing our cheapest, most robust components here physically protects the rest of the ROV.

Middle Layer (Power Distribution): Contains the main power busbar and the six Electronic Speed Controllers (ESCs).

Top Layer (Sensitive/High-Cost): Houses the 5V logic system, including the Raspberry Pi 5, Pixhawk, and USB cameras. Placed at the highest point, these expensive components are isolated from both EMI noise and potential water leakage. This internal layering dictates the layout of our rear aluminum faceplate. Pneumatic hoses enter through the bottom glands, heavy 12V thruster cables through the middle, and sensitive tether data cables through the top. Completely separating high-voltage lines from data lines prevents thruster noise from corrupting our near-zero latency USB camera feeds, which is crucial for completing visual tasks in the wave pool.

3.9.2 Custom Main Control PCB & Signal Architecture:

To eliminate wiring clutter and maximize reliability, we designed a custom Printed Circuit Board (PCB) (**Figure 16**) that acts as Leviathon's central nervous system. It securely distributes 5V power to the logic boards and consolidates the PWM signal pins from all six ESCs into a single, unified data cable routed to the Pixhawk. Crucially, this PCB protects the ROV's brain. It routes 3.3V signals from the Pixhawk through onboard industrial optocouplers. These optocouplers physically isolate and protect the sensitive Raspberry Pi and Pixhawk from the severe electrical noise generated by our heavy payload tools, such as the high-torque Task 2.5 rotary motor.

3.9.3 Equipment Safety Circuitry:

Our electrical safety architecture uses a dual-tier approach to ensure strict compliance with competition rules and guarantee the survival of our components.

System-Wide Protection: To comply with Ranger class rules and protect the entire ROV, a primary 25A inline fuse is installed on the tether within 30 cm of the topside power supply.

Logic Isolation: As calculated in our power budget, our sensitive 5V logic system (Raspberry Pi, Pixhawk, and 4 USB cameras) draws a combined total of 11.5A on the 5V rail. To protect this specific tier, we installed a dedicated 15A inline fuse to handle standard overcurrent and short-circuit protection.

Modular Overvoltage Defense (Crowbar Circuit): To protect against catastrophic voltage spikes on the 5V line, we engineered a custom 2.5 x 2.5 cm "crowbar" circuit. A Zener diode continuously monitors the voltage. If a dangerous spike occurs, it triggers a thyristor that instantly creates a direct short circuit to ground. This deliberate short forces a massive inrush of current that instantly

blows the dedicated 15A logic fuse. This action physically severs the power connection, sacrificing a cheap fuse to save the expensive microcontrollers before the voltage spike can reach them.

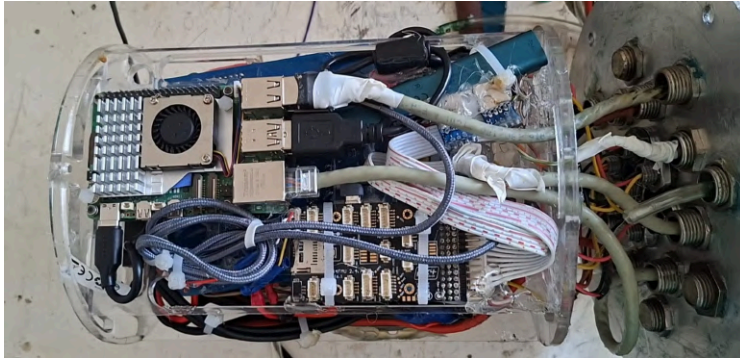


Fig. 15. The internal structure. Photograph by Omar Nabil.



Fig. 16. Custom main control PCB. Photograph by Hamza Amr.

3.9.4 Tether Design & Specifications:

Leviathon operates on a custom-built, neutrally buoyant 30-meter tether (**Figure 17**) tailored specifically for the 2026 World Championship mission requirements. To determine this optimal length, we bypassed guesswork and mathematically calculated the maximum 3D diagonal distance of the competition Flume Tank (22m Length x 8m Width x 4m Depth). Using the Pythagorean theorem in three dimensions, the absolute maximum subsea distance from corner to corner is calculated as:

$$d = \sqrt{(22^2 + 8^2 + 4^2)} = \sqrt{(484 + 64 + 16)} = \sqrt{564} \approx 23.75 \text{ meters}$$

We then added 2 meters to account for the distance from the water's edge to our topside control station, bringing the base requirement to 25.75 meters. Finally, operating in a high-current flume tank requires careful tension management; if a tether is too tight, it will artificially drag the ROV backward during delicate manipulation tasks. Therefore, we factored in a 15% slack buffer.

This strict calculation dictated our final 30-meter design. It guarantees Leviathon has unrestricted access to the entire tank while strictly minimizing excess cable that could otherwise tangle or act as a hydrodynamic sail in the heavy currents.

Power Transmission: To safely transmit up to 25A to the subsea busbar, we use heavy-duty 12 AWG marine-grade stranded copper wire. This minimizes resistance across the 60-meter total circuit loop, preventing severe voltage drop and heat generation and ensuring a stable 12V supply.

Data Transmission & EMI Shielding: A Shielded Twisted Pair (STP) CAT6E Ethernet cable connects the topside laptops to the subsea Raspberry Pi 5. The shielding actively rejects Electromagnetic Interference (EMI) from the adjacent high-current power lines, ensuring zero packet loss or latency for our HD video and telemetry.

Pneumatic Supply & Diagnostics: Two highly flexible 6mm polyurethane (PU) hoses are integrated into the tether:

Hose 1 (Actuation): Supplies compressed air to the dual horizontal grippers via an internal T-fitting.

Hose 2 (Diagnostics & Relief): Serves a critical dual purpose. Pre-dive, we use it to apply positive pressure and submerge the ROV to check for leaks visually. Mid-dive, it acts as a vent for internal pressure buildup.

3.9.5 Tether Management Protocol:

Operating a 30-meter cable in a massive flume tank with multi-directional waves presents a severe hydrodynamic challenge. If unmanaged, the tether acts as a massive underwater sail, catching heavy currents and artificially dragging Leviathon backward. To ensure operational safety and protect the ROV from wave impacts, Atlantis strictly adheres to the following three-phase protocol:

Phase 1: Pre-Dive Setup & Connection

Inspection & Unspooling: The tether is visually inspected for damage and smoothly unspooled directly from our custom rotary cable reel (**Figure 18**). Loose coiling on the pool deck is strictly prohibited to eliminate tripping hazards.

Strict Connection Sequence (Wave Protection): When heavy waves hit the ROV, the physical force is transferred directly down the tether. To prevent this tension from ripping cables out of the electronics enclosure, mechanical strain relief is securely anchored to the ROV's aluminum frame *first*. Only after the strain relief is verified on both ends do we connect the power, Ethernet, and pneumatic lines. This guarantees the frame absorbs wave impacts, not the delicate watertight glands.

Phase 2: In-Water Operations (Harsh Environment Focus)

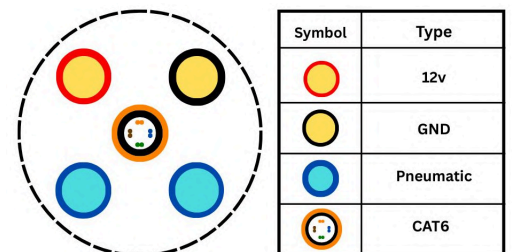


Fig. 17. Cross-sectional diagram of the tether. Diagram created by Fares Hossam.



The Dedicated Tetherman: A specific team member is designated to manage the cable for the entire dive.

Active Drag Reduction: In heavy currents, excess tether acts like a parachute, dragging the ROV backward and making delicate tasks—like aligning the PC02 connector (Task 2.5) - impossible. The Tetherman actively feeds only the exact length necessary. If the ROV stops to hold station against a wave, the Tetherman instantly pulls in the slack to minimize the cable's surface area in the current.

Neutral Buoyancy & Wave Evasion: Our tether is carefully balanced to be perfectly neutrally buoyant. This ensures it won't sink and knock over bottom props like the Coral Species (Task 1.1), nor will it float to the surface, where it would be violently whipped around by the offshore basin's surface waves.

Pilot Mitigation: The Pilot actively avoids unnecessary 360-degree rotations and maintains a safe perimeter around flume tank obstacles to prevent internal wire twisting and external tangling.

Phase 3: Post-Dive Teardown

Strict Disconnection Sequence: Once the ROV is safely surfaced and powered off, the Tetherman disconnects the topside 12V power supply first, followed by the data and pneumatic lines. The mechanical strain relief is always removed last.

Storage: The tether is immediately and evenly spooled back onto the rotary reel. This prevents kinks, twists, and tangles during transport and ensures it is perfectly prepped for the next deployment.

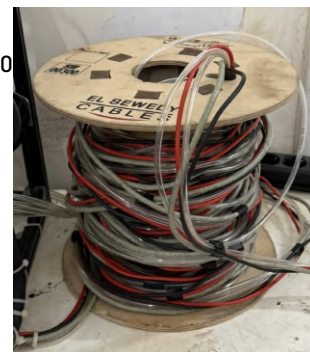


Fig. 18. Custom topside rotary cable reel. Photograph by Adam Gouda.

3.10 Control System Architecture:

Leviathon's control system is a software-based system engineered to provide stability in the turbulent flume tank, allowing the pilot to perform high-precision manipulation and station-keeping. The architecture rigidly separates safety-critical flight controls from high-level mission controls. A Pixhawk 2.4.8 flight controller handles low-level stabilization and motor output, while a Raspberry Pi 5 companion computer manages camera handling and mission logic. They communicate via the MAVLink protocol.

3.10.1 Computing Hardware & "Build vs. Buy" Justification:

High-Level Computing (Build): We custom-developed our mission software in Python. This handles sensor data processing, system coordination, and the real-time YOLO AI required for competition tasks.

Flight Controller (Buy): We chose to buy a Pixhawk 2.4.8 running ArduSub, as Underwater vehicle stabilization in multi-directional waves is a safety-critical subsystem. Using proven hardware drastically reduced our technical risk, granting us immediate access to a highly reliable IMU stabilization and configurable flight modes so we could focus our engineering efforts on mission-specific payload tools.

Future R&D (Custom Controller): While the Pixhawk is reliable, it occupies significant enclosure space. As part of our continuous R&D, Atlantis is currently designing a proprietary, highly compact flight controller. **(Figure 19)** featuring an integrated Raspberry Pi 4, onboard IMU sensors, and direct ESC connections.

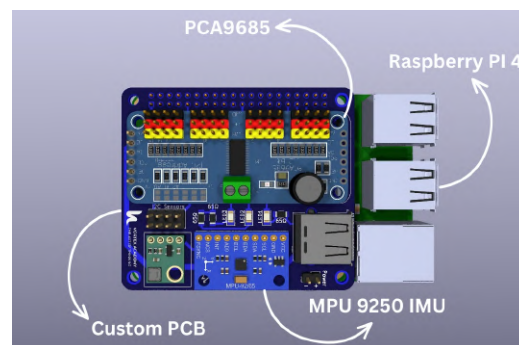


Fig.19. CAD layout of our future flight controller. Layout created by Zeyad Amr.

3.10.2 Software Architecture & Development Process:

Requirements & Task Integration: Our software requirements were derived directly from the 2026 tasks. For example, as defined in our system power budget (Table 3), running the high-torque rotary tool (Task 2.5) while fighting waves requires strict energy management. Our software actively coordinates these actions to ensure the vehicle safely maintains our calculated 24.3A maximum dynamic load, preventing blown 25A main fuses.

Development & Version Control: We manage our stack using GitHub. New features are developed on isolated branches and merged only after rigorous bench testing and in-water validation. This guarantees we always have a stable, competition-ready release on the master branch.

Advantages & Limitations: As detailed in our data flowchart (Appendix B), the primary advantage of this architecture is the physical separation of tasks. If the Raspberry Pi 5 crashes or the topside AI software freezes, the Pixhawk disarms the thrusters. This prevents the ROV from crashing into the flume tank walls, allowing the station to safely recover the vehicle.



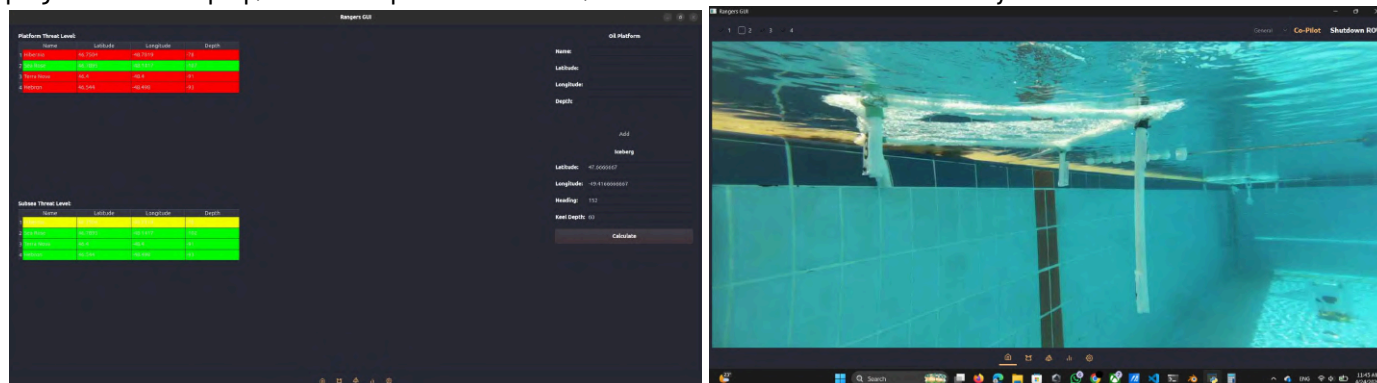
3.11 Custom Graphical User Interface(GUI):

To prevent pilot sensory overload during the strict 15-minute competition window, we developed a custom GUI (**Figures 20 & 21**) using PySide6 and Pygame. Featuring a high-contrast silver and olive green color scheme, the modular interface (separated into *main.py*, *cam.py*, and *rov.py*) prioritizes situational awareness and rapid accessibility for both the Pilot and Co-Pilot.

Advanced Video & AI Processing: The GUI seamlessly handles our four zero-latency USB camera streams. The pilot can instantly switch between individual views or display three simultaneous streams to execute complex, multi-angle tasks. Furthermore, the GUI integrates a specialized Computer Vision module that actively processes the benthic camera feed to automatically detect and count European Green Crabs (Task 1.3) using YOLO AI.

Live Telemetry & Active Safety: A real-time telemetry panel displays mission-critical data, including depth, voltage, current draw, and propulsion gain. This allows operators to monitor the electrical load and verify that the dynamic power allocation is functioning correctly. The GUI also features an integrated mission timer to pace the team and a controlled remote shutdown sequence to prevent file corruption on the onboard Pi 5.

Dynamic Role Assignment & Profiles: The software features distinct Pilot and Co-Pilot operating modes. Using our custom onboard *settings.json* architecture, pilots can instantly load individualized controller mappings and thruster inversions without rewriting hardcoded software. This GUI capability is what enables our 10-second rapid failover—if a station crashes, the pilot simply plugs into a new laptop, loads their profile via the GUI, and resumes the mission immediately.



Figs. 20 and 21. Snapshots taken from the GUI. Screenshots captured by Eyad Ashraf.

3.12 Computer Vision & Software:

To successfully perform visual tasks in a turbulent flume tank, Leviathon utilizes a highly efficient, task-specific Computer Vision (CV) strategy. We actively avoided stereo-camera or IP-camera architectures, which introduce severe latency, thermal overhead, and network bandwidth issues. Instead, we strategically distributed four zero-latency USB cameras across the ROV and implemented three distinct software pipelines tailored directly to the 2026 mission tasks.

Camera Distribution

Front Main Camera: Mounted behind a flat acrylic faceplate. Serves as the primary navigation feed and the main scientific sensor for capturing measurement and 3D reconstruction imagery.

Gripper Camera: Angled downward at the dual horizontal manipulators to provide the close-range, zero-latency visibility needed for precision tool operation.

Top-Facing Camera: Provides overhead spatial awareness, helping the pilot maintain orientation relative to the pool wall and surface station.

Benthic (Downward) Camera: Continuously observes the pool floor to supply the video stream used for AI crab detection.

1. Classical Dimensional Measurement (Tasks 1.2 & 2.2)

For estimating the length of the coral garden (**Task 1.2**) and the depth of the iceberg keel (**Task 2.2**), we use a classical pixel-ratio method rather than complex stereo triangulation. This is made possible by our flat acrylic faceplate, which eliminates the optical distortion caused by standard dome enclosures, preserving a reliable 1:1 image scale.

The Process: The pilot navigates to a parallel viewing angle and captures a high-resolution image. Our custom Python script compares the unknown target against multiple known reference points in the frame (such as the 45 cm, 25 cm, 21 cm, and 15 cm PVC segments, or the standard 1.27 cm pipe diameter). By calculating the target's size relative to *multiple* references and mathematically averaging the results, we drastically reduce perspective errors and ensure highly accurate mission measurements.



2. YOLO AI Crab Detection (Task 2.1)

To detect and count the invasive European Green Crabs along the benthic transect line (**Task 2.1**), we developed a custom YOLO (You Only Look Once) object-detection model (**Figure 22**).

Custom Training Dataset: Rather than using generic internet pictures, we trained our AI using an exclusive underwater dataset collected via Leviathon's own benthic camera. This ensured the model learned to recognize crabs under actual subsea conditions, naturally accounting for water color shift, reflections, and suspended-particle noise.

Performance: The model runs in real-time on our topside laptop, actively analyzing the benthic video feed. During validation, it achieved a mean Average Precision (mAP) of 0.937, demonstrating highly reliable detection capabilities.

3. 3D CAD Generation (Task 1.2)

To fulfill the requirement of generating a 3D CAD representation of the coral garden (**Task 1.2**), we employ the Tripo SR model using multi-image reconstruction (**Figure 23**).

The Process: Because single-view imagery cannot produce a reliable 3D model, the pilot utilizes Leviathon's flight-controller stability to carefully circle the target, capturing high-resolution images from multiple angles. The Tripo SR software processes these overlapping visual features to digitally reconstruct the geometry. This clever approach allows us to generate a highly accurate 3D CAD model using our existing, low-latency USB camera architecture, completely avoiding the cost and complexity of specialized stereo hardware.



Fig. 22. Our custom YOLO model detecting invasive crabs during training. Image captured by Ammar Abdelhakam.

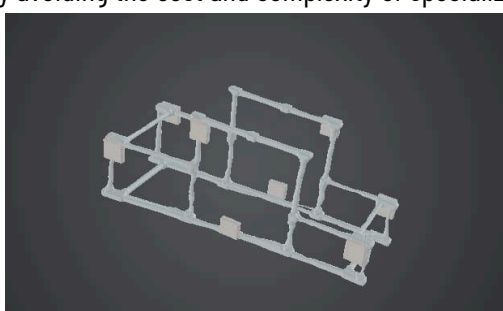


Fig. 23. Final 3D CAD model generated by the Tripo SR, constructed using multi-angle images. Model generated by Omar Shady.

3.13 Propulsion:

To conquer the extreme currents of the flume tank and execute heavy-lift tasks from the 5-meter pool depth, Leviathon utilizes an optimized six-thruster configuration (**Figure 24**). We deliberately reused six Blue Robotics T200 thrusters from our previous ROV. This decision saved \$1,380, preserving our budget for critical electrical upgrades while providing the proven brute force necessary to survive this year's harsh environment.

Placement & Mission Rationale

Horizontal Control (The 45-Degree Evolution): Last year, our planar thrusters were vectored at 60 degrees. While this prioritized fast forward and backward speeds, it left the ROV significantly weaker when moving side-to-side. This year, surviving the flume tank's multi-directional waves requires equal strength in every direction. Therefore, we shifted our four planar thrusters to a perfect 45-degree angle. This specific geometry mathematically balances our propulsion, guaranteeing equal maximum thrust for both surge (forward/backward) and sway (left/right). This true omnidirectional control is what allows Leviathon to actively fight heavy currents from any angle while holding perfectly still to align any task.

Vertical Control (2 Heave Thrusters): Two vertical thrusters manage the heave axis. By placing them far apart on our widened frame, we drastically increased the ROV's natural roll stability. This dual-vertical setup provides the massive, balanced lifting power required to haul heavy payloads—such as the waterlogged Lobster Pot (Task 2.3) and the dense legacy eDNA sensor—rapidly to the surface.

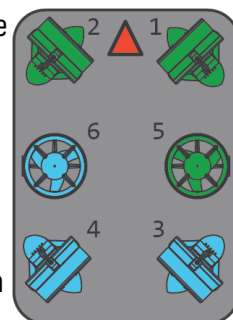


Fig. 24. Our thrusters configuration. Image retrieved from QGroundControl.

Trade-offs: Power, Cost, and Performance

Designing a propulsion system for the flume tank required balancing physical thrust against strict competition rules.

Trade-off 1: Thrust Capability vs. Power Constraints

The Problem: T200 thrusters are powerful but highly power-hungry. Running six thrusters simultaneously easily exceeds the strict 25A competition limit.

The Trade-off & Solution: We faced a choice: mechanically limit the thrusters' maximum output (which would cause us to fail heavy-lift tasks) or develop a complex software solution. We chose software. As detailed in our power calculations (**Table 3**), our Dynamic Power Allocation algorithm actively isolates the motion axes. It funnels our dedicated 240W propulsion budget *only* to the active thrusters,



successfully clamping our maximum total system draw at a safe 24.3A while still delivering maximum burst thrust when needed.

Trade-off 2: Mounting Durability vs. Weight and Fluid Dynamics

The Problem: We needed to mount the thrusters at exact 45-degree angles.

The Trade-off & Solution: CAD simulations showed that custom 3D-printed mounts were incredibly lightweight and hydrodynamically smooth. However, physical testing proved they were too brittle. Because the multi-directional waves in the flume tank threaten to violently push the ROV into the pool walls, we traded that marginal weight savings for superior impact durability. We manufactured custom-bent aluminum mounts to ensure our propulsion system survives collisions without snapping.

3.14 Buoyancy and Ballast:

To ensure absolute stability, Leviathon is engineered with a massive positive metacentric height. All heavy components (aluminum base, grippers) are mounted at the lowest possible points to lower the Center of Gravity (CG). In contrast, our flotation is mounted at the highest possible points to raise the Center of Buoyancy (CB), preventing uncontrolled pitch or roll.

Current Flotation & Empirical Tuning: For the 2026 competition configuration, Leviathon relies on high-density marine foam. To achieve perfect neutral buoyancy, we employ an empirical in-water calibration process. During pool testing, we systematically add or shave off foam volume, a highly controlled trial-and-error method—until the vehicle is perfectly suspended in the water column and balanced across all axes.

Future R&D: Calculated Displacement: Recognizing that empirical foam tuning is time-consuming, Atlantis has initiated an R&D phase to eliminate guesswork in future vehicle iterations. We are developing a modular buoyancy system utilizing 40 mm ping-pong balls. By applying Archimedes' Principle (Reference: White, F. M., Fluid Mechanics) to Leviathon's measured submerged weight, we are able to mathematically calculate the exact baseline sphere count required for neutral displacement. This calculated approach is currently undergoing validation testing to eventually replace our physical foam tuning.

3.15 Payload and Tools:

To successfully operate in the turbulent flume tank under a strict 15-minute time limit, Leviathon's payload suite is designed for absolute mechanical efficiency. We deliberately avoided over-engineering complex, multi-actuator tools. Instead, we designed fast, task-specific mechanisms that reduce pilot workload and slash task completion times.

3.15.1 Camera Rationale & Placement

Operating in multi-directional waves requires instant visual feedback. As established, we eliminated high-latency IP cameras in favor of four near-zero latency (<40ms) HD USB cameras. Their placement was strategically chosen to provide total situational awareness without overloading our data bandwidth:

Front Main Camera: Mounted centrally behind the flat acrylic faceplate. This serves as the pilot's primary navigation feed and the distortion-free scientific sensor for pixel-ratio measurements (Tasks 1.2 & 2.2).

Gripper Cameras: Mounted low and angled directly at the manipulators. This provides the crucial, close-up depth perception required for precise connector insertions (Task 2.5).

Benthic Camera: Mounted facing strictly downward. This provides a continuous feed of the pool floor to our topside YOLO AI for invasive crab counting (Task 2.1).

3.15.2 Task-Specific Payload Tools

Static Snap-Clips (Task 1.1: Basket Stars)

Mission Requirement: Rapidly secure the basket star O-balls before currents wash them away.

The Design: We designed a purely mechanical, "mouse-trap" style clip. It consists of just four laser-cut acrylic parts, two screws, and an elastic rubber band. When the ROV pushes the clip against the O-ball, the physical contact triggers the release, and the rubber band snaps the jaws permanently shut around the ball.

The Advantage: It requires zero electrical actuation, costs less than \$2 per unit, and secures the prop in less than one second. We mounted two of these on the ROV to grab both basket stars in a single run.

Buoy Anchor Release System (Task 2.4)

Mission Requirement: Recover the buoy anchor to the surface.

The Design: We scaled up our acrylic snap-clip design to replace an old, commercial metal hook. The old metal hook had a stiff spring that was incredibly difficult to push open underwater. Our new custom clip snaps instantly upon contact. We attached this clip to a retrieval cable spooled around a piece of highly buoyant foam.

The Advantage: Once the ROV snaps the clip onto the anchor, the foam spool is released. It floats to the surface on its own in seconds, allowing the topside team to quickly haul in the anchor for an easy 15 points, completely freeing the ROV to move on to the next task.

Biofouling Rotary Tool (Task 2.5: Observatory Camera)



*Fig. 25. Static Snap-Clips.
Photograph by Omar ElMasry.*



Mission Requirement: Perform three full, unidirectional rotations to clean the observatory camera.

The Design: (Reference Figure 15). The tool consists of a high-torque 12V DC motor. The motor's metal shaft is securely linked via a copper coupler to a custom, two-pronged fork made from standard PVC pipe.

The Advantage: The pilot navigates until the PVC fork slides over the observatory's handle and powers the motor. The wide PVC fork positively engages the handle without slipping, safely executing the three rotations in seconds without pushing the ROV backward.

3.15.3 Sensor Integration

To meet the flume tank's mission requirements, we strictly limited our sensor suite to the two devices that actually improve vehicle handling in waves:

Bar30 Pressure Sensor: Provides the highly accurate depth telemetry required for the Pixhawk to execute "Depth Hold" mode, allowing stable, horizontal-only flight during transects.

Pixhawk IMU: The internal Inertial Measurement Unit provides the rapid pitch and roll data necessary for the flight controller to auto-stabilize the ROV when struck by multi-directional waves.

3.16 Build vs. Buy & Component Lifecycle:

To survive the extreme conditions of the flume tank while maximizing our operational budget, every component on Leviathon was evaluated through a rigorous resource allocation matrix.

New vs. Reused Decisions

We minimized e-waste and preserved our financial budget by reusing 70% of the hardware from our previous ROV, Kratos.

The "Reused" Strategy: We inherited our six T200 thrusters, the Pixhawk flight controller, aluminum extrusions, and our primary watertight enclosures. These specific components were chosen for reuse because their proven durability easily meets the heavy-lift and high-current demands of this year's wave pool, saving us over \$1,380.

The "New" Investment (Raspberry Pi 5 Justification): Our primary "New" investment was upgrading our main computer from a Raspberry Pi 4 to a Pi 5. The strict engineering justification for this upgrade lies in the USB architecture. The Pi 4 shares a single internal bus for all USB ports; when attempting to stream four cameras, it bottlenecks the bandwidth, causing severe latency and dropped frames. In a wave pool, a dropped frame means missing a critical grab. The Pi 5 features dedicated, separated USB bandwidth controllers. This hardware upgrade is the definitive factor that allows us to stream four zero-latency HD cameras, run real-time YOLO AI (Task 2.1), and process multi-image 3D CAD generation (Task 1.2) simultaneously without crashing.

The "Buy" Decisions

We deliberately bought highly complex, standardized commercial-off-the-shelf (COTS) components, such as the Blue Robotics thrusters and the Pixhawk controller.

Mission Link: Building a custom flight controller or thruster from scratch requires immense R&D and introduces a high risk of failure in the water. Buying these safety-critical systems saved hundreds of development hours, ensured core vehicle reliability in the multi-directional waves, and freed our software team to focus entirely on our dynamic power and computer vision innovations.

The "Build" Decisions

HDPE Manipulators (Tasks 1.1, 2.3, 2.5): Commercial underwater grippers are incredibly expensive and generally use standard parallel jaws. We built our own pneumatic HDPE manipulators because we needed custom, specialized geometries (like our 45-degree angled gripper) designed specifically to interface with this year's PVC competition props.

Hydrofoil Thruster Guards: Standard commercial thruster guards use flat 2D plates that choke water flow. We 3D-printed custom hydrofoil meshes to eliminate boundary-layer drag, achieving a hydrodynamic efficiency that commercial plates cannot provide.

3.17 Autonomous Float System "Crystal":

For the 2026 season, we completely redesigned our standalone active buoyancy float, Crystal (**Figure 26**). By replacing the heavy pneumatic piston with a dual-pump bladder system, we drastically reduced the float's footprint while improving its operational range.

Physical Upgrades & Capacity

Size & Weight: We reduced the overall height from 70 cm to 28 cm, and cut the weight down from 17 kg to a highly portable 4 kg

Water Intake: Despite the smaller size, the new bladder system doubled our capacity from 150 ml to 300 ml.

Buoyancy Control: This expands our variable density range (0.92 to 1.07), allowing Crystal to transition easily between positive, neutral, and negative buoyancy.

Electrical Architecture

Independent System: Crystal operates entirely independent of Leviathon, powered by its own onboard 12V battery.



Custom Electronics: The system is controlled by an ESP32 microcontroller mounted on a custom PCB.

Power Management: We designed a custom MOSFET switching circuit to safely handle the high current demands of the two 12V water pumps (one for intake/descent, one for drain/ascent).

Depth Control Strategy & Efficiency

Telemetry: The ESP32 continuously reads a Bar30 pressure sensor for high-resolution depth data.

Low-Speed Control: To manage buoyancy, we utilize a simplified, highly controlled approach. By running the pumps at a very low speed during vertical transitions, we prevent depth overshooting.

Competition Compliance: This slow-speed adjustment allows us to successfully maintain a stable depth hold within the required 66 cm range, perfectly adhering to competition rules.

Efficiency: This active buoyancy method is significantly more energy-efficient than using continuous vertical motor thrust, saving battery life for the duration of the mission.

4.0 Safety

4.1 Safety Philosophy & Culture At Atlantis, safety is a core value embedded in every aspect of our engineering cycle. Our philosophy is simple: protect people, preserve equipment, and ensure reliable operations. By adhering to industry best practices and MATE ROV competition regulations, we foster a culture of accountability where every team member is empowered to identify hazards and propose immediate mitigations.

4.2 Training & Lab Protocols To ensure a uniformly high level of safety awareness, all members complete a structured safety training program before interacting with Leviathon.

Inductions & Drills: Members undergo rigorous inductions covering lab rules, emergency protocols, and the proper use of Personal Protective Equipment (PPE) (**Figure 27**).

Supervised Operations: We enforce a strict "No Solo Operation" rule; no member may operate power tools or conduct live electrical testing alone.

Jobsite Safety and Environmental Analysis (JSEA): Before major manufacturing tasks, members Conduct a JSEA to assess potential risks (e.g., electrical shorts, entanglement) and define immediate mitigation strategies.

4.3 Task-Specific Vehicle Safety Features Leviathon was engineered to mitigate operational hazards inherently, with physical safety features designed specifically to protect the ROV during this year's mission tasks:

Electrical Protection: To strictly comply with Ranger class specifications, a primary 25A inline fuse is installed within 30 cm of the surface power supply. Furthermore, our custom Overvoltage "Crowbar" PCB instantly shorts and blows the logic fuse if a dangerous voltage spike occurs. This is specifically critical during heavy-load operations, such as hauling the waterlogged Lobster Pot (**Task 2.3**), where sudden motor stalls in the heavy flume currents could otherwise fry the microcontrollers.

Thruster Guards: Protective 3D-printed hydrodynamic meshes (**Figure 28**) encompass all six T200 thrusters, strictly complying with the IP20 standard (blocking objects larger than 12.5 mm). This ensures fingers remain safe poolside and completely prevents tether entanglement when the ROV is fighting multi-directional waves.

Mechanical & Pneumatic Safety: Leviathon's aluminum extrusion frame was manually deburred to eliminate sharp edges, and exposed bolt threads are capped to prevent snagged tethers. Additionally, the pneumatic payload system uses a strict pressure regulator. This prevents hose bursts and ensures a safe, controlled clamping force so the grippers do not crush delicate mission items like the Coral Species (**Task 1.1**).

4.4 Warning Labels & Operational Task Protocols High-visibility warning labels are applied to critical components to identify pinch points on the HDPE grippers, high-voltage junctions, and spinning thruster guards. During pool deployment, the topside station is secured away from moisture, cables are routed under high-traction rubber mats, and a closed-loop communication protocol is strictly maintained.

Task-Specific Operational Safety: We adapt our driving protocols directly to the environmental risks of the tasks. For example, during the coral imaging and 3D modeling (**Task 1.2**), the pilot actively switches the ROV to a "minimum-gain" flight mode. This deliberate



Fig. 26. Crystal. Photograph by Eyad Ashraf.

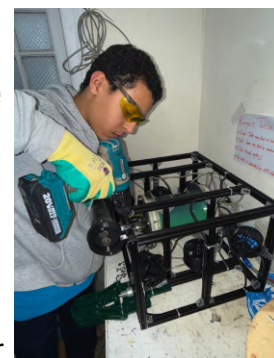


Fig.27. Mohamed elsayed adhering to mandatory PPE protocols.



Fig. 28. Thruster guards. Photograph by Habiba Ahmed.



safety protocol prevents violent thruster wash from disturbing the physical PVC props or kicking up benthic debris that would blind the cameras.

Pre-Dive Tool Inspections: To guarantee both safety and task readiness, the ROV is never armed until the Tetherman verbally confirms the water is clear. Furthermore, we have updated our [*\(mandatory Construction and Operational Safety Checklists are provided in Appendix E\)*](#) to include strict, task-specific tool inspections before every dive:

Pneumatic Grippers: Verify pressure gauge readings, confirm the regulator set point, and inspect total hose integrity to prevent underwater air leaks.

Rotary Tool: Confirm engagement clearance and perform a dry free-rotation test to ensure the motor is not jammed.

Crystal Float: Conduct a dedicated pump function test and bladder leak check before initiating any autonomous deployment sequences under the ice.

4.5 Harsh Environment Personnel Safety Operating Leviathon at world-class marine research facilities requires strict personnel safety measures adapted for extreme physical conditions. The flume tank and offshore wave basin present severe slipping hazards due to heavy currents and continuous splashing on the pool deck. To mitigate these risks, all team members operating near the water's edge must wear high-traction, non-slip waterproof footwear. Furthermore, any member handling the tether or physically deploying the ROV into these turbulent zones is required to wear an approved personal flotation device, ensuring immediate buoyancy in the event of an accidental fall into the high-velocity water. The Ice Tank facility introduces severe cold-exposure risks during our autonomous float deployment task. To protect our personnel from hypothermia and frostbite, Atlantis enforces a strict thermal dress code for this specific environment. Members must wear heavy insulated clothing, including thermal base layers, windproof winter coats, and water-resistant insulated gloves. This specialized clothing guarantees that the team can safely and comfortably remain focused on executing the under-ice mission without suffering from physical fatigue, loss of dexterity, or numbness caused by the freezing temperatures.

5.0 Critical Analysis: Testing & Troubleshooting

To guarantee vehicle reliability, Atlantis enforces a strict "isolate before integration" philosophy. By verifying every component independently before it joins the broader ROV network, we prevent cascading failures and resolve technical challenges rapidly.

5.1 Evaluating Design Options via Prototyping

(Rubric: Described use of prototyping and testing to evaluate design options) We utilize a phased prototyping approach to evaluate design viability cheaply and quickly before committing to final manufacturing.

Mechanical Evaluation (Oball Tool): We created our first Oball recovery tool prototype out of inexpensive wood. Testing revealed the scale was incorrect and the fixation holes were misaligned. We iterated a second wooden prototype with corrected dimensions. Only after this physical validation was successful did we manufacture the final tool from our primary, more expensive material.

Electrical Evaluation (Safety Circuit): For our custom overvoltage protection circuit, we first built and tested the logic on a standard breadboard. After validating the concept, we designed and printed a custom PCB. We tested this PCB independently on a dry bench to ensure it worked perfectly before allowing it to interface with the ROV's main power system.

5.2 Vehicle Testing Methodology

Phase 1: Dry Testing (Workshop & Lab)

Electrical & Software Validation: Using multimeters, we independently test every PCB trace for continuity and isolation before applying power. We then utilize QGroundControl for Hardware-in-the-Loop (HIL) simulations, validating software and sensor synchronization before the vehicle touches water.

Structural & Safety Testing: We conduct repetitive stress testing on the ROV frame to ensure no components fail under operational load. For safety compliance, we test our custom thruster guards using an industry-standard IP20 probe pen to guarantee that a human finger (or ROV assistant) cannot physically touch the propellers.

"Divide and Conquer" Integration: We fully wire, power, and stress-test the entire propulsion network (custom PCB, ESCs, and thrusters) on a dry bench **(Figure 29)** before permanently mounting them inside the watertight enclosure.

Phase 2: Wet Testing (Pool Environment)

Sealing & Pressure: We conduct shallow-water tests at the side of the pool. We submerge the main enclosure just below the surface to safely inspect for micro-leaks before attempting any deep-water dives.

Buoyancy Calibration: We achieve neutral buoyancy through systematic in-water trial and error. We add foam when the ROV sinks too fast and remove

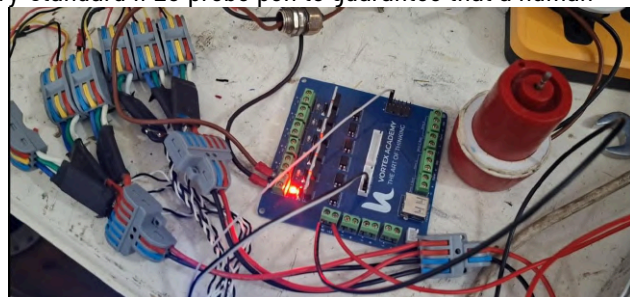


Fig. 29. Propulsion and manipulators testing before creating the internal structure.

foam when it floats. We repeat this process until the vehicle is perfectly suspended in the water column.

5.3 Troubleshooting Strategies & Practical Application

Example 1: Pre-Deployment ESC Failure. If a T200 thruster fails to spin, we execute our domain-specific fault tree:

Mechanical: Inspect the Cobalt bulkhead connectors and cable glands to ensure they are fully seated.

Electrical: Visually verify main power and signal cables. Use a multimeter to confirm 12V reaches the ESC, the PWM signal is present, and the 3-phase output pins show proper continuity.

Software: Check QGroundControl to ensure the ESC servo pins are correctly mapped and receiving the arming command. *(If the fault persists, we extract the ESC and test it on a bench supply with an external PWM generator.)*

Example 2: Post-Regional Power Shutdown (Raspberry Pi 5) During a post-regional pool test, pushing the ROV to 100% thruster gain caused the Raspberry Pi 5 to suddenly shut down, resulting in total loss of control.

Diagnosis: We used an oscilloscope to measure system-wide voltages and currents. We discovered that spiking the thruster gain from 0% to 100% instantly caused a massive input voltage drop at the buck converter. This forced the buck converter's output below 4.7V, killing power to the Pi.

Hardware Solution: We integrated a buck-boost converter. This ensures that even during high-current thruster spikes, the input voltage to the buck converter never drops below 12V, keeping the final output to the Pi perfectly stable.

Software Solution: We reprogrammed the software to ramp the thruster gain gradually rather than jumping instantly, smoothing out the current draw.

Lesson Learned: This taught us that correct wiring is not enough; we must thoroughly analyze every subsystem under peak load using advanced diagnostic tools (like oscilloscopes) to catch dynamic voltage drops

6.0 Budget & Cost Accounting

6.1 Financial Planning & Travel Budget:

To ensure absolute transparency and effective resource management, Atlantis developed a comprehensive 2026 budget baselined against historical costs from our previous ROV, *Kratos*. All departmental purchase requests are subject to a strict approval workflow evaluated by the company CFO and Vortex Academy mentors to guarantee necessity and cost-effectiveness. Furthermore, our finance team developed meticulous travel expense estimates to deploy a specialized 10-member operational team to the MATE World Championship in St. John's, Canada. We established a strict baseline travel budget of **\$28,328 USD**, which serves as our primary corporate fundraising target. This estimate covers international round-trip flights from Alexandria, Egypt (**\$10,420**), cost-effective residential lodging (**\$6,320**), local van rentals for ROV transport (**\$2,708**), visa processing, and team per diems. A fully itemized breakdown of these travel logistics is provided in **Table 4** below.

6.2 Cashbook Accounting & Resource Management:

Atlantis utilizes a centralized Cashbook tracking system to log every project expenditure, ensuring real-time budget monitoring and financial accountability. To demonstrate sustainable resource management, our Cashbook strictly categorizes every item into one of three classifications: New (Purchased), Reused, or Donated. As detailed in our Build vs. Buy analysis (**Section 3.16**), our most effective use of funds was the strategic reuse of over 70% of *Kratos*'s hardware (including six T200 thrusters and the Pixhawk), which saved thousands of dollars. This allowed us to reallocate capital toward critical new purchases, such as the Raspberry Pi 5. All revenue streams, including team dues and corporate sponsorships, are fully acknowledged in our financial ledgers. For in-kind donations (such as access to CAD software), we calculated a reasonable Fair Market Value (FMV) of **\$60.00 USD** based on standard commercial rates.

2026 Financial Summary (USD)

To demonstrate effective resource management, our strict reuse of components allowed us to execute this project for a fraction of its total market value while maintaining a positive cash flow.

Table 4: Travel Budget Breakdown:

Expense Category	Description	Qty	Unit Cost (USD)	Total Cost (USD)
Visas	Canadian Visa fees	10	\$148.00	\$1,480.00
Flight tickets	Round-trip airfare	10	\$1,042.00	\$10,420.00
Local Transportation	7-day passenger van rental for the team and ROV transport	2	\$1,354.00	\$2,708.00
Accommodation	7-day residential house rental for 10 members	1	\$6,320.00	\$6,320.00
Per Diem / Stipend	Weekly pocket money and meal allowance	10	\$740.00	\$7,400.00
TOTAL TRAVEL BUDGET				\$28,328.00

Project Costs & Savings:

Total Project Value (If built from scratch): \$5,519.80

Total Savings (Reused Parts + In-Kind Software): -\$2,532.00

Actual Cash Spent (Build + Logistics + Fees): \$2,987.80

Project Income & Net Result:

Total Cash Income (Self-Funds from Team): \$3,700.00

Net Cash Surplus: +\$712.20.

A comprehensive breakdown of our Profit & Loss sheet, Fair Market Value estimates, and categorized component expenses is available in **Appendix F: Project Budget & Costing Sheets**.

7.0 References:

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8.0 Acknowledgements:

Atlantis extends our deepest gratitude to the MATE Center, MATE II, and AASTMT (Arab Academy for Science, Technology & Maritime Transport) for organizing this incredible platform and hosting our regional competition. We owe a special, profound thanks to the Marine Technology Society (MTS) and the esteemed international sponsors of the MATE ROV competition. Without the visionary financial and operational support of MTS, Fugro, and the dedicated judges and volunteers, the global advancement of student-led marine robotics would not be possible. We are honored to recognize their contributions below.

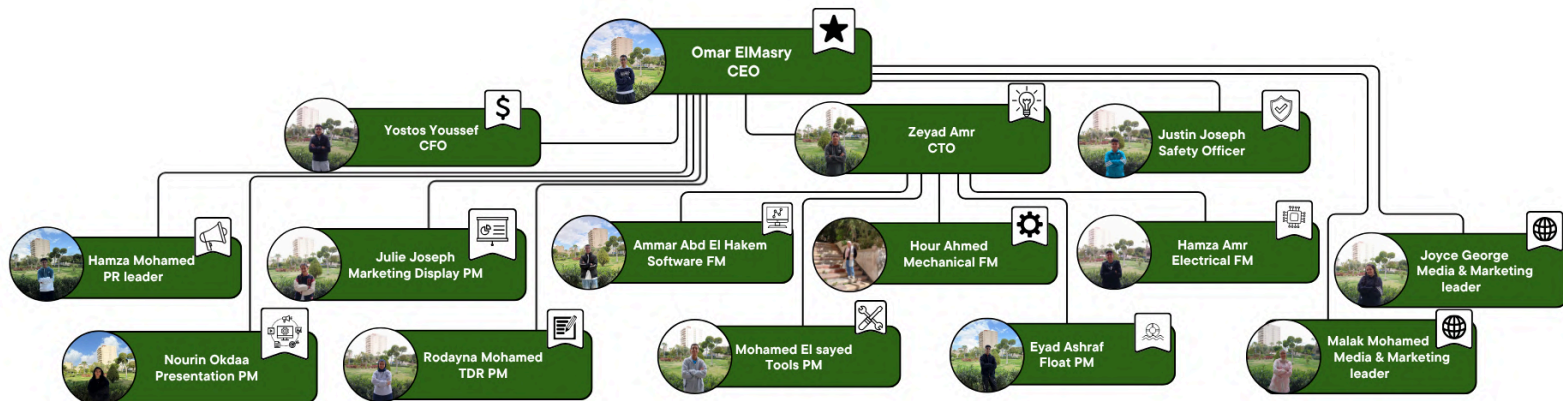


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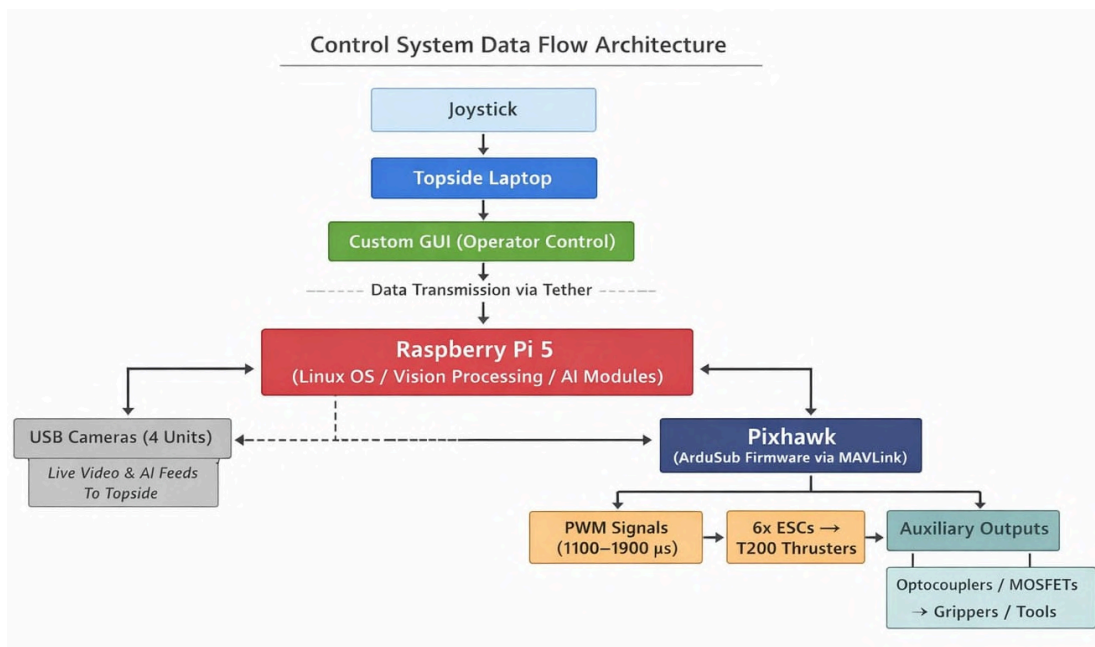
Our sincere appreciation also goes to Vortex Academy and our esteemed mentors for their unwavering technical guidance and moral support throughout the 2026 season. We are equally grateful to our families, friends, and the dedicated members of Atlantis for their steadfast encouragement. Finally, we acknowledge the pivotal resources and corporate partners that made *Leviathon* a reality. We also thank our hardware and software enablers: Blue Robotics, the Raspberry Pi Foundation, and Pixhawk for their cutting-edge components; Google Colab for supplying the GPU compute power required to train our custom deep learning models; and SolidWorks, Ansys, GitHub, and VS Code.

9.0 Appendices:

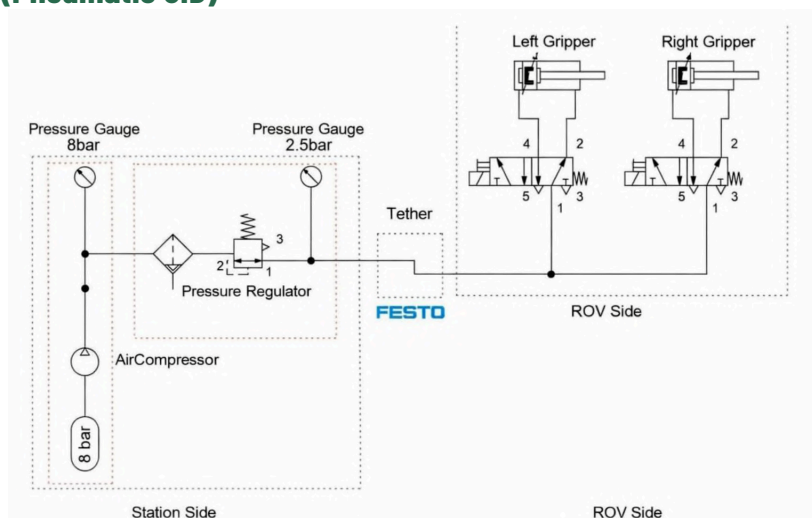
9.1 Appendix A (Hierarchy Chart)



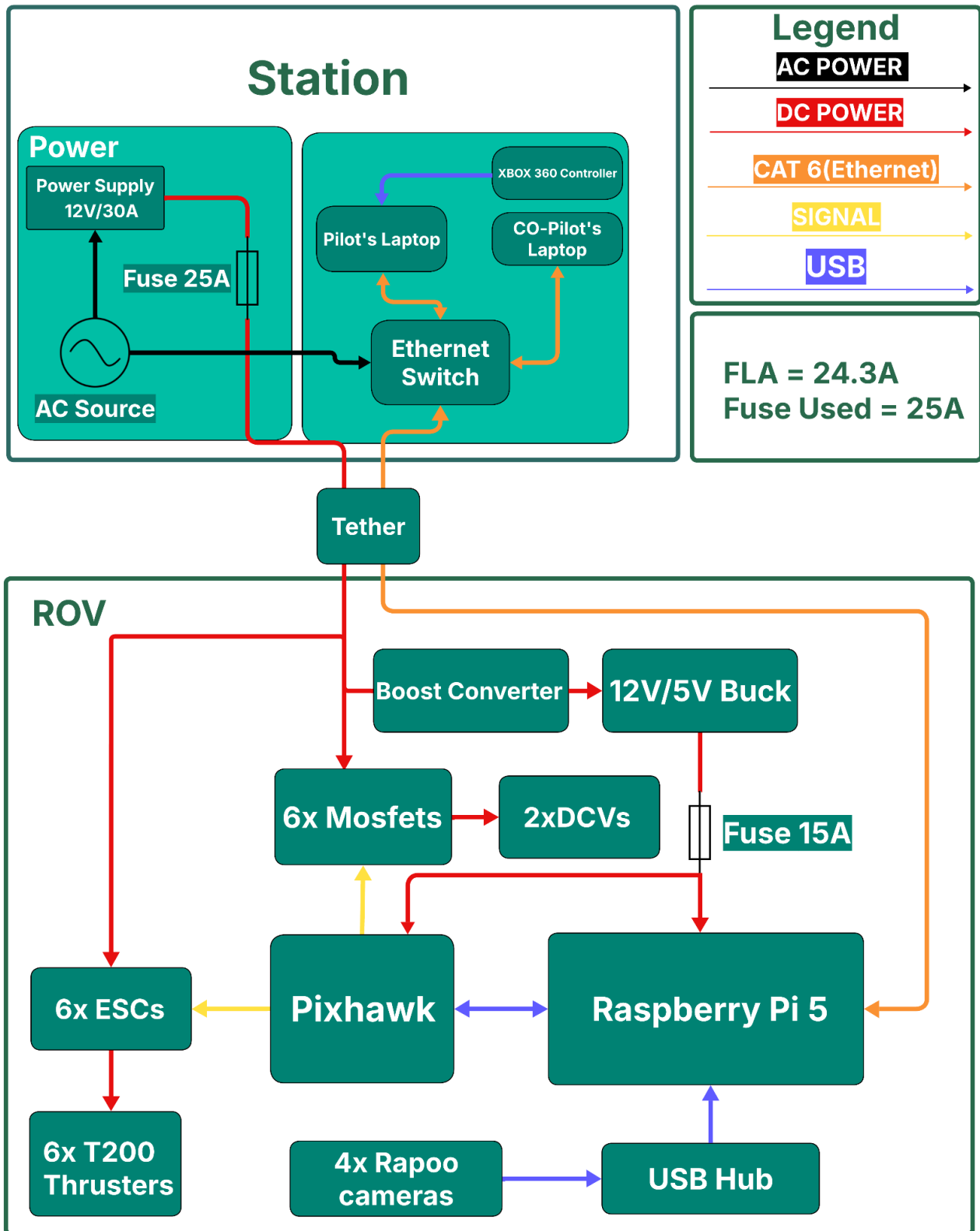
9.2 Appendix B (Software Flowchart)



9.3 Appendix C (Pneumatic SID)



9.3 Appendix D (Leviathon SID)





9.6 Appendix E (Safety Checklists)

Procedure	check Mark
• Environmental & PPE	
Footwear: Wear non-slip, closed-toe footwear at all times, especially on wet or icy decks.	
Ice Tank Gear: Wear thermal base layers, windproof coats, and water-resistant insulated gloves.	
Turbulent Water: Wear an approved personal flotation device (PFD) during deployment.	
No Solo Rule: Never operate alone near the ice tank edge, active pools, or machinery.	
• High-Pressure Systems	
Eye Protection: Wear safety goggles during all pneumatic pressurization steps	
Safe Limits: Set regulator to a maximum of 2.75 bar. Pressurize slowly in quarter-turn	
Leak Testing: Apply soapy water to 6mm PU hoses and fittings; verify no bubbles at 2.5 bar.	
Disconnection: Fully depressurize the system (gauge reads 0 bar) before removing lines.	
• Sealing & Waterproofing	
Strain Relief: Connect mechanical strain relief to the frame <i>before</i> any electrical or pneumatic lines.	
Integrity Check: Verify all cable glands are hand-tight and O-rings are lightly lubricated and seated.	
Bubble Test: Apply positive pressure, submerge ROV/Float to 30 cm for 60 seconds, and inspect for leaks	
Thrusters: Confirm all guards are securely installed (IP20 test) and clear of obstructions	
• Electrical Isolation	
Bench Checks: Test all PCB traces for continuity and verify optocoupler isolation before live testing.	
Fusing: Confirm the 15A logic fuse and 25A main fuse are properly rated and seated safely.	
No Live Water Connections: Ensure the ROV is completely powered OFF before making any connections.	
• Ice Tank & Autonomous Deployments	
Failsafe Tether: Always attach a manual tether line to the Crystal Float before autonomous drops	
Pre-Drop Status: Verify onboard 12V battery is $\geq 11.5V$ and the depth sensor reads 0.0 m.	
Active Monitoring: Monitor ESP32 telemetry continuously; retrieve immediately if depth hold fails.	
Ice Removal: Rinse the hull with fresh water to clear ice residue before inspecting seals post-recovery	
• Emergency Recovery & Post-Dive	
Comms Loss: Pilot calls "Comms Loss." Topside immediately switches OFF the 12V power supply	
Manual Retrieval: Tetherman retrieves the vehicle slowly and steadily by hand	
Safe Disconnect: Disconnect Ethernet and pneumatics first. Remove mechanical strain relief <i>last</i> .	
Immediate Inspection: Inspect all cable glands and O-ring faces for water ingress the moment the ROV clears the water.	





9.7 Appendix F (Budget Sheet)

Category	Type	Description	Projected Cost	Cash Spent
Income	Cash	Self-Funds from Team Members	\$3,700.00	+ \$3,700.00
	Donation	SolidWorks Student Edition License (FMV)	\$60.00	\$0.00
Operations & Logistics	Purchased	Internal Logistics & Training Villa	\$930.00	\$930.00
	Purchased	Regional Registration Fee (9,000 EGP)	\$187.50	\$187.50
	Purchased	International Registration Fee	\$270.00	\$270.00
Tether	Purchased	Power Cable (30 Meters)	\$45.30	\$45.30
	Re-used	Pneumatic Cables (32 Meters)	\$22.30	\$0.00
	Re-used	Cat 6 (30 Meters)	\$45.60	\$0.00
	Re-used	Anderson Connector	\$19.00	\$0.00
Electronics	Purchased	ESCs (6 Units)	\$240.00	\$240.00
	Purchased	Main PCB	\$62.50	\$62.50
	Re-used	Raspberry Pi 5	\$104.00	\$0.00
	Re-used	Pixhawk	\$193.00	\$0.00
	Purchased	Rapoo Cams (4 Units)	\$80.00	\$80.00
	Purchased	Buck Converter	\$4.00	\$4.00
	Re-used	Bilge Pump	\$60.00	\$0.00
	Re-used	Power Supply 30A	\$82.00	\$0.00
	Purchased	Bar30 Pressure Sensor	\$85.00	\$85.00
	Re-used	Materials & Fabrication	\$63.50	\$0.00
Float Engine	Re-used	ESP32	\$11.60	\$0.00
	Purchased	Pumps (2 Units)	\$12.00	\$12.00
	Purchased	Bar30 Pressure Sensor	\$85.00	\$85.00
	Purchased	PCB	\$33.30	\$33.30
	Purchased	Batteries	\$52.00	\$52.00
Hardware	Re-used	Main Enclosure Material (PMMA & PA type 6)	\$190.00	\$0.00
	Re-used	Camera Box (Face Seal)	\$80.00	\$0.00
	Re-used	Camera Box (Piston Seal)	\$35.00	\$0.00
	Purchased	Grippers Material (PMMA)	\$41.00	\$41.00
	Purchased	Grippers Manufacturing (Laser-Cutting)	\$29.00	\$29.00
	Purchased	Aluminum Extrusion	\$112.00	\$112.00
	Re-used	Agro Glands (22 Units)	\$100.00	\$0.00
	Purchased	O-Rings	\$5.60	\$5.60
	Re-used	DCVs (2 Units)	\$51.00	\$0.00
	Re-used	Pneumatic Piston, fittings	\$90.00	\$0.00
	Purchased	Bolts & Nuts	\$70.00	\$70.00
	Purchased	3D Printed Parts	\$152.00	\$152.00
	Re-used	T200 Motors (6 Units)	\$1,200.00	\$0.00
	Re-used	Compressor	\$135.00	\$0.00
Customs	Purchased	Customs & Shipping for Imported Items	\$465.00	\$465.00
		Total Savings (Reused Parts)	-\$2,532.00	
		Total Cash Income (Self-Funds)		\$3,700.00
		Total Cash Spent (Build + Logistics + Fees)		-\$2,987.80
		NET CASH SURPLUS		+\$712.20

