

OVERFLOW ROBOTICS

ALEXANDRIA , EGYPT EST . 2021

OVERFLOW ROBOTICS Inc.



TECHNICAL DOCUMENTATION

ELECTRICAL

- 26 Omar Shahin // CFO
- 26 Youssef Wael // Hardware CTO
- 29 Lama Amir // Pcb Designer
- 26 Shady Mohamed // Float Engineer
- 28 Yassin Mohamed // Float Engineer
- 27 Omar Ahmed // Pcb Designer
- 27 Saif Mohamed // Pcb Welder
- 27 Khalid Walid // Float Engineer
- 26 Omar Helal // Troubleshooting Specialist
- 26 Yassin El-sharkasy // Troubleshooting Specialist

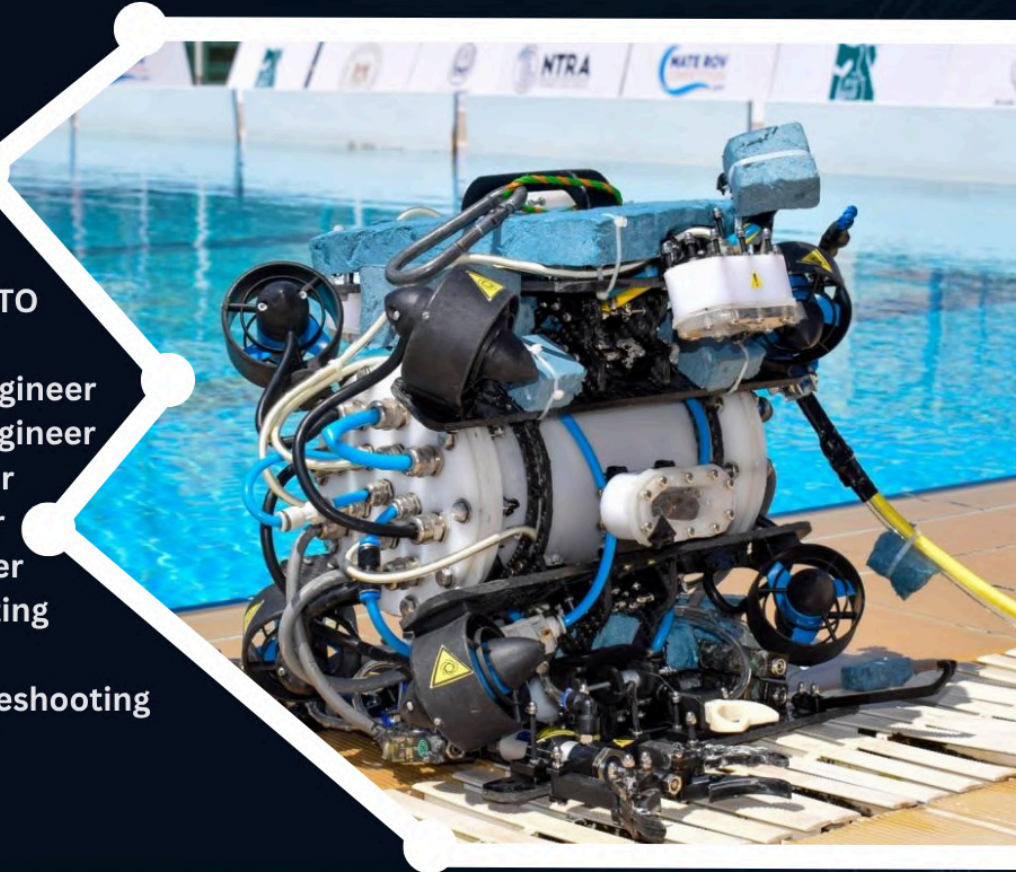
MECHANICAL

- 26 Baraa Gomaa // CEO
- 26 Mohamed Seddik // Mechanical CTO
- 27 Fagr El- hawary // Doc Lead
- 27 Moez El-din // Cad Designer
- 29 Farida Gomaa // Cad Designer
- 27 Abdelrahman Ahmed // Fabricator
- 27 Youssef Raslan // Cad Designer
- 26 Eyad Mohamed // Fabricator
- 26 Ahmed Ghazy // Fabricator
- 27 Adam El-shenawy // Fabricator
- 27 Farouk El-shenawy // Simulation Specialist

MENTORS

- 26 Ahmed Amr
- 26 Ezz El-din

****Numbers Indicate Graduation Year**



SOFTWARE

- 26 Youssef Karim // Software CTO
- 26 Marwan El-megharbel // Backend Developer
- 26 Jolie Islam // Backend Developer
- 26 Mariam Emad // Image Processing Specialist
- 27 Nour Awadallah // Backend Developer
- 26 Mohamed Ahmed // Float Engineer
- 26 Ahmed Osama // Backend Developer
- 26 Mohamed Walid // Float Engineer
- 26 Eyad El-zayat // Image Processing Specialist
- 27 Mohamed Montasser // Backend Developer

ENCORE



OVERFLOW
ROBOTICS

IN SEARCH OF PERFECTION



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1.0 Abstract

Driven by five years of competitive evolution, Overflow Robotics' 31-member team developed **Encore**: a 7.60 kg ROV designed for the 2026 MATE offshore mission. Our engineering philosophy prioritized quantifiable reliability, keeping the project 13.1% under budget at a \$6,470 total value. We replaced traditional layouts with an eight-thruster propulsion system, yielding a 38% boost in vertical speed, and secured stability using a 2,300 cm³ foam correction. This achieved a +0.29 N neutral buoyancy, reconciling our 94.44 N buoyant force validated against pool-measured neutral buoyancy results. We tackled single points of failure by redesigning our electronics into three custom PCBs, slashing potential repair costs by 75%. To bridge the gap between pilot and machine, **Encore** utilizes an NVIDIA Jetson Orin Nano Super to run YOLO-based crab detection and SLAM-based 3D mapping for actionable visual intelligence. Task execution is handled by three pneumatic manipulators, three mission-specific tools, and an airbag retrieval system. However, **Encore's** true strength lies in safety and preparation. Guided by our Triple-Zero Initiative, 6 incidents were resolved with 0 recurrences. Forged through 60 pool sessions and 700 hours of sub-surface testing, we entered the competition with a 100% resolution rate for all identified system bugs. **Encore** demonstrates a deliberate shift toward high-efficiency, test-driven underwater system design.



Fig 1: Overflow Robotics company 31 member, Alexandria Egypt 2026

2.0 Teamwork & Project Management

A. Management Structure, Planning, & Team Responsibilities

Overflow Robotics managed the 2026 ROV project using a centralized project management system to coordinate a 31-member multidisciplinary team (Refer to home page for personnel). The team was structured into specialized sub-teams with clearly defined responsibilities to ensure accountability and efficient execution (Refer to Fig 2).

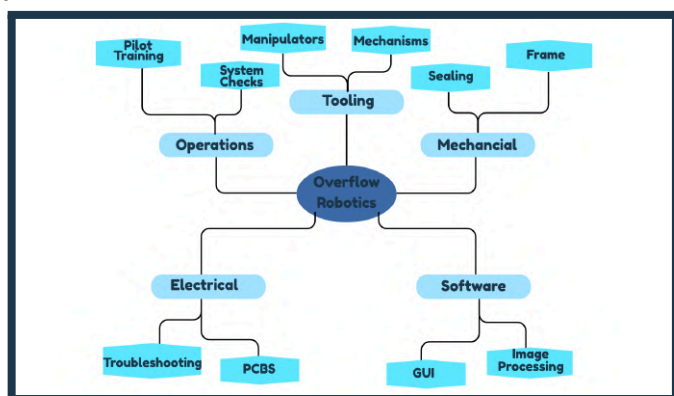


Fig 2: Overflow Robotics Sub-Team Tree

- **Mechanical Sub-Team:** Responsible for frame design, buoyancy configuration, structural analysis, and integration of propulsion and tooling systems.
- **Electrical Sub-Team:** Responsible for power distribution, wiring, sealing, safety systems, and electrical reliability under submerged conditions.
- **Software and Controls Sub-Team:** Responsible for vehicle control logic, sensor integration, pilot interface development, and system responsiveness.
- **Tooling Sub-Team:** Responsible for the design, fabrication, and testing of mission-specific end-effectors and manipulators.
- **Operations Sub-Team:** Responsible for pilot training, mission planning, system checks, and operational procedures during testing and competition runs.

B. Project Management, Communication & Risk Control

Overflow Robotics established a centralized **Notion Workspace** (Figure 3) to serve as the company's digital headquarters. This environment integrated the **Sub-Team Tree** (Figure 2) with a rigorous project timeline, breaking the season into five phases: concept development, prototyping, integration, testing, and refinement.

By assigning clear task ownership and measurable checkpoints within Notion, (Refer to Figure 3 for **Notion dashboard**) The team maintained the "In Search of Perfection" philosophy, successfully hitting the critical milestone of **full in-water deployment before January** and ensuring all deliverables were submitted on schedule.

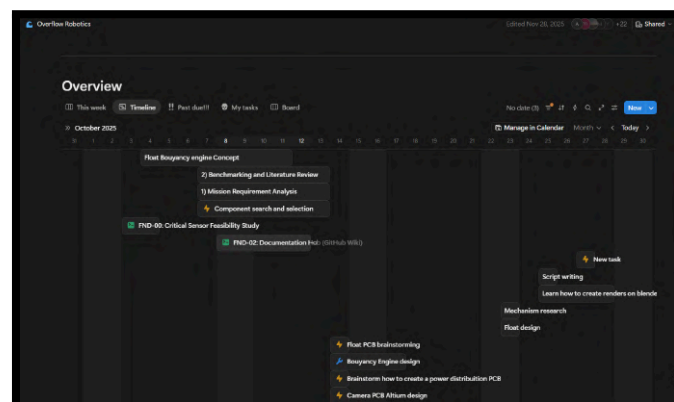


Fig 3: Notion Team Timeline Dashboard

Operational stability was sustained through a three-tiered communication and documentation framework:

- **Real-Time Coordination:** A **WhatsApp community** enabled rapid-response troubleshooting and time-sensitive cross-team agility.
- **Technical Repository:** A shared, version-controlled **Google Drive** housed all CAD models, electrical schematics, and software repositories, ensuring documentation integrity.
- **Formal Accountability:** Official team email accounts were used for all external correspondence and competition-related record keeping.

Effort distribution was monitored via **Sub-Team Man-Hour Tracking** (Figure 4), allowing leadership to balance technical progress with project stability. A total of 4821 man hours were spent distributed as follows:

- **Mechanical:** 2100 hours
- **Software:** 1439 hours
- **Hardware:** 1282 hours

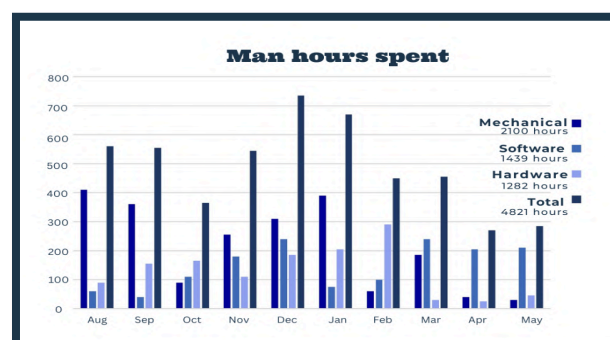


Fig 4: Sub Team Man Hour Tracking Graph

This data-driven approach extended to **Risk Control**, where potential failures such as water ingress, electrical faults, and schedule compression were tracked from the design phase. We mitigated these through modular architecture and early subsystem validation, a process visualized in our **Task Completion Graph (Figure 5)**, which demonstrates consistent progress and successful risk reduction throughout the development cycle.

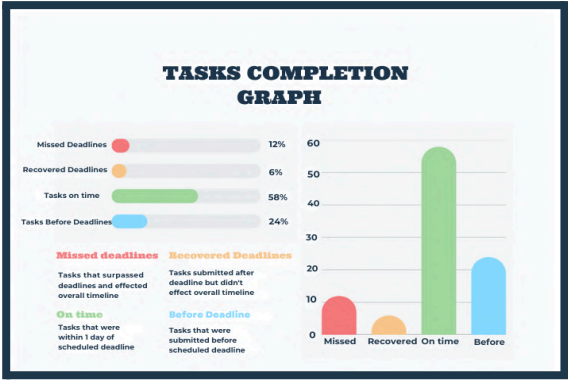


Fig 5: Task Completion Graph

As shown in the data, these mitigation efforts allowed **82%** of tasks to be finalized on or before their deadlines, demonstrating consistent progress and successful risk reduction throughout the development cycle.

C. Scheduled Project Management

The season was structured around a comprehensive Gantt chart (Figure 6), reviewed at every Thursday board meeting by the executive board and sub-team leads. The timeline spanned July 2025 through June 2026, organized into eight parallel tracks: Planning, Research, Mechanical, Software, Hardware, Payloads, Funding, and Testing each with defined deliverables, assigned ownership, and hard checkpoint dates.

OVERFLOW ROBOTICS 2026

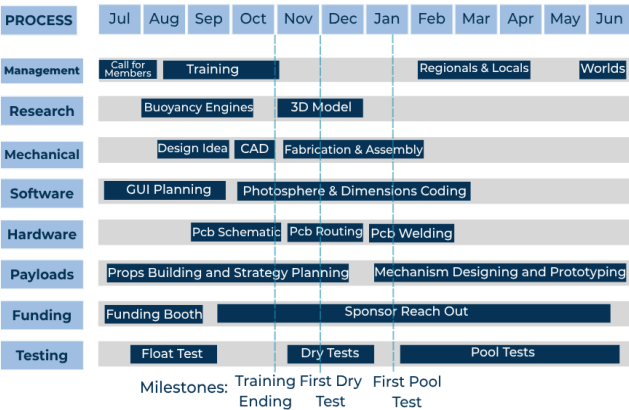


Fig 6: Overflow Robotics 2026 Gantt Chart

The **Mechanical and Hardware tracks** were deliberately run in parallel from September through December, progressing through CAD, fabrication, PCB schematic, routing, and welding simultaneously. This was a direct response to a bottleneck experienced in the 2025 season where electrical assembly lagged mechanical completion by three weeks. Running both tracks in parallel ensured the frame and electrical system reached integration readiness at the same time in December. The **Software track** began independently in August, developing and unit-testing modules in isolation so that by the first Dry Test in mid-December, the control interface, camera feeds, and MAVLink stack were already validated and ready for integration. Testing was structured in **three escalating phases**: Float Tests in August, Dry Tests in mid-December, and Pool Tests from January through May with each phase gated behind full resolution of all issues identified in the previous phase. This policy contributed directly to the **100%** issue resolution rate across **all 60 pool sessions**. Tracking against this plan was active throughout the season. When the November 3D printing milestone slipped 11 days due to filament supply delays, the executive board redistributed electrical component testing to fill the gap and authorized a fabrication recovery sprint during the December holiday break, successfully avoiding any compression of the dry test window. This recovery is reflected in the **6% "Recovered Deadlines"** category in the Task Completion Graph (Figure 5) and confirmed in the Milestone Tracker (Refer to Table 1 Milestone Tracker).

Milestone	Planned date	Actual date	Variance	Status
Member recruitment & training complete	Oct 31	Oct 28	-2 days	✓ Early
CAD design & mechanical layout finalized	Nov 10	Nov 12	+2 days	✓ On time
3D printing & mechanical assembly complete	Nov 15	Nov 26	+11 days	⚠ Recovered
PCB schematic & routing finalized	Nov 20	Nov 22	+2 days	✓ On time
PCB welding & electrical assembly complete	Dec 10	Dec 12	+2 days	✓ On time
First dry test (electronics & thrusters)	Dec 15	Dec 15	0 days	✓ On time
First in-water pool test	Jan 10	Jan 12	+2 days	✓ On time
All mission mechanisms validated	Feb 28	Feb 26	-2 days	✓ Early
Autonomous functions integrated & tested	Mar 15	Mar 14	-1 day	✓ Early

Table 1: Milestone Tracker

3.0 Design Rationale

Encore is a durable and serviceable modular remotely operated vehicle (ROV) designed to meet the mission-specific requirements of the 2026 MATE ROV Competition. (Refer to Fig 7 for **Encore ROV Picture**). Through the integration of customized design features, the vehicle enables efficient task execution while maintaining compliance with the Marine Advanced Technology Education (MATE) Request for Proposals (RFP) and supporting the United Nations Sustainable Development Goals. The **Encore** ROV successfully adheres to the MATE 2026 RFP size constraints with total dimensions of 40 x 35 x 35 cm, while simultaneously securing the maximum weight bonus points by maintaining a dry mass of 7.60 kg.

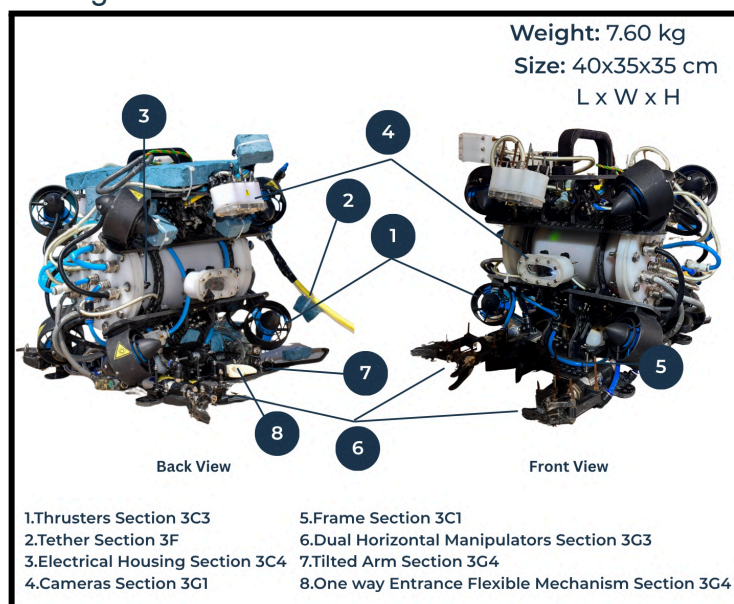


Fig 7: Encore ROV Breakdown

A. Design Methodology & Process

The design of **Encore** is centered on mission-driven decision-making and rapid iteration. For every subsystem, development begins by identifying the **specific mission task**, ensuring objectives remain the primary driver throughout the design process. Potential solutions are generated through brainstorming and evaluated by comparing advantages, limitations, and implementation trade-offs. This cycle emphasizes producing reliable, cost-effective solutions tailored to specific MATE ROV requirements. **Encore** represents the culmination of Overflow Robotics' accumulated experience over multiple competition seasons. Lessons learned from previous vehicles informed key decisions regarding structural design and material selection. While earlier designs prioritized rapid prototyping, they revealed limitations in durability and precision. These

insights guided the transition toward the more robust construction methods and improved design standards seen in **Encore**. The design was finalized through detailed **CAD modeling** and **precision fabrication** to ensure dimensional accuracy and structural integrity. This approach supports modularity and serviceability while reducing integration risk, resulting in a vehicle balanced for the demanding operational conditions of the 2026 competition.

B. Brainstorming & Ideation Process

Before any design decision was committed to CAD or procurement, every subsystem passed through a structured ideation phase conducted across the full cross-functional team. Rather than delegating concept generation to individual sub-teams in isolation, Overflow Robotics used a three-stage brainstorming model (**Figure 8**) to ensure that solutions were evaluated from mechanical, electrical, and software perspectives simultaneously.

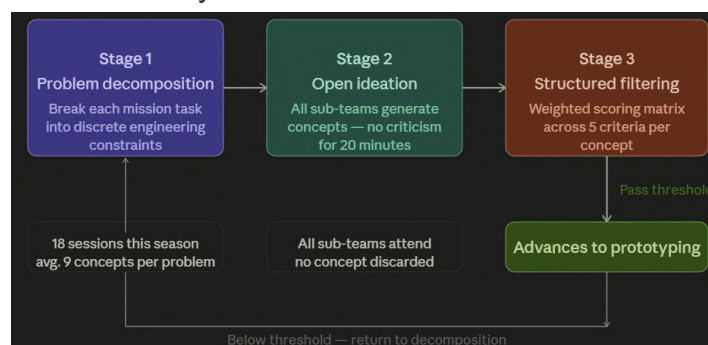


Fig 8: Brainstorming Stages

Stage 1 — Problem Decomposition: Each mission task from the 2026 MATE RFP was broken into discrete physical challenges at a dedicated ideation session attended by all sub-team leads. For example, the weighted pot retrieval task was decomposed into three independent problems: generating sufficient upward force, securing the pot handle reliably, and maintaining stable depth control during ascent. This decomposition ensured that brainstorming targeted specific engineering constraints rather than vague goals.

Stage 2 — Open Ideation: For each identified problem, a 20-minute open ideation round was conducted in which all members, regardless of sub-team, contributed candidate solutions on a shared Notion board without evaluation or criticism. This phase generated between 6 and 14 distinct concepts per problem across the season. For the pot retrieval force problem alone, concepts ranged from upgraded thrusters and rigid foam

attachment to a pneumatic bladder, a counter-weight release mechanism, and a dedicated ascent winch. No concept was discarded during this stage.

Stage 3 — Structured Filtering: Concepts were then evaluated by the relevant sub-team leads using a weighted scoring matrix (**Table 2**) covering five criteria: technical feasibility, mission time impact, cost, weight penalty, and integration complexity. Only solutions that scored above a defined threshold advanced to prototyping. This process is what produced the trade-off tables seen throughout Section 3; each table is the final output of a brainstorming cycle, not an after-the-fact justification.

Over the full season, the team ran 18 formal ideation sessions covering all major subsystems, with an average of 9 concepts generated per problem. This volume of ideation was essential to arriving at unconventional solutions such as the TPU one-way buoy funnel, the 15° tilted O-ball collection arms, and the pneumatically-inflated airbag retrieval bladder, none of which emerged from the first brainstorming round.

Concept Selection Matrix						
Concept	Technical feasibility (25%)	Mission time impact (20%)	Cost (20%)	Weight penalty (20%)	Integration complexity (15%)	Weighted total
Pneumatic bladder	Selected	4	4	3	3	3.75
Rigid foam attachment	Rejected	3,2	4,4	3,3	4	2.95
Thruster upgrade	Rejected	2,3	2,3	2,1	1,2	2.05
Counter-weight release	Rejected	2,2	2,3	4,1	4,1	2.35
Ascent winch	Rejected	1,3	1,1	1,1	1,1	1.55

■ Above threshold (~3.5) — advances to prototyping ■ Below threshold — returned to decomposition

Table 2: Concept Selection for pot retrieve Matrix

C. Mechanical Systems

Encore’s mechanical systems form the structural foundation of the vehicle, supporting propulsion, buoyancy, and mission tooling while maintaining a compact and balanced configuration. The design emphasizes structural strength, modular integration, and serviceability to ensure reliable operation during testing and competition.

1.0 Frame

In the last season, Overflow Robotics used carbon fiber as the main material for the ROV frame. In the evaluation of materials, acrylic and aluminum alloys were examined in conjunction with carbon fiber. Eventually, carbon fiber was selected as the main material for the **Encore frame** due to its

special features. (Refer to Table 3 for comparative analysis)

The primary advantage of carbon fiber was the great strength-to-weight ratio, corrosion resistance, and design flexibility which would help to realize the objectives. Acrylic, while lightweight and economical, is no match for this material for strength and durability. Aluminum, while strong, is neither lightweight nor resistant to corrosion, and does not afford the same flexibility with complex designs. Therefore, the frame for the **Encore** was entirely manufactured from carbon fiber and this frame was assembled using 3D-printed joints, thus resulting in a very lightweight structure with a great strength-to-weight ratio. While the carbon fiber comes at a high cost, this investment was definitely well worth it for the performance and durability achieved (Refer to Figure 9 for frame only render).

Carbon fiber (selected)	Aluminum	Acrylic
Excellent High strength, minimal weight.	Moderate Strong but not lightweight.	Poor Light but weak.
High Ideal for underwater use.	Low Not corrosion resistant.	High Naturally resistant.
High Supports complex designs.	Low Limited flexibility.	Moderate Limited durability.
High Passed all structural tests.	Moderate Fails corrosion tests.	Low Poor durability.
High Significant investment.	Moderate Standard cost.	Low Economical.

Table 3: Material Trade-off

Encore features a unique and highly functional design, equipped with 8 thrusters, 3 manipulators, 7 cameras, and an electronic housing. Its frame is primarily composed of four main components:

- 1. **Upper Plate:** Used to mount cameras and the handle.
- 2. **Lower Plate:** Provides mounting points for manipulators and additional cameras.
- 3. **Thruster Fixation Plates:** Secure the thrusters and light casings in place.
- 4. **Electronic Housing Fixation Plates:** Connect all frame parts and securely hold the electronic housing.

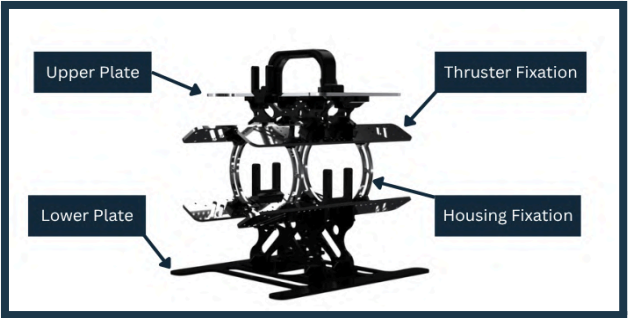


Fig 9: Encore Frame

2.0 Buoyancy & ballast

Encore demonstrates buoyancy, which is the ability of an object to stay afloat. Buoyant force is the one that decides whether an object will sink or float based on its weight and displaced fluid weight. When an object floats, it pushes away that mass of water equal to its own weight. Conversely, if the weight of the object is greater than that of the displaced fluid, the object will sink. This principle is influenced by the density or weight of the fluid; denser fluids can prop up heavier bodies. In a static fluid, pressure increases with depth due to the weight of the overlying fluid. Therefore, the pressure at the bottom of a submerged object is greater than at the top, creating an upward buoyant force. Using this concept, a spreadsheet was developed to calculate the volume, buoyant force, and weight of each component in water (**Table 4**). The analysis revealed that **Encore** was slightly negatively buoyant, requiring additional foam to achieve neutral buoyancy. **Encore's** total dry weight is 94.44 N, with a displacement volume of 9,630 cm³. Archimedes' principle, expressed as $F_{\text{Buoyancy}} = V \times \rho \times g$, was applied to determine neutral.

Component	Mass (kg)	Vol (cm³)	FB (N)	UW (N)
Structural				
Carbon fiber frame	1.29	1000	9.81	-2.84
3D-printed joints	0.24	250	2.45	0.15
HDPE housing (body)	0.94	3100	30.4	21.19
HDPE end caps (2×)	0.47	580	5.69	1.08
Propulsion				
Thrusters (8× U2)	0.65	600	5.88	-0.50
Thruster shrouds (8×)	0.28	240	2.35	-0.41
Electronics				
Jetson Orin Nano	0.14	60	0.59	-0.79
Arduino Nano	0.04	20	0.20	-0.17
PCBs (4× custom)	0.24	150	1.47	-0.83
USB cameras (7×)	0.33	300	2.94	-0.28
RealSense camera	0.08	80	0.78	0.05
Sensors	0.09	50	0.49	-0.43
Tools				
Dual horizontal (2×)	0.47	180	1.77	-2.84
Vertical scissor	0.33	150	1.47	-1.75
Servo motor	0.38	160	1.57	-2.11
Mission mechanisms	0.24	120	1.18	-1.13
Cabling				
Internal wiring	0.24	110	1.08	-1.22
Pneumatic lines	0.14	90	0.88	-0.50
Connectors & glands	0.24	60	0.59	-1.71
Subtotal	6.80	7300	71.59	-14.71
Correction				
Foam flotation	0.50	2300	22.56	17.65
Ballast weights	0.30	30	0.29	-2.65
Correction subtotal	0.80	2330	22.85	14.99
Total analysis	7.60 kg	9630 cm³	94.44 N	+0.29 N

Table 4: Buoyancy Calculations

buoyancy. The buoyant force was calculated at 94.44 N. Without foam correction, the vehicle's component subtotal produced a net negative buoyancy of -14.71 N, as confirmed in Table 4. To counteract this, foam flotation was added, ensuring the vehicle became neutrally buoyant as a key design consideration. The calculated buoyancy configuration was validated through a structured series of float and pool tests before the vehicle was cleared for full-depth operation. In the initial float test conducted in August, **Encore** with no foam attached sank to the pool floor at a measured descent rate of 0.18 m/s, confirming the predicted negative buoyancy of -14.71 N from Table 4. Foam flotation blocks totaling 2,300 cm³ were then added incrementally in three stages 1,000 cm³, then 800 cm³, then 500 cm³ with a static hover test performed at 1.0 m depth after each addition to observe trim and drift rate. After the full 2,300 cm³ configuration was installed, **Encore** achieved a measured upward vertical drift rate of less than 0.02 m/s at 1.0 m depth with all thrusters at zero throttle, confirming near-neutral buoyancy consistent with the predicted +0.29 N residual. Trim was assessed at 1.5 m depth by releasing the vehicle from a horizontal hold and observing its orientation after 10 seconds. The vehicle maintained a level pitch (< 2° nose-up deviation) and zero roll, confirming that the foam placement centered longitudinally on the upper plate and distributed symmetrically across the port and starboard sides produced a stable upright trim without ballast redistribution. Ballast weights of 0.30 kg were added to the lower plate to lower the center of gravity relative to the center of buoyancy, improving passive roll stability during thruster-off hover. Final depth validation was conducted at 5.5 m, the maximum operating depth for the 2026 mission, where **Encore** held station within a ±0.08 m vertical band for 3 minutes with depth-hold mode active, confirming that the buoyancy configuration remained stable under the increased hydrostatic pressure at full operating depth.

3.0 Propulsion & Thrusters

In previous seasons, Overflow Robotics relied on Blue Robotics T200 thrusters due to their strong thrust-to-current performance and proven

reliability. For the 2026 season, the propulsion system was re-evaluated to better align with the MATE ROV RFP requirements for repeated vertical motion and dynamic maneuvering in the waves and currents expected at the Newfoundland competition site. Testing and analysis showed that the previous six-thruster vectored configuration was not optimally efficient for sustained vertical operation, prompting a comprehensive redesign. Multiple propulsion layouts were evaluated through force analysis simulations and in-water testing. The 3D configuration was adopted over the vectored alternative, leveraging all eight thrusters across every degree of freedom to improve thrust distribution, speed, and vehicle control while minimizing size. Thrusters were mounted at strategic angles of 30° and 60° in the XY and YZ planes, enabling efficient forward propulsion while maintaining strong vertical and lateral stability. To complement the redesigned layout, Overflow Robotics transitioned to ApisQueen U2 thrusters (**Refer to Table 5 Thruster Comparison**). The U2 was selected for its compact form factor, lower mass, and favorable efficiency, reducing drag, simplifying buoyancy management, and easing integration. Delivering approximately 0.8 kgf while saving 70% in size and weight over the T200, the U2 also offered a significantly lower unit cost, freeing resources for other subsystems. While the eight-thruster configuration increased power demand, this was justified by the gains in vertical efficiency, depth control, and handling confirmed through simulation and in-water testing

Criterion	Weight	T200 6× Vectored	T200 8× 3D	U2 8× 3D
Vertical thrust at 5m	30%	4.8 kgf	8.2 kgf	6.4 kgf
Total current draw	25%	14.4 A	19.2 A	14.4 A
Vehicle weight impact	20%	+2.4 kg	+3.2 kg	+1.8 kg
Unit cost	15%	\$720	\$960	\$396
Integration complexity	10%	Low	Medium	Medium
Weighted total score		6.2	7.1	8.4 — Selected

Table 5: Thrusters’ Comparison

4.0 Sealing

Encore is equipped with a cylindrical electronic housing made of **HDPE** (**Refer to Table 6**), positioned sideways at the center of the vehicle to minimize drag. HDPE plates with stainless steel glands are mounted on both sides to securely seal

the cables. Gaskets are fitted on both sides and fastened with screws to ensure a watertight seal for the HDPE plates.

Criterion	Weight	HDPE (Selected)	ABS (Common)	PC/ABS (Premium)
Impact resistance (Structural performance)	20%	Good (Resistant to cracking)	Good (Moderate)	Excellent (High impact)
Chemical resistance (Environments & cleaning)	15%	Excellent (Broad chemical resistance)	Good (Moderate)	Good (Moderate)
Moisture absorption (Dimensional stability)	10%	Excellent (<0.01%)	Fair (~0.3%)	Fair (~0.2%)
Temperature performance	15%	Fair (~80 °C max)	Good (~90 °C max)	Excellent (~120 °C max)
Weight (Assembly & shipping)	10%	Excellent (Lightest)	Good (Moderate)	Fair (Heavier)
Manufacturability (Processing ease)	10%	Excellent (Easy to mold)	Good (Easy)	Good (Easy)
Cost (Material cost)	15%	Excellent (Lowest)	Good (Moderate)	Fair (Highest)
Sustainability (Recyclability)	5%	Excellent (Recyclable)	Fair (Limited)	Fair (Limited)
Weighted total score		8.6 — Selected	7.0	6.6

Table 6: HDPE Trade-off

D. Electrical Systems

Encore’s electrical systems form the backbone of vehicle control and power delivery, supporting propulsion, sensing, and tooling subsystems. The system was engineered with an emphasis on electrical safety, consistent performance, and simplified troubleshooting to ensure dependable operation during testing and competition (**Refer to Figure 10 for Encore Electrical System**)

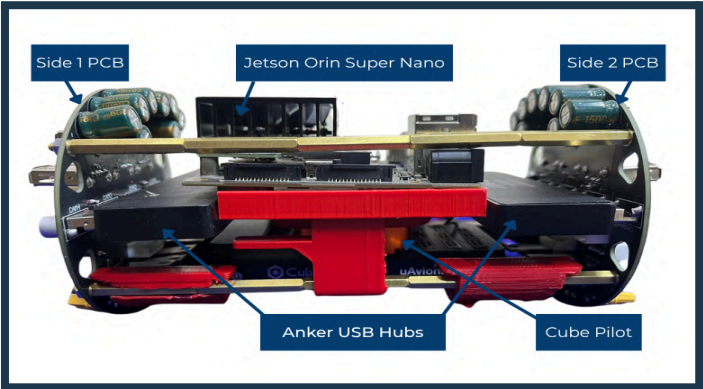


Fig 10: Encore Electrical System

1.0 Major Electrical Components & Selection Rationale

Encore’s electrical system is built around a modular, mission-driven architecture designed to balance processing capability, reliability, and system integration. Components were selected

based on performance requirements, subsystem compatibility, and proven reliability in underwater robotics applications.

At the core of the system is the **NVIDIA Jetson Orin Nano Super**, which serves as the primary onboard computer. It was selected over the Jetson Nano for its significantly higher computational performance and improved efficiency, enabling real-time processing of data from multiple cameras while supporting advanced vision algorithms and future software expansion. Although it consumes more power, the performance benefits were necessary to support the vehicle's multi-camera vision system. Low-level control is handled by a **Cube flight controller**, responsible for stabilization, sensor fusion, and actuator control. The Cube was chosen over a microcontroller-based solution due to its integrated high-quality IMU, real-time processing capabilities, and proven control firmware, reducing system complexity and improving reliability. Depth sensing is provided by the **Blue Robotics BAR030** pressure sensor for accurate depth measurement and stable vertical control. Motor actuation is handled by **Blue Robotics ESCs**, selected for their reliability, smooth control, and electrical isolation between high- and low-power systems. The vision system includes seven USB cameras for full situational awareness and redundancy, along with an Intel RealSense depth camera for spatial perception and future autonomy support. Two USB hubs connect all cameras to the Jetson. Three custom PCBs were developed to streamline power and signal routing, including camera connections, actuator interfaces, regulated power distribution, and current backflow protection.



Fig 11: Electrical components; Left to right: NVIDIA Jetson Orin Super nano | ESC | Cube flight controller | Anker USB hub

Side 1: This PCB connects four camera USBs to the USB hub, links four actuators to the Cube via

JST connectors, and provides a stable power supply to the Jetson.

Side 2: Similarly, this PCB connects four additional cameras and four actuators.

Main Power: The system uses ten XT-60 connectors—one serves as the main input, eight distribute power to the thrusters, and one powers the other PCBs. This board also includes diodes to prevent backflow of current.

2.0 Power Architecture & Protection Strategy

Power is delivered from the surface station via **two 3 mm copper cables with XT60 connectors**, chosen for low resistance and high current capacity. Onboard, a dedicated Power Distribution PCB regulates and distributes power to all subsystems (**Refer to Table 7 for Power Distribution**), incorporating diodes to prevent reverse polarity and fault propagation. A boost converter provides a **19 V** rail for the Jetson Orin Nano Super, while a DC–DC buck converter supplies **5 V** to low-voltage systems, including the USB cameras, reducing interference between high- and low-power circuits. Sixteen bulk and decoupling capacitors mitigate voltage drops from thruster startup and load changes, ensuring stable operation. This power architecture enhances electrical stability, protects sensitive electronics, and supports reliable performance under dynamic competition loads. Displayed below is the full amp distribution budget, including expected and measured current values validated at full load.

POWER DISTRIBUTION — AMP BUDGET					
Component	Qty	A / Unit	Total (A)	Expected (A)	Measured (A)
PROPULSION					
Thrusters (U2)	8	2	16	16	16
COMPUTING					
Jetson Orin Nano Super	1	4	4	4	
VISION					
USB Cameras (6x)	6	0.25	1.5	1.5	
Intel RealSense	1	0.5	0.5	0.5	
MISC					
Manipulator Solenoids	3	0.2	0.6	0.6	
SUBTOTAL			22.6	22.6	
Fuse Selected			25	25	25
Peak Draw (Measured)					22.6

Table 7: Amp Distribution Budget

3.0 Signal Architecture & Control Integration

Data communication between the surface station and the vehicle is established through a **Cat6 Ethernet tether**, providing high bandwidth and low-latency transmission of commands and telemetry. Commands are received by the **Jetson**

Orin Nano Super, which handles **high-level processing** and forwards structured control inputs to the **Cube flight controller**. This separation isolates computationally intensive tasks from time-critical control functions, ensuring stable operation under high processing loads. The Cube executes low-level control loops and distributes signals to actuators, with thrusters controlled via dedicated PWM channels and other actuators connected to auxiliary outputs. Physical separation of power and signal wiring reduces electromagnetic interference. The Cube also provides operational redundancy, maintaining basic control in the event of degraded communication with the main computer. This architecture ensures reliable communication, precise control, and consistent vehicle behavior.

E. Software Architecture

The software architecture of **Encore** was designed to provide reliable, modular, and scalable control of the vehicle while supporting real-time operation and future system expansion. The system is structured around a layered architecture that separates **high-level decision-making**, perception, and operator interaction from time-critical control and actuation. This approach improves system stability, simplifies debugging, and allows individual software modules to be developed, tested, and updated independently. Before describing individual subsystems, **Table 8** captures how each major system integrates with the others—what it outputs, what it depends on, and the operational consequence if it fails.

Encore 2026 — Subsystem Dependency & Integration Table				
Subsystem	Outputs to	Depends on	Interface type	Failure impact
Power Chain				
Surface Supply	Main power via 3mm tether	Shore power / battery	2× 3mm copper, XT60, 25A fuse	Total vehicle loss. Fuse protects.
Main Power PCB	Thrusters (8×), Side PCBs (2×), boost converter, buck converter	Surface supply, tether continuity	XT60 distribution, diode backflow protection	All subsystems lose power. Modular design isolates fault.
Boost Converter (19V)	NVIDIA Jetson Orin Nano Super	Main Power PCB	DC–DC, regulated rail	Jetson offline — autonomy and camera lost.
Buck Converter (5V)	7× USB cameras via USB hubs	Main Power PCB	DC–DC, regulated rail	All camera feeds lost. Pilot blind. Mission abort.
Control Chain				
Jetson Orin Nano Super	MAVLink Router → Cube Orange; camera feeds → GUI; YOLO/SLAM outputs → autonomous commands	19V rail, Cat6 tether, Linux OS	Ethernet LAN, MAVLink over UDP	Autonomous functions offline. Manual control still possible.
Cube Orange (FC)	ESCs (PWM), auxiliary actuators	MAVLink from Jetson or laptop, IMU sensors	PWM output, JST connectors via Side PCBs	All thruster control lost. Vehicle uncontrollable. Emergency ascent.
Blue Robotics ESCs (8×)	ApisQueen U2 thrusters	PWM from Cube, 24V from Main PCB	PWM signal, XT60 power	Per-thruster isolation — single ESC failure reduces DoF but vehicle remains operable.
Cat6 Tether (Data)	Jetson ↔ control laptop LAN	Tether physical integrity, surface switch	Ethernet over IP, MAVLink UDP	Loss of pilot input and telemetry. Cube holds last commanded state.

Table 8: System dependency and integration

While Table 8 captures the static dependency architecture of **Encore's** systems, the design also required active cross-system negotiation throughout the season. Decisions made within one sub-team consistently propagated concrete changes into others, identifying single points of

failure and driving major architectural choices, including the Cube's redundant control capability and the dual-path power distribution PCB design.

Three representative decision cascades are documented in **Table 9**, demonstrating the integrated development approach that underpins **Encore's** architecture.

Chain	Originating decision	Subsystems affected	Result
Chain 1 — Tooling → Mechanical → Electrical			
Airbag bladder added for pot retrieval	+0.50 kg mass; 2.5 kg buoyancy on demand	Buoyancy recalculated (Table 4); solenoid valve needed dedicated aux PWM on Side PCB 1	Foam volume revised; PCB routing updated — one tooling decision changed two subsystems
Chain 2 — Software → Electrical → Mechanical			
Jetson Orin Nano Super selected over Jetson Nano	Required 67 TOPS for YOLO + SLAM — Jetson Nano insufficient	Orin Nano Super needs 19 V; boost converter added to Power PCB; heat output affected housing layout	Power PCB redesigned; housing arrangement revised for thermal clearance
Chain 3 — Payload → Electrical → Architecture			
7-camera vision system required	Exceeds single USB hub capacity; two hubs needed	Routing complexity made single PCB impractical — drove the 3-PCB split (Side 1, Side 2, Main Power)	3-PCB architecture adopted — 75% repair cost reduction was a downstream consequence of camera count

Table 9: Encore Subsystem Integration Chains

1.0 Sensors & perception

The perception system is centered on an **Intel RealSense** sensor suite, which includes **two stereo depth cameras**, an **RGB camera**, a **laser sensor**, and an **IMU**. The stereo cameras estimate depth by comparing images from different angles, while the laser provides accurate distance measurements and the RGB camera captures color information. Each frame produces both an RGB image and a depth map, allowing the system to understand how far every pixel is from the camera. The IMU tracks movement and orientation, helping align consecutive frames in space. All this data is processed on the Jetson.

For **object recognition**, a **YOLO-based** deep learning **model** is used for real-time crab detection. The model analyzes live camera frames, identifies crabs, and estimates their position by linking detection results with depth data. Navigation is guided using vision-based line detection. Blue lines define the intended path, and the ROV continuously adjusts its motion to stay centered between them. If it drifts or tilts, the system automatically corrects its position. Red lines represent restricted zones and are intentionally ignored by the navigation logic.

2.0 Communication Protocols

The ROV communication system is based on **Ethernet networking** and the **MAVLink** protocol. Ethernet is used to establish a fixed local area network (LAN) connecting the Jetson, the Cube flight controller, and the control laptop. Both the

Jetson and laptop are configured on the same IP network, enabling direct device discovery and low-latency data exchange.

For vehicle control, **MAVLink** is used as the primary communication protocol between the Cube and the control station. MAVLink Router is deployed on the Jetson, allowing it to function as a **transparent MAVLink bridge** between the Cube and any device connected to the Jetson. With the Cube directly connected to the Jetson and an Ethernet link established between the Jetson and the laptop, MAVLink Router forwards MAVLink packets without modification, making the laptop and Cube appear as if they are directly connected.

This enables seamless integration with **ArduPilot** ground control software such as **QGroundControl** and **Mission Planner**, allowing joystick input, flight controller configuration, motor control, and gripper setup to be handled directly from the laptop. Without the MAVLink Router, joystick commands would require custom Python scripts to capture inputs on the laptop, relay them to the Jetson, and then transmit MAVLink commands to the Cube, eliminating compatibility with standard ground control software and requiring manual implementation of control logic. The use of MAVLink Router therefore simplifies the communication architecture while providing reliable control and configuration capabilities.

3.0 Control System

Control system requirements were derived directly from the mission task specifications in the 2026 MATE RFP, documented before implementation, and verified through structured pool testing. The table below maps each mission task to its derived control requirement, the verification method used, and the result was achieved.

Mission task	Derived control requirement	Verification method	Result
Pot retrieval at 5.5 m	Depth-hold accuracy ± 0.10 m; vertical ascent rate ≥ 0.20 m/s sustained	Timed descent/ascent runs with depth logged via BAR030 telemetry	± 0.07 m achieved; ascent rate 0.28 m/s — pass
Transect navigation between blue lines	Lateral deviation ≤ 5 cm from midpoint during forward motion	Vision overlay recorded at 30 fps; deviation measured frame-by-frame in post-processing	Mean deviation 3.2 cm across 10 runs — pass
Infrastructure cap removal & connector install	Manipulator positioning accuracy ± 2 cm; stable hover during tool engagement	Manipulator approach logged via manipulator-facing camera; hover drift measured via HUD overlay	Drift < 1.5 cm during all final validation runs — pass
Coral basket retrieval	Simultaneous two-point grip force; zero basket contact with thrusters during ascent	Visual inspection of basket on retrieval; tether camera reviewed for thruster proximity	100% retrieval with no thruster contact across 8 runs — pass
3D model photogrammetry	Minimum image overlap 60% across all surface faces; stable station-keeping during capture	Trio3D reconstruction quality score logged; pilot station-keeping error reviewed from top camera	Acceptable 3D model generated in 100% of final validation runs — pass

Table 10: Mission task test with results.

The control architecture is organized into two layers: an inner loop and an outer loop. The inner loop runs on the Cube Orange flight controller and uses PID control to stabilize the ROV's motion (**Figure 12 for pid architecture**). It continuously

processes sensor data such as orientation and position and adjusts actuators in real time to maintain stability and track commanded motion, operating independently of operator input. The outer loop serves as the high-level control layer, where commands originate from either the joystick or autonomous scripts running on the Jetson or laptop. This layer provides guidance to the inner loop, enabling tasks such as path following, alignment between blue lines, and obstacle avoidance. When autonomous mode is enabled, the ROV performs mission tasks without human intervention using feedback from onboard perception systems.

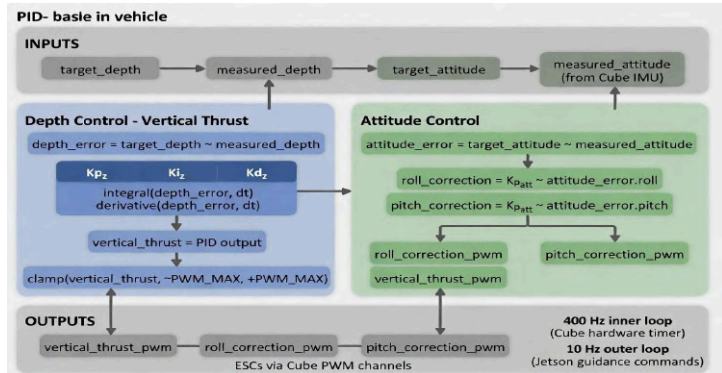


Fig 12: PID Control Architecture for Encore

4.0 Software Stack

The software stack is organized in layers (**Refer to Figure 13 for stack flowchart**) to ensure smooth and reliable operation. At the base, it runs on a **Linux operating system**, which provides stability, manages hardware resources, and handles networking. High-level software is mainly written in **Python and C++**, relying on tools that are central to the ROV's operation. **OpenCV** is used for general image processing, the **Intel RealSense SDK** handles RGB and depth data acquisition, and **YOLO** enables fast object detection. **NumPy** supports numerical computations, while **Ethernet** over IP ensures reliable communication between the Jetson and the control laptop.

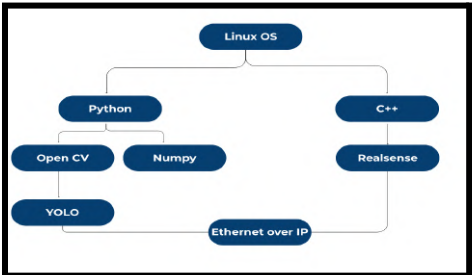


Fig 13: Software Stack

Software development followed a feature-branch Git workflow hosted on a private GitHub repository, with a structured branch naming convention enforced across all contributors. Branch names follow the pattern

`feature/[module]-[description]` for new functionality for example `feature/yolo-crab-detection` and `feature/transect-hsv-tuning`
`fix/[module]-[issue]` for bug corrections such as `fix/mavlink-bridge-dropout`, and `test/[module]` for isolated unit test scripts. No code was merged to the `main` branch without a pull request reviewed and approved by at least one member from a different sub-team, enforcing cross-functional review on every change. The PR template required the author to state: (1) what the change does, (2) which mission task or subsystem it affects, and (3) the test performed to verify it before submission. Each software module YOLO detection, transect navigation, GUI, MAVLink bridge was developed and unit-tested independently on its feature branch before integration. Integration testing was then conducted in the following sequence:

1. Individual sensor verification
2. MAVLink bridge validation via QGroundControl
3. Full-stack pool test

Version tags were created at each major milestone to enable rollback if integration failures occurred. The current software design has known limitations that inform the testing strategy and represent areas for future development. The YOLO crab detection model was trained exclusively on frames extracted from videos of printed crab images rather than live underwater specimens, creating a domain gap that may reduce detection confidence in the variable lighting and turbidity conditions of the Newfoundland competition pool. The transect navigation algorithm relies on HSV color thresholding and is sensitive to ambient light intensity; significant changes in pool lighting between practice and competition runs may require real-time threshold recalibration. The SLAM-based 3D mapping pipeline is not yet executed in real time at full camera resolution; it operates on down-sampled frames to meet Jetson's processing budget, which reduces map fidelity for small objects. These limitations were acknowledged during design review and mitigated through extensive pool testing under varied lighting conditions, dataset augmentation in RoboFlow, and conservative mission planning that does not rely on SLAM output for time-critical decisions.

5.0 Assisted & Autonomous Functions

Transect: This system uses computer vision to **autonomously** detect and navigate between two blue lines using real-time video, which is also recorded for post-run review and analysis. HSV color space was chosen over BGR for robustness under varying lighting conditions. Morphological filtering reduces noise and fills gaps, while contour-based detection identifies valid lines based on size and aspect ratio. Line centers are calculated using image moments, and the midpoint between them is used for alignment. Forward motion is commanded when centered, and realignment occurs if one line is lost. Traditional computer vision was selected over deep learning to avoid training requirements, and Canny edge detection was rejected due to noise sensitivity.

Crab Detection: Crab detection was implemented using a **YOLO-based deep learning model** for real-time object detection. YOLO was chosen over R-CNN due to its superior processing speed. A dataset was created by extracting frames from videos of printed crab images, manually annotating them in RoboFlow, and applying automated data augmentation to increase dataset size. RoboFlow was selected for its integrated annotation, augmentation, and export capabilities.

3D Model: For the **3D modeling mission task**, the team employed AI-assisted photogrammetry using Tripo3D as the primary tool. Photogrammetry reconstructs a three-dimensional model from a series of overlapping images by identifying common feature points across frames. Tripo3D automates this pipeline through machine learning, enabling accurate 3D reconstruction without requiring specialized modeling expertise or extensive processing time. This approach was selected over manual video capture methods, where the pilot would be required to systematically orbit the target object to ensure full surface coverage, consuming valuable mission time and increasing pilot workload. By leveraging AI-assisted photogrammetry, sufficient image data can be captured incidentally during task execution, eliminating the need for a dedicated sweeping pass and freeing mission time for other tasks.

Measuring Distance: Distance measurements are obtained using **Intel RealSense RGB**, stereo, and IR depth data to provide pixel-level distance information. Stereo and IR sensors enable full-object distance measurement, unlike ultrasonic sensors, which were rejected due to limited range and point-only measurement. Distances are extracted and displayed using the RealSense Viewer.

F. Tether

1.0 Integrated Tether Design

The **Encore** system utilizes a dual-line tether assembly designed for high-power throughput and low-latency data, while maintaining a low



Fig 14: Tether

hydrodynamic profile (**Figure 14**). The assembly consists of a **VideoRay multi-conductor cable** and a **parallel high-flexibility pneumatic line**, unified within a custom braided sleeve to prevent snagging.

Internal Architecture of the VideoRay Cable:

Power Core: The tether contains **two 3mm heavy-duty power wires**, providing the high-current capacity required to drive the eight-thruster propulsion system without significant voltage drop over the 20-meter run.

Data Core: A **CAT6 Ethernet cable** is integrated centrally within the VideoRay jacket. This twisted-pair configuration is essential for maintaining a high-bandwidth connection for the **7-camera HD vision system** and real-time telemetry from the NVIDIA Jetson Orin Nano Super.

Table A — Tether conductor parameters (3 mm diameter copper, 20 m run)				
Parameter	Symbol	Value	Unit	Source
Conductor diameter	d	3.00	mm	Specified
Conductor radius	r	1.50	mm	$d \div 2$
Cross-sectional area	A	7.07	mm ²	$\pi \times r^2$
Copper resistivity (20°C)	ρ	1.72×10^{-8}	$\Omega \cdot m$	Standard
Single conductor length	L	20	m	Tether spec
Round-trip length (+ and -)	2L	40	m	$2 \times L$
Resistance per conductor	R_i	0.0487	Ω	$\rho \times L \div A$
Total tether resistance (both conductors)	R_{total}	0.0973	Ω	$2 \times R_i$

Table 11: Resistance for tether calculation

EMI Mitigation: The internal layout is designed to isolate the high-frequency data signals in the CAT6 core from the electromagnetic interference (EMI) generated by the adjacent 3mm power conductors.

Pneumatic Support: A single 6mm polyurethane line runs parallel to the VideoRay cable, delivering constant pressure to the **three carbon fiber manipulators** for rapid, precise underwater actuation.

Navigation Aids: The assembly features **high-visibility color-coded markers** (**Table 12**) at specific intervals. These serve as a visual "fuel gauge" for the pilot, indicating exactly how much of the 20-meter line remains available for deep-environment exploration.

Buoyancy & Torsion Control: To prevent "tether drag," we integrated **strategic foam flotation** for

near-neutral buoyancy. At the vehicle interface, a **360° rotating strain-relief mechanism** decouples the vehicle's six-degree-of-freedom rotations from the tether, protecting the 3mm power wires and CAT6 core from fatigue and twisting.

Marker	Depth	Color code	Handler call-out (mandatory)	Status
M1	5m	Blue	"5 meters deployed - Flotation 1 clear"	SAFE
M2	10m	Green	"10 meters deployed - Flotation 2 clear"	SAFE
M3	15m	Yellow	"15 meters deployed - Flotation 3 clear"	SAFE
M4	20m	Orange	"20 meters deployed - Approaching depth"	CAUTION
M5	25m	Red	"25 METERS - APPROACHING LIMIT"	WARNING
M6	30m	Black	"STOP - 30 METERS - MAX DEPLOYMENT"	CRITICAL

Table 12: Color Coding for Tether Length

2.0 Tether Management Protocol

To ensure operational safety and protect the internal conductors, the team adheres to a strict three-phase protocol:

Phase 1: Pre-Dive Setup

Mechanical First: The 360° strain relief is anchored to the ROV frame before any electrical or pneumatic connections are made, ensuring no tension is placed on the pins.

Reel Deployment: The tether is unspooled directly from the rotary reel; any coiling on the pool deck is prohibited to prevent tripping or crushing.

Phase 2: In-Water Operations

The Dedicated Tetherman: One crew member is assigned exclusively to monitor the line, feeding out slack to support **38% improvement in vertical speed** while ensuring the tether does not drift into the thruster intake.

Rotational Awareness: The pilot monitors the color-coded markers and avoids excessive axial turns to preserve the copper structure of the internal power and data lines.

Phase 3: Post-Dive Recovery

Safe Isolation: Topside power is disconnected first, followed by data and pneumatics.

Careful Spooling: The tether is wiped clean and spooled back onto the reel in even layers to avoid "cable memory," which can lead to permanent kinking and internal conductor failure.

Scenario	Immediate action (Step 1)	Secondary action (Step 2)	Pilot comms
Snag / Tension	STOP all movement	0.1 m/s reverse for 5s	"Tether Snagged"
Data Dropout	Check surface connectors	Monitor ping/video feed	"Loss of Comms"
Pressure Loss	Check manifold gauge	Abort pneumatic tasks	"Pneumatic Fail"
Prop Tangle	EMERGENCY KILL power	Visual camera inspection	"Tether in Prop"
Human Hazard	Handler signals "Stop"	Clear 1m deck safety zone	"Deck Hazard"

Table 13: Tether emergencies call outs

G. Payloads

1.0 Cameras:

Equipped with seven strategically placed cameras, **Encore's** cameras deliver comprehensive visual coverage for navigation and task execution (**Refer to Table 14**). The cameras provide simultaneous forward, downward, side, rear, and tool-facing views, allowing the pilot to maintain full situational awareness at all times. This configuration supports precise maneuvering, accurate payload manipulation, and effective obstacle avoidance while reducing blind spots.

The multi-camera setup improves mission efficiency by limiting unnecessary repositioning and ensuring critical operations can be performed with confidence and accuracy.

Cam	Position	Primary mission task	Rationale for placement
1	Forward-center	Navigation, transect following	Primary pilot view; blue line detection for autonomous transect
2	Downward	O-ball collection, coral basket approach	Vertical positioning accuracy for pick-and-place operations
3	Manipulator-facing	Pot retrieval, cap removal, connector install	Direct tool alignment view during fine manipulation tasks
4	Rear	Reverse maneuvering near buoy anchor	Prevents tether snagging during reverse approach maneuver
5	Port-side	Lateral station-keeping	Depth reference against pool wall during station-keeping
6	Starboard-side	Bilateral situational awareness	Redundancy + wider coverage to eliminate blind spots
7	RealSense (front)	3D modeling, distance measurement	Stereo depth perception for SLAM pipeline and autonomous tasks

Table 14: Cameras Index

2.0 Sensors:

Encore utilizes a Bar030 pressure sensor from **Blue Robotics** (**Refer to Figure 15**) along with a Cube IMU that integrates a compass and accelerometer to provide accurate and reliable navigation data.



Fig 15: Depth Sensor

The **Bar030 sensor** enables precise depth measurement, allowing **Encore** to maintain stable depth control and execute missions that require consistent vertical positioning. The Cube IMU supplies **real-time orientation**, heading, and acceleration data, which are essential for maintaining vehicle stability, smooth maneuvering, and accurate directional control. Together, these sensors enhance **Encore's** ability to perform controlled movements, navigate complex underwater environments, and collect dependable data throughout each mission. (**Refer to Table 15 for Sensor Selection**).

Sensor requirement	Alternative considered	Selected	Reason alternative was rejected
Depth measurement	Bar010 (2025 model)	Bar030	Bar010 rated to 10 bar; Bar030 to 30 bar — 3× safety margin at operating depth
Orientation / IMU	Separate BNO055	Cube integrated IMU	Separate IMU adds I2C wiring and timing conflicts; Cube eliminates both
Spatial perception	Ultrasonic sensor	RealSense D435i	Ultrasonic: point measurement only, <3m range. RealSense: full-frame depth map at 6m+

Table 15: Sensors' Selection

3.0 Manipulators

The 2026 MATE mission requires interaction with objects across multiple spatial orientations: horizontal gripping for cap removal and connector installation, vertical clamping for pot and coral basket retrieval, and simultaneous two-point contact for tasks requiring bilateral engagement. Rather than designing separate mechanisms for each orientation, **Encore** uses three identical dual horizontal manipulators (**Figure 16**), each capable of operating in both horizontal and vertical orientations by rotating the mounting bracket 90°. This standardization reduces fabrication complexity, lowers spare parts overhead, and allows any manipulator to be redeployed to a different task configuration between runs without design modification. All three are fabricated from carbon fiber and 3D-printed components and operated by double-acting pneumatic pistons controlled by 5/2 solenoid valves.

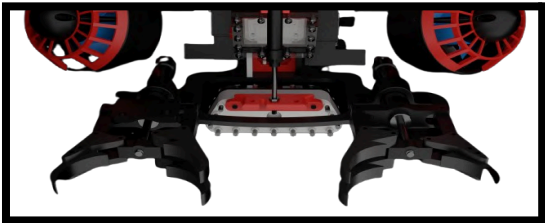


Fig 16: Dual Horizontal Manipulator

Dual Horizontal Manipulator - Horizontal Configuration: Mounted on the lower plate in the standard horizontal orientation. Used for: removing the power connector cap, installing the power connector, and connecting the sensor to the station. The dual-arm geometry provides simultaneous two-point contact on symmetrical objects, improving grip stability and reducing the precision required from the pilot during engagement.

Dual Horizontal Manipulator - Vertical Configuration: The same manipulator design rotated 90° at the mounting bracket, reorienting the gripping axis to vertical. Used for: releasing and recovering the weighted pot by its handle, and recovering coral baskets by engaging the substrate frame and star attachments. The ability to redeploy the same hardware in a vertical

orientation eliminates the need for a separate scissor mechanism, saving both weight and a dedicated pneumatic line.

4.0 Mission Specific Tools

The 2026 MATE RFP demands repeated vertical transport of objects across a 5.5m water column, retrieving weighted pots from the seafloor, collecting negatively buoyant O-balls, and securing anchor lines at depth. None of these tasks could be reliably solved with thruster power alone. Each required a dedicated mechanical innovation designed around the specific physics of the task.

Airbag-Assisted Pot Retrieval: The weighted pot exceeded **Encore's** continuous vertical thrust capacity, making unassisted ascent either thermally unsafe or too slow for mission time limits. A thruster upgrade and rigid foam attachment were both rejected; the former exceeded the 25A fuse rating, the latter added pre-rigging dependency. The solution was a pneumatically-inflated centered bladder providing 2.5 kg of additional buoyancy on demand, reducing thruster ascent load by 60%. Pot retrieval completed within time limits in 100% of final validation runs.

One-Way Flexible Buoy Anchor Mechanism: Threading a line onto a U-bolt at depth requires precise angular alignment. Initial pool testing with a rigid hook achieved below 40% first-attempt success due to vehicle oscillation. Magnetic coupling was rejected as the U-bolt is non-ferromagnetic stainless steel. The solution was a TPU funnel with inward-facing flexible fingers tolerating 360° of approach angle, connected to a bearing-mounted spooling wheel. Post-iteration first-attempt success rate reached 100% across all mission simulations.



Fig 17: Flexible Mechanism

O-Ball Tilted Collection Arms: O-balls are negatively buoyant. Horizontal collection arms achieved 0% retention during ascent as upward water flow displaced the balls over the tray edge. A sealed lid mechanism was rejected for adding pneumatic complexity. A 15° inward tilt was determined empirically, 10° was insufficient at full ascent speed, and 20° caused frame contact creating a bowl geometry that uses the ball's own negative buoyancy to hold it in place. Retention rate reached 100% with no additional mechanisms or pilot inputs required.



Fig 18: Tilted Arm

Non-ROV Device (Float)

Buoyancy Control System: The float regulates ascent and descent using a buoyancy engine that alters mass by drawing in or expelling water. A motor driver and power screw linear actuator extend four 50-mL syringes to intake water (negative buoyancy) and retract them to expel it (positive buoyancy). Dual limit switches protect the system from overextension, preventing internal leakage or syringe separation.

Structural Design: The internal frame features six machined iron rings with component mounting holes, housed inside a transparent cylindrical acrylic shell for maximum visibility. The assembly is secured by two pop-off valves for overpressure relief, while the caps utilize dual rubber O-rings to maintain a watertight seal down to six meters. The top cap features two sealed cable glands for the pneumatic lines connected to the syringes.

Control and Electronics: An ESP32 microcontroller manages system communication and drives the motor driver for bidirectional actuator motion, ensuring precise buoyancy adjustments.

H. Build Vs Buy & New Vs Reused:

The team categorized components based on whether in-house production would provide a significant advantage or if the complexity of the part necessitated a commercial purchase. Any component where in-house fabrication achieved >30% cost savings AND required no specialized certification (e.g., pressure calibration) was built in-house. Components requiring factory-grade tolerances, specialized waterproofing, or calibration equipment were purchased. **(Refer to Table 16)** Savings in fabrication funded the 60 pool sessions totaling \$450.

Component	Buy cost (USD)	Build cost (USD)	Decision	Justification	% Savings
Electronic housing	\$250.00	\$75.00	BUILD	70% savings; custom dimensions for internal stack.	70%
Power dist. PCB	\$180.00	\$102.70	BUILD	43% savings; custom layout for 8-thruster config.	43%
Camera PCB	N/A	\$102.70	BUILD	No commercial equivalent meets specific project requirements.	N/A
Pressure sensor	\$75.00	\$250.00+	BUY	R&D cost too high; calibration is extremely difficult in-house.	-233%
Thrusters (8x U2)	\$498.00	\$800.00+	BUY	Waterproof sealing and dynamic balancing require expertise.	-60%
Frame (carbon fiber)	\$350.00	\$205.50	BUILD	41% savings; allows for custom design iterations.	41%
Manipulator grippers	\$540.00	\$141.00	BUILD	74% savings; mission-specific geometry for tasks.	74%
IMU (BNO055)	\$48.00	\$120.00+	BUY	Precision sensors require factory-grade calibration.	-150%

Table 16: Build vs Buy Justification

Pressure Sensor (Buy): The team purchased the Blue Robotics Bar030. While expensive, the decision avoided the extensive trial-and-error

costs associated with developing a custom sensor capable of maintaining high-precision depth data.

Waterproof Thrusters (Buy): ApisQueen U2 were purchased off-the-shelf. The R&D required to reliably seal brushless motors in-house was deemed impractical compared to the immediate reliability of a commercial solution.

Electronic Enclosure (Build): Designed and manufactured in-house to achieve a 70% cost reduction compared to market alternatives. This approach provided total flexibility in dimensions and modularity for internal mounting.

Electronic System (Build): Custom PCBs were designed in-house. Although this required significant engineering effort, it proved more cost-effective and ensured the system could be easily upgraded for future iterations.

●**New vs. Reused:** Resource Optimization
Reusing existing inventory was a key tactic for reducing overhead. To ensure "reused" did not mean "compromised," all components underwent a rigorous testing phase before integration.

Component	Status	Justification	Test performed / Result
ApisQueen U2 Thrusters	New	Meets 2026 design methodology requirements for compact 3D-vectored propulsion	New component — no reuse testing required
VideoRay Buoyant Tether	New	Single-cable integrated design selected for 2026 — no legacy tether met spec	New component — no reuse testing required
Pneumatic pistons	Reused	Valves and fittings carried over to reduce overhead; tested before integration	✓ PASS — Pressure-tested at 8 bar for 30 min; no leakage detected
Magnets	Reused	Cuboid magnets retained from previous season; verified against 2026 mission requirement	✓ PASS — Pull-force tested at 2.3 kg; meets >1.5 kg mission requirement
Intel RealSense D435i	Reused	Depth camera retained from previous build; accuracy verified at multiple depths	✓ PASS — Depth accuracy verified at 0.5 / 1.0 / 2.0m; within 2% of specification

Table 17: New Vs Reused Justification

Thrusters (New): The company decided to invest in ApisQueen u2 thrusters as they meet the company's new design methodology.

Tether (New): The vehicle's tether was a new component as the company used VideoRay single cable buoyant tether.

Pneumatic Components (Reused): Various valves and fittings underwent performance and pressure tests to ensure safety and functional integrity under operational loads.

Here are some of the tests performed on reused components.

Pneumatic pistons (Reused): pressure-tested at 8 bar for 30 minutes, no leakage detected. These components directly serve the 2026 RFP

requirement to interact with objects across multiple spatial orientations, specifically the cap removal task, which requires a minimum grip force of 1.5 kg sustained across manipulators' full travel range.

Magnets (Reused): pull-force tested at 2.3 kg, meets 2026 mission requirement of >1.5 kg.

RealSense D435i (Reused): depth accuracy verified at 0.5/1.0/2.0m, within 2% of specifications. The 2026 RFP requires measurement of object dimensions and distances to within ±5 cm accuracy; depth accuracy verified at 0.5 m, 1.0 m, and 2.0 m within 2% of manufacturer specification confirms the sensor meets this requirement at all operationally relevant ranges, and its RGB output feeds the SLAM pipeline required for the 3D modelling task.

4.0 Safety and Risk Mitigation

A. Safety Rationale the Triple-Zero Initiative

Overflow Robotics operates under the **Triple-Zero Initiative:** Zero preventable injuries, Zero unplanned system shutdowns, and Zero environmental contamination. Every protocol below is a direct engineering response to an identified risk category across personnel, equipment, and operational safety.

Personnel Safety is managed through a three-tier competency system enforced by the Internal Safety Competency Audit (ISCA) (**Refer to Table 18**). No member operates above their certified tier. A Tier 3 supervisor must be present during all pool deployments.

Tier	Members	Authorized activities	Requirement
1	Observers, documentation	General lab access	Lab orientation
2	Mechanical assembly, fabrication	Tool operation, PPE-required tasks	Written competency test
3	Electrical, pneumatic, poolside ops	High-voltage, pressure systems, deployment	Formal ISCA certification

Table 18: Personnel Safety Requirements

Equipment Safety governs the ROV across its full operational cycle. Carbon fiber cutting is performed under a HEPA extraction unit. The electronics housing is pressure-tested to 0.6 bar (6m equivalent — 1.1× operating depth) before every in-water session. Following each pool test, the housing is opened and inspected for moisture, corrosion, and seal compression. A structured inspection log is maintained across all 60 testing sessions in the team's Notion workspace.

Operational Safety is managed through the Human-Machine Interface (HMI) protocol. The Pilot and Tetherman maintain unobstructed sightlines to the ROV at all times, with all commands confirmed through verbal call-and-response before any thruster activation. During airbag retrieval and pneumatic manipulator tasks, a dedicated Deck Safety Monitor is assigned responsible solely for tether management and poolside hazard monitoring while the Pilot focuses on the tasks.

Environmental Safety is embedded into material selection. **Encore** uses non-toxic expanded polyethylene foam and food-grade silicone O-rings exclusively, ensuring no hazardous discharge in the event of a structural breach.

B. Vehicle-Specific Safety Systems

Encore's safety architecture uses **Active** (software-enforced) and **Passive** (hardware-enforced) layers, each tied to specific mission task hazards:

Active — Hall-Effect Current Monitoring. Hall-effect sensors on the power distribution PCB monitor each thruster output. If any thruster exceeds 3A, the firmware triggers an automatic Current-Cutoff within 40ms while maintaining power to all remaining thrusters. *Mission relevance: the buoy anchor lateral approach brings the tether near Thrusters 5 and 6 entanglements without this protection risks motor burnout or arcing at the surface supply.*

Active — Dual Leak Detection Array. Two moisture sensors sit at the lowest point inside the electronics housing, **determined based on the vehicle's neutral position.** Detection triggers a visual HUD alarm, which is monitored by the Deck Safety Monitor, and an audio alert at the surface, initiating immediate emergency ascent. *Mission relevance: the pot retrieval task combines maximum operating depth with the pressurized airbag assembly, representing the highest simultaneous stress on the housing seal.*

Active — Depth-Triggered Overspeed Alert. If the descent rate exceeds 0.3 m/s below 4.5m, the system flags an alert. Added after pool testing showed the deflated airbag assembly generates 2.65N of negative buoyancy, creating an uncontrolled descent risk during pot retrieval.

Passive — Mesh-Grid Thruster Shrouds. All eight U2 thrusters are enclosed in 3D-printed shrouds with a maximum 8mm aperture, exceeding MATE specification MECH006 and

preventing finger contact at any approach angle. *Mission relevance: coral basket recovery operates in close proximity to substrate structures and diver safety lanes.*

Passive — 40 PSI Manual Bleed Valve. The topside pneumatic manifold includes a manual bleed valve that depressurizes the full system in under 2 seconds. Activated by the Deck Safety Monitor if a pneumatic line is compromised, a manipulator fails to return to neutral.

Passive — Rounded and Deburred Frame Geometry. All carbon fiber edges are routed to a 2mm radius and wet-sanded to 400 grits. *Mission relevance: during O-ball collection, deck crew handle the ROV immediately after retrieval while the tilted collection arms are still loaded sharp edges under mechanical stress are a direct laceration hazard.*

C. Safety Procedures and Workspace Management

Splash Zone: A 2-meter exclusion zone marked with safety tape surrounds the pool edge during all deployments. No electronic equipment other than the ROV, and no non-operational personnel, may enter this zone. The Tetherman operates from the boundary using a 3-meter handling extension.

Fabrication Safety: All soldering is performed at stations equipped with fume extraction and heat-resistant mats. A "hot iron in holder only" rule is enforced by the Tier 3 supervisor at all times. Conformal coating application is performed in a dedicated ventilated enclosure.

PPE: Eye protection and closed-toe footwear are mandatory for all poolside personnel. Gloves are mandatory for carbon fiber handling and pneumatic pressurization. The Tether-Safe policy prohibits loose clothing or jewelry within 1 meter of the tether spool.

Post-Incident Review: Every unplanned event is documented within 24 hours in Notion, capturing root cause, contributing factors, immediate corrective action, and long-term process change. Six incident reports were filed during the 2026 season; none of their root causes recurred after corrective actions were implemented.

5.0 Critical Analysis

A. Testing Methodology and Validation

Encore's testing program follows a structured **bottom-up validation framework** in which no system is integrated until its constituent components are independently verified. This

approach was chosen to isolate failure modes early, reduce integration risk, and ensure that performance data at each level is traceable to a specific design requirement.

The framework operates across four sequential phases (Refer to Table 19).

Each phase must pass before the next begins. Failures at any phase trigger a return to component-level diagnosis before re-integration.

Phase	Scope	Pass criteria	Tools used
Component	Individual parts (thrusters, sensors, PCBs)	Meets datasheet specification under load	Ammeter, oscilloscope, pressure gauge
Subsystem	Integrated groups (propulsion, electronics, sealing)	Meets derived requirement from mission analysis	Pool tank, logging software
System	Full vehicle, controlled conditions	Completes all predefined maneuvers within tolerance	Pool, HUD telemetry, stopwatch
Mission simulation	Full vehicle, competition-representative conditions	All 2026 mission tasks completed within time limits	Competition-format pool session

Table 19: Framework Phases

Component-level testing focused on thrusters and electronics. Each ApisQueen U2 thruster was submerged individually and tested at 25%, 50%, 75%, and 100% throttle to measure thrust output, current draw, and thermal rise over a 10-minute sustained run. Acceptance criterion: current draw must not exceed 9A at full throttle and housing temperature must not exceed 45°C. All eight thrusters passed on first test.

Subsystem-level testing focused on sealing integrity and propulsion performance. The electronics housing was pressure-tested to 0.6 bar (6m equivalent, 1.1× operating depth) using a hand pump and dial gauge before any in-water deployment. Propulsion performance was measured as time-to-depth at 5.0m, with a target of under 30 seconds derived from mission task timing requirements.

System and mission-level testing was conducted weekly across 60 pool sessions totaling 700 hours. Performance data was logged each session and reviewed at the Thursday board meeting to drive the following week’s design

Metric	Value
Total testing sessions	60 sessions
Total pool time	700 hours
Issues identified	6
Issues resolved	6 — 100% resolution rate
Maximum depth tested	6.0 meters
Longest continuous operation	3 hours 15 minutes (Jan 26)
Consecutive clean mission sims required for sign-off	3

Table 20: System & Mission Level Testing

changes. Final validation required **Encore** to complete all predefined maneuvers, depth changes, station-keeping, obstacle avoidance, and all four 2026 mission tasks within competition time limits on three consecutive runs before the vehicle was declared competition-ready. (Table 20)

B. Troubleshooting Strategies & Diagnostic Techniques

Encore's troubleshooting methodology was built around a principle of evidence-first diagnosis: no component was replaced or modified until the root cause of a failure was confirmed through measurement. This discipline was enforced across all 60 pool sessions and resulted in six formal incident reports, none of whose root causes recurred after corrective action was applied.

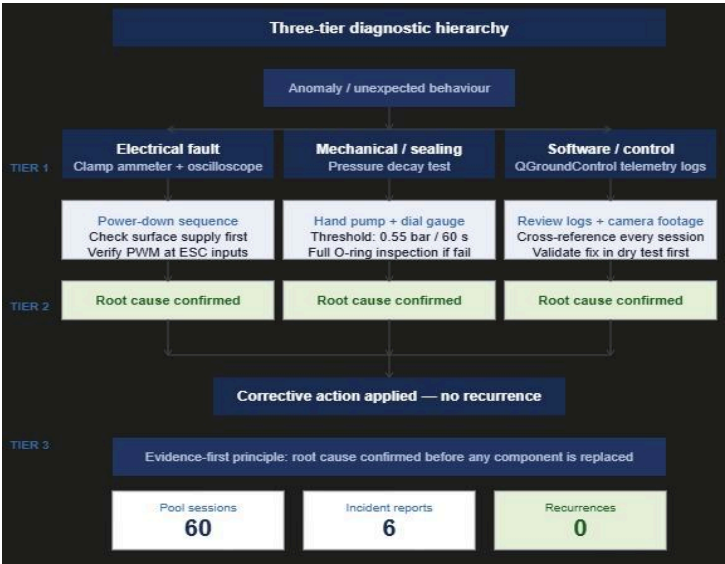


Figure 19: three tier failure approach

The team employed a three-tier diagnostic hierarchy depending on the nature and location of the fault:

Electrical faults were isolated using a structured power-down sequence. When an anomalous reading or unexpected behavior occurred, the system was first checked at the surface supply before any onboard component was examined. A clamp ammeter was used to measure per-thruster current draw in real time, and an oscilloscope was used to verify PWM signal integrity at the ESC inputs. This approach was instrumental in identifying a ground loop introduced during the integration of Side PCB 1, which caused intermittent camera dropouts. The fault was initially misattributed to a USB hub failure; current measurement at the affected rail revealed a 0.3 A offset that led directly to the real cause of a shared ground path between the camera power rail and the Jetson's 19 V input.

Mechanical and sealing faults were diagnosed using a pressure decay test conducted with a hand pump and calibrated dial gauge before every in-water session. Any reading below 0.55 bar within 60 seconds of pressurization triggered a full O-ring inspection and resealing procedure before the vehicle entered the water. This protocol identified two instances of O-ring compression set over the season, both detected pre-dives, preventing in-water flooding events.

Software and control faults were isolated using QGroundControl's telemetry logs, which were reviewed after every pool session alongside recorded camera footage. When the transect navigation system produced erratic corrections during pool session 14, log review revealed the issue was not in the algorithm but in inconsistent ambient lighting causing HSV threshold drift. The fix tightening the hue band and adding a brightness normalization step was validated in a dry test before the next pool session.

C. Prototyping & Iterative Development

Every mission-specific tool on **Encore** reached its final design through a minimum of two physical prototype iterations, each informed by quantified failure data from the previous version. The team adopted a build-measure-fix cycle in which no iteration advanced without a clearly defined success metric, ensuring that design changes were driven by data rather than intuition.

Prototype iteration outcomes — build-measure-fix cycle					
System	Proto.	Approach	Key metric	Result	Status
Airbag retrieval system					
Airbag — thrust only	P1	Increased PWM ceiling	26 A at full load	Exceeds 25 A fuse	Rejected
Airbag — foam block	P2	Rigid closed-cell foam bonded to bracket	+40 s setup time	Single-point dependency	Rejected
Airbag — pneumatic bladder	P3	Centred inflatable bladder	+2.5 kg lift @ 6 bar	100% in time — 12 runs	Selected
One-way buoy anchor mechanism					
Anchor — steel hook	P1	Rigid stainless steel hook	15 attempts	40% first-attempt rate	Rejected
Anchor — magnetic	P2	Magnetic coupling	Design stage	Non-ferromagnet U-bolt	Rejected
Anchor — TPU funnel	P3	TPU funnel + flexible fingers + bearing wheel	360° approach tolerance	100% first-attempt	Selected
O-ball collection arms					
Arms — flat tray	P1	Flat horizontal tray	Pool: ascent speed	0% retention	Rejected
Arms — 10° tilt	P2	10° inward tilt	Pool: ascent speed	60% retention	Rejected
Arms — 15° tilt	P3	15° tilt (tested 10°–20° in 2.5° steps)	Bowl effect geometry	100% retention	Selected
Thruster configuration					
6-thruster vectored	P1	Carried from 2025 vehicle	Time to 4 m depth	48 s — exceeds 30 s target	Rejected
8-thruster 3D config	P2	3D-printed mock-up, float-tested Aug	Time to 4 m depth	<22 s — within 30 s target	Selected
Overall: avg. first-attempt success P1 → 28% Final validated versions → 100%					

Table 21: Prototypes iteration spreadsheet

Airbag retrieval system: The requirement was to lift a weighted pot exceeding **Encore's** continuous

vertical thrust capacity within mission time limits. Prototype 1 was a thrust-only approach with an increased PWM ceiling. Bench testing showed it would require 26A at full load, exceeding the 25A fuse rating and creating a thermal risk. Rejected. Prototype 2 was a rigid closed-cell foam block bonded to the pot retrieval bracket. Pool testing revealed that pre-rigging the foam before each run added 40 seconds of setup time and introduced a single-point dependency on the surface crew. Rejected. Prototype 3 was a pneumatically inflated centered bladder. Bench testing confirmed 2.5 kg of additional lift at 6 bars. Pool validation across 12 runs achieved 100% completion within time limits with no surface pre-rigging required. Selected.

One-way buoy anchor mechanism: The requirement was to thread a line through a U-bolt at depth. Prototype 1, a rigid stainless-steel hook, yielded a 40% first-attempt success rate across 15 pool trials; failure was caused by vehicle oscillation preventing precise angular alignment. Rejected. Prototype 2 introduced magnetic coupling, rejected at the design stage when the U-bolt material was confirmed as non-ferromagnetic 316 stainless steel. Prototype 3 was a TPU funnel with inward-facing flexible fingers providing 360° approach tolerance, attached to a bearing-mounted spooling wheel. After two iterations of finger geometry (the first version's fingers were too stiff and deflected laterally), the final version achieved 100% first-attempt success across all mission simulations.

O-ball collection arms: The requirement was to collect negatively buoyant O-balls and retain them during a 5.5 m ascent. Prototype 1, a flat horizontal tray, showed 0% retention as upward water flow at full ascent speed displaced every ball over the edge. Prototype 2 introduced a 10° inward tilt; pool testing improved retention to 60%, but balls were still lost at maximum ascent speed. Prototype 3 used a 15° inward tilt, determined empirically by testing angles from 10° to 20° in 2.5° increments. At 15°, the geometry creates a bowl effect that uses the ball's negative buoyancy to hold it against the ascent flow. Pool testing achieved 100% retention with no additional mechanisms or pilot inputs.

Thruster configuration: The original six-thruster vectored layout from the 2025 vehicle was carried into the early 2026 design phase as Prototype 1. Force analysis simulations and initial float tests revealed it could not sustain the vertical thrust required for repeated 4 m depth cycling within

mission time limits. A 3D-printed mock-up of the eight-thruster 3D configuration was assembled on the existing frame within one week and float-tested in August. Time-to-depth improved from 48 seconds to under 22 seconds - well within the 30-second target - validating the configuration for full fabrication.

Across all four development tracks, the iterative process reduced average first-attempt success rates from 28% on Prototype 1 to 100% on the final validated version, demonstrating that the team's build-measure-fix methodology was the primary driver of competition readiness.

6.0 Acknowledgements

The success of Overflow Robotics and the development of **Encore** were made possible through the collaborative efforts of our partners, mentors, and community. We extend our deepest gratitude to the following:

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MATE ROV Egypt & MATE Center: We are immensely grateful for their invaluable technical support. MATE ROV Egypt, in particular, was instrumental in navigating the complexities of the registration process and providing solutions to critical challenges.

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8.0 Accounting

A. Budget

Income source	Projected income	Actual income	Type	Description
Employee dues	\$5,020	\$5,020	Cash	Monthly employee dues — \$145/member
Mid Year Camp	\$290	\$320	Self-Fund	Mid Year Camp profit
Funding Booth	\$150	\$150	Donations	Funding booth donations
Robotics Events	\$100	\$100	Donations	Robotics courses / Events profit
TOTAL INCOME	\$5,560	\$5,590	+\$30 above projection	

Table 22: Total Income & income sources

At the beginning of the season, Overflow Robotics adopted a responsible and proactive approach to budgeting, drawing on insights from the previous year’s financial records alongside research into local suppliers to secure reasonable pricing for major components. Each sub-team contributed detailed cost assessments and technical justifications for their proposed expenses. After review and approval by the CEO and CFO, teams proceeded with technical development while ensuring that design decisions remained aligned with the established financial plan. In addition to direct technical expenses, portions of the budget were allocated to team identity and outreach initiatives such as team apparel, marketing materials, and social media engagement, which support visibility and long-term sustainability. A significant portion of the project funding was achieved through self-funding efforts by team members, supplemented by organized fundraising activities throughout the season. These included the establishment of fundraising booths, hosting a mid-year robotics camp, and organizing robotics-related events that both supported financial needs and promoted STEM engagement within the community. For travel planning, a structured budget allocation was provided to each team member, encouraging personal responsibility for expenses and fostering a culture of accountability. Overall, the budgeting process enabled effective resource allocation while

maintaining financial sustainability, supporting both the technical development of the ROV and the broader growth of Overflow Robotics’ initiatives. (Refer to Table 22 for estimated cost and total income spreadsheet).

B. Cost

Economic instability and component price fluctuations in Egypt required continuous budget reassessments. (Refer to Table 23 for total project value) To maintain financial responsibility without sacrificing ROV reliability, Overflow Robotics adopted cost-efficient engineering solutions. High import tariffs and international market volatility heavily impacted the cost of essential electronics and specialized tools. In response, the team minimized expenses through targeted fundraising, fair resource allocation, and a strict "make vs. buy vs. recycle" evaluation. While demanding more design and manufacturing effort, custom in-house fabrication and material reuse successfully reduced costs while maintaining high performance standards.

Category	Budgeted (USD)	Actual (USD)	Variance
General & admin	\$1,998.00	\$1,892.50	+\$105.50 saved
Electrical & vision	\$1,565.00	\$1,478.00	+\$87 saved
Mechanical systems	\$1,470.00	\$988.00	+\$482 saved
Float	\$187.00	\$174.00	+\$13 saved
Training	\$30.00	\$30.00	\$0
TOTAL OUT OF POCKET	\$5,250.00	\$4,562.50	+\$687.50 (13.1% under)
Reused components (fair market value)	—	\$1,528.00	—
Donated items & services (FMV)	—	\$380.00	—
TOTAL PROJECT VALUE	—	\$6,470.50	—

Table 23: Total Project Value

Item	Unit rate	Units	Est. total (USD)	Notes
➔ AIRFARE — CAIRO (CAI) → ST. JOHN'S (YYT), ROUND-TRIP				
Economy class airfare per person	\$1,050/person	8	\$8,400	Via Montreal/Toronto — estimate Jun 2026
Checked baggage fee per bag	\$60/bag	16 bags	\$960	2 bags per person avg (1 personal + 1 equipment)
ROV equipment excess/oversize fee	\$200 flat	1	\$200	One-time charge for oversized ROV crate
Airfare subtotal			\$9,560	
🏠 ACCOMMODATION — ST. JOHN'S / VENUE AREA				
Hotel nightly rate per room	\$130/night	4 rooms	\$130 × 4	Double occupancy — 2 persons per room
Competition nights	\$520/night	5 nights	\$2,600	Mid-range hotel; book early — rates spike competition week
Extra nights (arrival + departure)	\$520/night	2 nights	\$1,040	1 arrival night + 1 departure night
Accommodation subtotal			\$3,640	7 nights × 4 rooms × \$130
🚗 GROUND TRANSPORTATION — ST. JOHN'S				
Car rental (full-size / minivan)	\$80/day	7 days	\$560	Enough capacity for team + equipment transport
Fuel estimate	\$50/day	7 days	\$350	Airport ↔ hotel ↔ venue daily runs
Airport transfers (arrival + departure)	\$60 flat	2	\$120	Group taxi/shuttle if no rental on arrival day
Transportation subtotal			\$1,030	
🍽️ MEALS & DAILY EXPENSES				
Meals per person per day	\$40/person	8 × 7 days	\$2,240	Estimate — mix of team meals and individual expenses
Meals subtotal			\$2,240	
ESTIMATED GRAND TOTAL — 8 persons			\$16,470	Airfare \$9,560 + Hotel \$3,840 + Transport \$1,030 + Meals \$2,240

Table 24: Estimated travel expenses in USD

9.0 SID

A. Electrical SID:

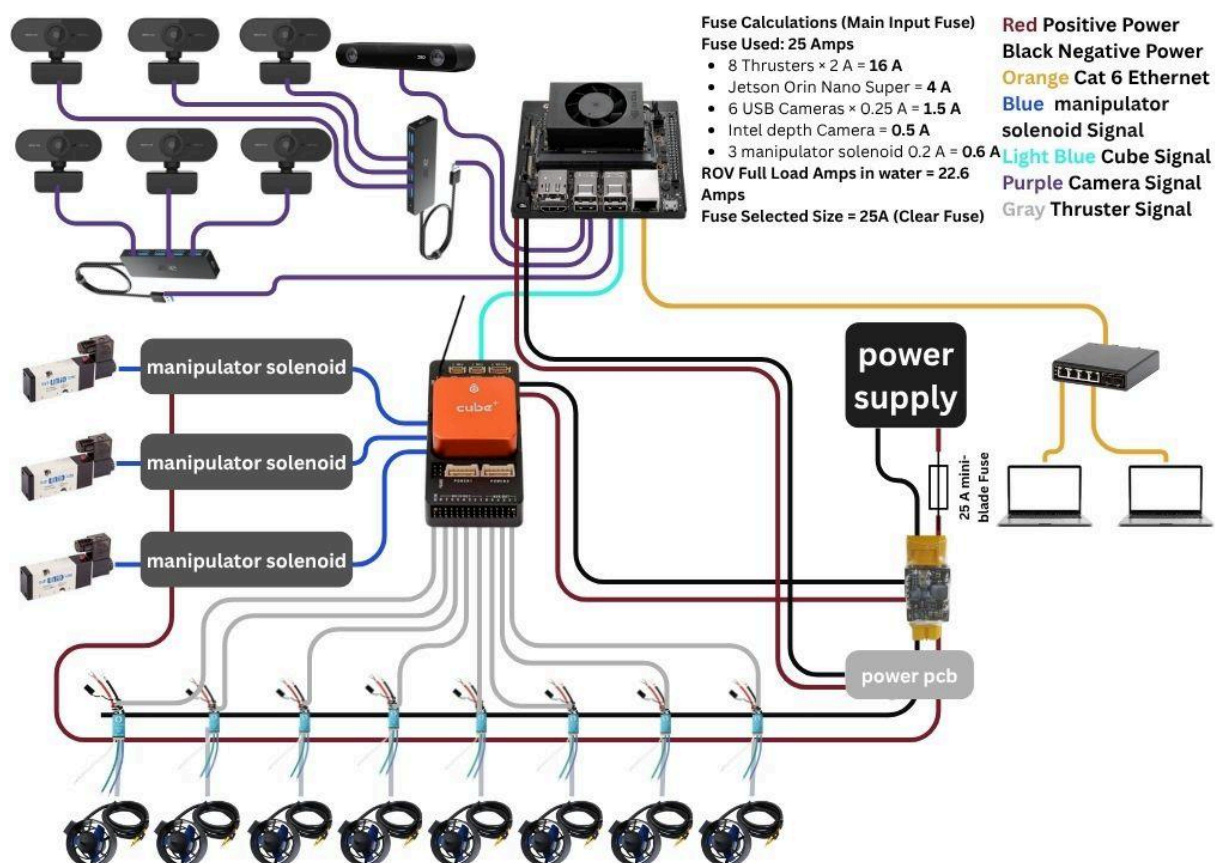


Fig 20: Electrical SID

B. Pneumatic SID:

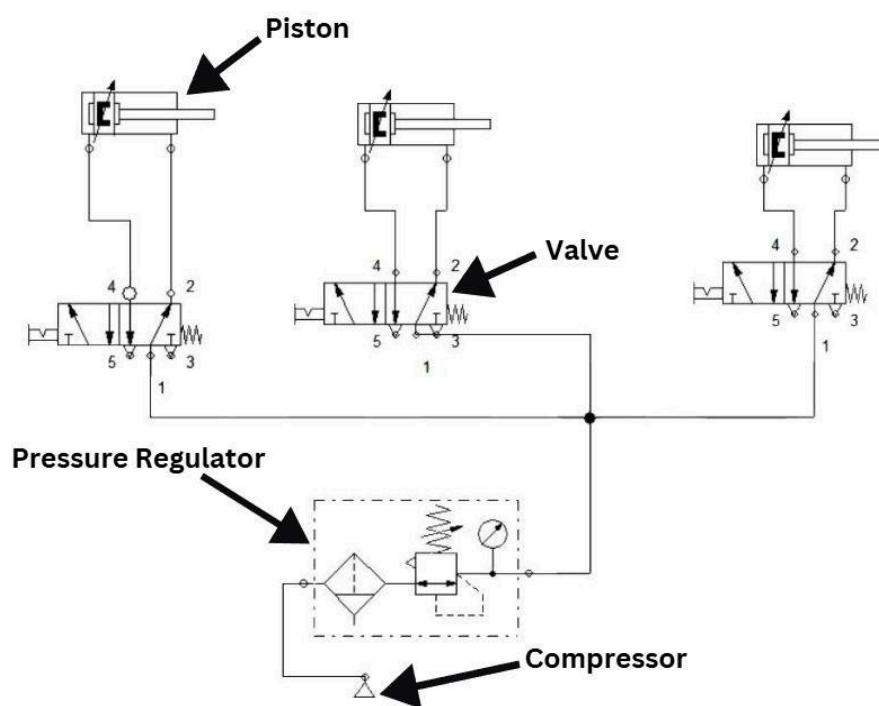


Fig 21: Pneumatic SID

10.0 Appendices:

A. Total Cost

Item	Description	Qty	Status	Category	Budget (\$)	Cost (\$)	Diff (\$)
GENERAL							
Registration	Regional registration	1	Fees	General	200	187.5	+12.5
International	International registration	1	Fees	General	300	280	+20
Thruster	Apisqueen U2	8	New	General	500	498	+2
ESC	Blue Robotics 30A	3	New	General	100	103	-3
Tether	VideoRay buoyant tether	2	Donated	General	0	0	0
Pool	700 hours	700	Fees	General	500	450	+50
Utilities	Internet, electricity	4	Fees	General	250	258	-8
Marketing	Flyers, posters	2000	New	General	80	74	+6
Tools	Screwdrivers, bits, caliper	21	New	General	68	42	+26
ELECTRICAL							
Nvidia Jetson	Orin Nano Super	1	New	Electrical	250	249	+1
Cube pilot	Cube Orange	1	New	Electrical	350	385	-35
SSD	WD NVME 256gb	1	New	Electrical	35	55	-20
Power brick	Cube power brick	1	New	Electrical	30	30	0
PWM expander	PWM expander	1	New	Electrical	10	8	+2
Depth camera	Intel RealSense D435i	1	Reused	Electrical	0	0	0
Camera	HD webcams	8	New	Electrical	350	252	+98
USB hubs	Anker 4 port 3.0 hub	2	Reused	Electrical	0	0	0
PCBs	3x custom PCBs	15	New	Electrical	150	126	+24
PCB components	Resistors, capacitors, transistors	150	New	Electrical	200	180	+20
Connectors	XT 60 & MT 60	100	New	Electrical	60	75	-15
Fuses	Fuses	500	New	Electrical	50	41	+9
IMU	IMU BNO055	1	New	Electrical	50	48	+2
Pressure sensor	Blue Robotics Bar030	1	Reused	Electrical	0	0	0
Cables	HDMI, Ethernet	4	New	Electrical	30	29	+1
MECHANICAL							
Carbon fiber	6 layer 100x50 cm sheet	1	New	Mechanical	250	257	-7
HDPE	Sealing box body	1	New	Mechanical	70	65	+5
3D printing	PETG, TPU	150	New	Mechanical	350	95	+255
Rubber silicon	1x1M	3	New	Mechanical	50	47	+3
Chemical sealing	Epoxy, ekflx, silicone spray	15	New	Mechanical	100	88	+12
Pneumatic	Pistons, pistons	20	Reused	Mechanical	0	0	0
Pneumatic	Compressor	1	Donated	Mechanical	0	0	0
Fasteners	Screws, nuts, bolts	1000	New	Mechanical	250	150	+100
Magnets	Cuboid magnets	16	Reused	Mechanical	0	0	0
PVC	Pipes, joints	50	New	Mechanical	150	139	+11
Machining	CNC laser, center lathe, router	11	New	Mechanical	250	147	+103
FLOAT							
Motor drivers	IBT2	4	New	Float	30	23	+7
ESP 32	ESP 32 38 devkit	3	New	Float	12	12	0
Linear actuator	Buoyancy engine motor	3	New	Float	45	41	+4
SD card	Kingston 32gb	3	New	Float	30	27	+3
HDPE	Float body and end caps	1	New	Float	40	42	-2
Weights	Metal parts for buoyancy	8	New	Float	20	22	-2
Batteries	Batteries for float power	9	New	Float	10	7	+3
TRAINING							
Raspberry Pi 5	Pi 5 8gb	6	Sponsored	Training	0	0	0
Raspberry Pi Pico	Pi Pico	12	Sponsored	Training	0	0	0
Components	Final project	3	New	Training	30	30	0
TOTAL		4,395			\$5,250	\$4,562.5	+\$687.5

Table 25: Total Cost Breakdown

B. Safety Checklist



SAFETY CHECKLIST

PROJECT / MISSION: _____

DATE: _____

CREW / OPERATOR: _____

LOCATION: _____



SAFETY FIRST
Think safe, act safe, be safe.



WEAR PPE
Use appropriate personal protective equipment.



STAY ALERT
Be aware of your surroundings and the task at hand.



COMMUNICATE
Use clear communication and follow all protocols.


TETHER

BEFORE USE

- ☐ Straighten and eliminate any kinks in the tether.
- ☐ Safely plug the tether into the control box.
- ☐ Secure strain relief to prevent accidental disconnection from the control box.
- ☐ Inform other employees about the deployed tether to prevent accidental stepping.
- ☐ Attach the strain relief to the ROV.
- ☐ Connect the tether to the ROV.

POST-RUN

- ☐ Safely disconnect the tether from the control box.
- ☐ Safely disconnect the tether from the ROV.
- ☐ Neatly roll up the tether on the hose reel.


ON-DECK

- ☐ Follow the tether setup protocol.
- ☐ Connect the power supply and set it to 12v.
- ☐ Power up the ROV.
- ☐ Test the thrusters and claws.
- ☐ Verify camera views on the designated deck screens.
- ☐ Carefully lower the ROV into the water.
- ☐ Release any trapped air bubbles.
- ☐ Await the "ready" signal from deck crew.
- ☐ Initiate launch with a countdown.


PRE-RUN

- ☐ Inspect electrical power connections.
- ☐ Perform a dry run to ensure unobstructed and functional cameras.


POST-RUN

- ☐ Power off the Control Box.
- ☐ Turn off the power supply.
- ☐ Follow the tether disconnect procedure.
- ☐ Dry the ROV and place it safely on the cart.


FABRICATION

- ☐ **CARBON FIBER CUTTING:** Ensure HEPA extraction is active and cut-resistant gloves are worn.
- ☐ **SOLDERING:** Use activated fume extraction, place soldering iron on heat mat, and strictly observe "hot iron in holder only" rule.
- ☐ **PRESSURE TESTING:** Verify all pressure gauges are zeroed and at least two personnel are present throughout the test.
- ☐ **CONFORMAL COATING:** Apply coating only within a confirmed, running ventilated enclosure.



IMPORTANT REMINDERS

- Never work alone. Always have a buddy.
- Report any issues or damage immediately.
- Do not take shortcuts. Follow every step.
- Stop work if an unsafe condition exists.

SIGN-OFF

OPERATOR: _____

SIGNATURE: _____

 **SAFETY IS EVERYONE'S RESPONSIBILITY. THANK YOU FOR WORKING SAFE!**

Fig 22: Safety Checklist