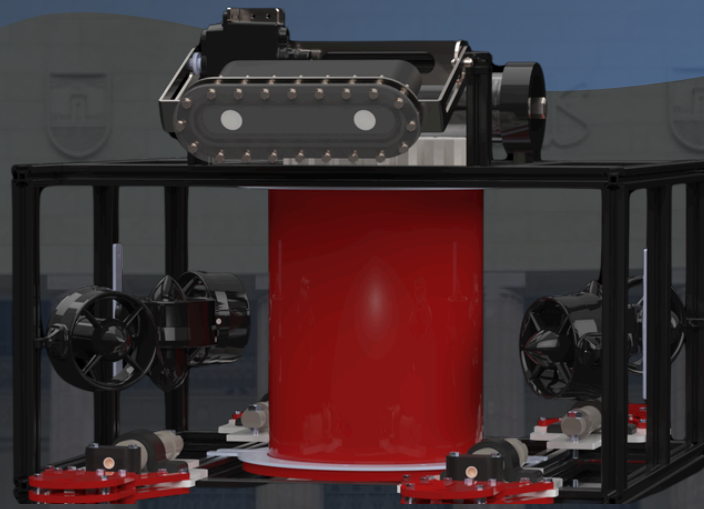


NEPTUNE-X



TITANS ROBOTICS TECHNICAL DOCUMENTATION

ALEXANDRIA UNIVERSITY
ALEXANDRIA, EGYPT



COMPANY STRUCTURE

SOFTWARE ENGINEERS

28' Marwan Eltete *CEO*
27' Hamdy Ahmed *CFO*
27' Youssef Emara *FM*
27' Ali Ahmed *CV/ML Lead*
29' Mohamed Ashraf *Control Lead*
28' Yassin Khaled *TDR & PR Lead*
27' Salma Hassanien *Media Lead*
26' Youssef Elgazar*
27' Ammar Elsaadany*
27' Aya Aziz*
27' Fajr Muhammad*
27' Mostafa Ghalwash*
28' Abdelrhman Hazem*
28' Ahmed Hany*
28' Amr Kenawy*
28' Farah Fawzy*
28' Jana Mehanna*
28' Tasneem Ashraf*
28' Mariam Elshamy*
28' Mostafa Elshafey*
28' Youssef Mohamed*
29' Rodina Ghazaly*

MECHANICAL ENGINEERS

HS' Nouraldeem Hassanien *FM*
26' Ahmed Hatim*
26' Seif Elsayed*
27' Mohamed Hany*
27' Yousab Youssef
28' Ahmed Farouk*
28' Mohamed Youssef*
28' Saifeldeen Khafagi*

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20' Esraa Moghazy*
27' Ahmed Fawzy*
28' Mohamed Samir*
28' Omar Tabouna
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Graduation Year

*Denotes New Members

*HS : High School

FM : Functional Manager

TDR : Technical Documentation

PR : Public Relations

ABSTRACT

Titans Robotics Team from Alexandria University is a group of students dedicated to developing underwater robotic systems. Our main goal is to design solutions that facilitate sea exploration, support the maintenance of underwater structures, and enable environmental monitoring. By integrating knowledge from mechanical, electrical, and software engineering, we aim to build practical systems with real-world impact.

For the MATE ROV 2026 competition, we designed and built our ROV, **NEPTUNE-X**. The name is inspired by Neptune, the Roman god of the sea, representing the underwater environment in which the vehicle operates, while the “X” symbolizes exploration and advanced engineering. This reflects the ROV’s ability to operate efficiently and reliably under challenging underwater conditions.

During the development of **NEPTUNE-X**, we focused on creating a practical and user-friendly system. The ROV features a modular design that allows for easy adjustment and maintenance, along with a control system that enhances operator interaction and usability. It can perform tasks such as shipwreck inspection, buoy maintenance, environmental monitoring, and water sampling.

The development process involved multiple stages, from initial concept design to testing and iterative improvements, with emphasis on system stability, safety, and reliability.

This report presents the design approach, teamwork, and testing procedures.



Figure 1. Titans Robotics Photo By Abdullah Fawzy



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Company & Personnel Overview

Titans Robotics operates as a student-led engineering team focused on pushing the boundaries of subsea robotics.

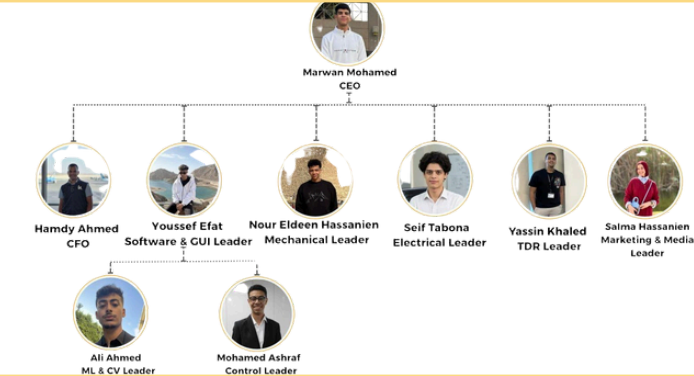


Figure 2 : Company Structure
Corporate Structure & Leadership

Position	Responsibilities
CEO	Defines the overall strategy, sets long-term goals, and manages external relations and partnerships
CFO	Oversees financial planning, budgeting, and resource allocation
Leaders	Coordinate between team members, manage workflow, and ensure tasks are completed on time and aligned with team objectives
Members (Technical & Non-Technical)	Contribute to project execution across different domains, including engineering, programming, marketing, media, and documentation, while collaborating with leaders for guidance and direction.

Table 1: Corporate Structure

Project Management Schedule

In September, the entire team collaborated on comprehensive project planning. This phase involved defining the overall project scope, setting a timeline, and dividing the project into clear development phases. During this time, we also established Key Performance Indicators (KPIs) to assess progress, evaluate departmental productivity, and identify areas requiring additional support. These KPIs are revisited regularly to ensure alignment with project goals.

Phase 1: R&D and Recruitment (September – November 2025)

This phase focused on two parallel efforts:
R&D: We performed a detailed analysis and enhancement of the previous ROV model (MEGATRON) and float system. Issues identified in past performance were addressed, and new design opportunities were explored.
Training and Recruitment: New team members were onboarded and trained in department-specific fundamentals (e.g., PCB design, SolidWorks, embedded systems). Cross-training sessions promoted interdisciplinary awareness.

Phase 2: Design and Ideation (December 2025– January 2026)

Following the release of the official competition manual, this stage combined R&D findings with new requirements to brainstorm and develop the new vehicle concept. Each subsystem (mechanical, electrical, software) proposed initial designs, which were reviewed and refined collaboratively. This stage also involved the design of mission-specific tools and payloads

Phase 3: Manufacturing and Assembly (February– March 2026)

Subsystems moved into fabrication and assembly. Mechanical components were 3D printed or machined, electrical systems were soldered and tested, and software was integrated into embedded systems. Interdepartmental collaboration was critical to ensure timely handoffs and efficient integration

Phase 4: Debugging and Continuous Improvement (April 2026)

This will be a critical and iterative phase where each subsystem will undergo rigorous testing. Extensive in-water tests in competition-simulated environments will be conducted. Tools and payloads will be refined based on performance, and operational reliability will be prioritized. Continuous debugging cycles will allow us to improve both system response and operator control.

Phase 5: Post-Competition Enhancements (May – June 2026)

Based on competition feedback, the ROV's scope and performance will be optimized to improve efficiency, fault tolerance, and task automation for international readiness.

Key Milestones:

Milestone 1: MATE Regional Competition (April 22–25, 2026)

This milestone marked the completion of a full-system trial under competitive conditions, providing key insights and qualifying the team for the MATE International Competition.

Milestone 2: MATE International Competition (June, 2026) The ultimate test: competing at the World

This milestone represents the team ultimate goal where Titans Robotics competes on a global stage against the world's top ROV teams.

ROV Project Gantt Chart

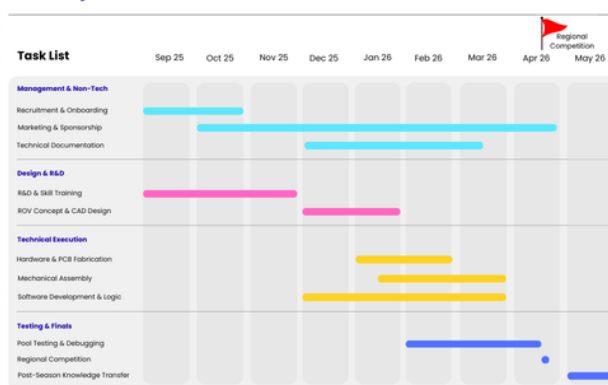


Figure 3: Project Gantt Chart



Resource, Procedure, & Protocol Management

To maintain a high Operational Tempo, we operate on a framework established during our August planning phase. We prioritize agility and traceability, ensuring that every engineering decision is backed by data and every resource is used to its maximum potential.

Resource	Usage Area
Slack → Discord	Started with Slack during training phase, then transitioned to Discord for more efficient team communication, coordination, and real-time collaboration
GitHub	Version control, code management, and collaboration on software and system integration
Google Drive	Organizing documents for leadership, subteams, and administrative workflows
Google Photos	Storing and sharing media from pool testing, events, and project milestones

Table 2 : Communication Protocols

DESIGN RATIONALE

Engineering Design Rationale

Mechanical Design Design Methodology:

The design process followed a systematic engineering approach:

- Defining mission requirements
- Brainstorming concepts
- Trade-off analysis
- CAD modeling
- CFD simulation
- Prototyping and testing
- Final optimization

Vehicle Structure



Figure 4 : NEPTUNE-X Structure

NEPTUNE-X uses a modular open-frame aluminum structure that provides good strength, easy access for maintenance, and balanced force distribution.

The total mass is 17.8 kg, which we optimized to keep the structure strong without adding unnecessary weight that could affect buoyancy and maneuverability.

The overall dimensions are 830 mm in length, 560 mm in width, and 440 mm in height. All dimensions in the figures(5 & 6) are in millimeters (mm).

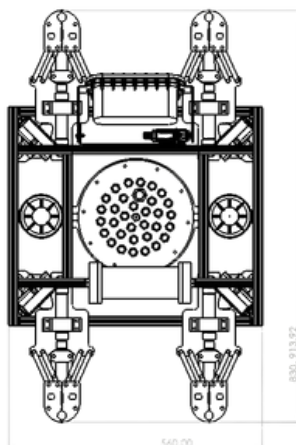


Figure 5: NEPTUNE-X Structure top view

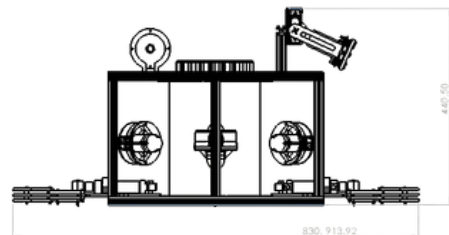


Figure 6: NEPTUNE-X Structure side view

Propulsion System

In NEPTUNE-X, The aim was to utilize an optimal number of thrusters and appropriate types to maintain all necessary degrees-of-freedom for smooth maneuvering. After multiple tests with various thruster configurations and numbers, six thrusters were selected in order to support NEPTUNE-X's size and weight under water. The chosen configuration for the thrusters was the vectored configuration with four horizontally-mounted thrusters each at a 30°/60° angle in order to achieve stable horizontal movement and even force-distribution across the frame of NEPTUNE-X and two vertically-mounted thrusters to enable heave and roll movements.

Thruster Configuration

The choice of six thrusters enabled NEPTUNE-X to have the necessary degrees-of-freedom: surge, sway, heave, yaw, and roll.

The vectored configuration was selected following a comparison with an alternative configuration mounting two thrusters facing the front and back, two facing the sides, and two mounted vertically. The test showed that having the thrusters mounted in this configuration achieved semi-stable movement with the relatively big size of NEPTUNE-X, as it exhibited positional drift along unintended axes, while horizontal movement with the vectored configuration was significantly more stable since forces were distributed across the corners of the frame. The two vertical thrusters were retained in the vectored configuration as the vertical movements were of lower operational demand.

Direction	Maximum Thrust
Upward	$2 \times 3.55 = 7.1 \text{ Kg}$
Downward	$2 \times 3.0 = 6 \text{ Kg}$
Forward	$4 \times 3.55 \times \sin(45) = 12.0 \text{ Kg}$
Backward	$4 \times 3.0 \times \cos(45) = 10.2 \text{ Kg}$
Lateral	$(2 \times 3.0 \cos(45)) + (2 \times 3.55 \times \sin(45)) = 9.19 \text{ Kg}$

Table 3: Propulsion system

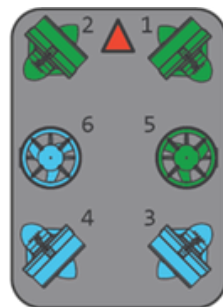


Figure 7 : Thruster Configuration



Thruster Fixation



Figure 8: Thruster Fixation

The 30°/60° angled thruster mounts, manufactured using PETG 3D printing, enable multi-directional movement for the four horizontal thrusters. This new design provides a rigid, small and compact mounting structure that securely holds the thrusters at fixed angles 30° toward the forward and backward directions and 60° laterally replacing last year's 45° configuration. The change enhances forward/backward speed, improving maneuverability and reducing the need for additional thrusters. The two vertical thrusters retain the previous year's 90° aluminum mounts. This resulted in smoother control and better overall stability during operation.

ZED 2i Camera Enclosure

The ZED 2i camera enclosure is manufactured from Aluminum 7075-T6 and features an acrylic front face with an O-ring face seal to ensure reliable waterproofing. Aluminum 7075-T6 was selected over HDPE because of its superior stiffness and thermal conductivity. Although aluminum adds more weight, it provides better sealing integrity by reducing deformation under pressure and improves heat dissipation from the camera during operation. The enclosure also integrates a sealed 180° servo mechanism, allowing controlled rotation of the camera for wider field coverage while maintaining full waterproof integrity. In addition, the design separates the sealing interface from the mounting structure, which enhances overall reliability, minimizes the transfer of vibration to the sealing area, and makes maintenance and disassembly easier.

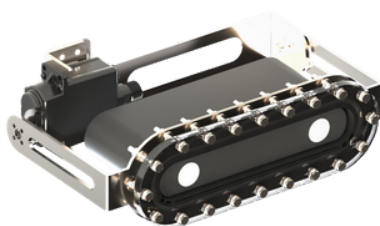


Figure 9: ZED Enclosure

Main Enclosure

A cylindrical HDPE housing is used, featuring a face seal with an O-ring to ensure reliable waterproofing. The sealing system is designed to operate with a pressure rating up to 5 bar, making it suitable for the expected underwater conditions. Acrylic cracking caused by uneven stress distribution across the sealing surface was a major issue encountered during testing. This issue was resolved by introducing a load-distribution ring, which ensures uniform pressure on the acrylic face. This improvement significantly enhanced sealing performance, reduced the risk of leakage, and minimized material fatigue over repeated use.

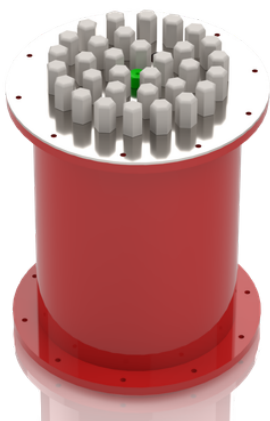


Figure 10: NEPTUNE-X Main Enclosure

Material Selection

Materials were selected based on a deterministic-engineering trade-off analysis, considering key factors such as strength, weight, corrosion resistance, manufacturability, and cost. The final approach adopted aluminium extrusion, as it provides an optimal balance between structural rigidity and weight reduction, while also enabling modular assembly and ease of manufacturing. Additionally, aluminum offers good corrosion resistance in underwater environments and allows for efficient heat dissipation, making it well-suited for the system's operational requirements as shown in table.

	HPDE	Acrylic (PMMA)	Aluminum	PLA	Stainless Steel 304
Density (g/cm ³)	1	1.2	2.7	1.24	8
Impact Strength (J/m)	260	74	294	96.1	325
Flexibility (MPa)	24	71	90	80	540
Cost	Moderate	Moderate	Moderate	High	Moderate

Table 4 : Mecahnical Matrials



CFD Analysis

CFD simulation at 0.7 m/s revealed flow disturbances caused by the open-frame design and sharp edges.

High velocity regions formed around structural edges, while low-velocity wake regions developed behind the cylindrical housing. This pressure difference increased drag force, reducing propulsion efficiency.

Flow separation and vortex formation were observed, leading to energy losses and unstable flow behavior.

Based on these results, design improvements included:

- Reducing sharp edges
- Optimizing component spacing
- Improving thruster placement

These modifications enhanced hydrodynamic efficiency and stability during operation.

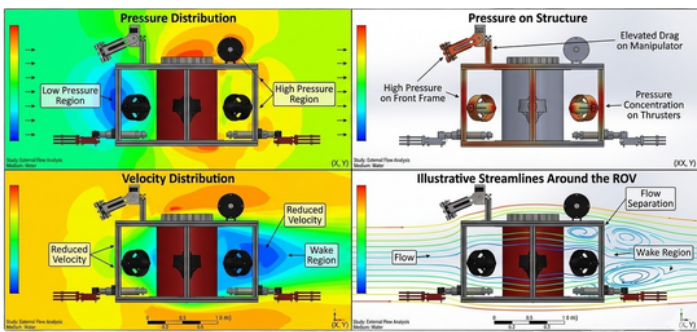


Figure 11: CFD Analysis Diagram

Buoyancy and Stability

During the initial assembly stage, NEPTUNE-X was negatively buoyant due to the combined weight of the structural frame, pressure housing, and mounted subsystems. To correct this, buoyancy foam was added to the upper region of the vehicle until neutral buoyancy was achieved. This solution provided two key benefits. First, it reduced the continuous thrust demand on the vertical thrusters, improving energy efficiency during depth control. Second, placing the foam above the main mass helped raise the center of buoyancy relative to the center of gravity, improving restoring stability and resulting in smoother underwater motion.

The final configuration was tuned to achieve near-neutral buoyancy, allowing the vehicle to maintain depth more efficiently while preserving overall stability during operation.

System approach

NEPTUNE-X was developed using a systems-based design approach. This ensured smooth integration between mechanical, electrical, and software subsystems. We broke down mission objectives into specific design requirements, ensuring every component had a clear purpose within the overall system. To make informed design choices, we conducted trade studies that evaluated options based on cost, efficiency, manufacturability, reliability, and system performance. We researched past ROV designs, competitor methods, and industry standards. This helped us implement proven solutions and introduce improvements, including a 3 IP camera monitoring network, an NVIDIA Jetson Nano for onboard computing, a ZED 2i stereo camera for depth perception, and a dual-PCB architecture to reduce EMI interference and enhance signal stability. A collaborative, interdisciplinary approach ensured seamless integration among subsystems. This reduced compatibility issues and improved reliability. Mechanical, electrical, and software teams collaborated closely, maintaining continuous communication to ensure that subsystem designs aligned with the overall system. We prioritized redundancy and risk management based on industry practices and our past experiences. We used an iterative design process, relying on simulations, prototyping, and testing to refine NEPTUNE-X's performance. Subsystems were validated individually before integrating the full system.

This helped us spot and fix potential issues early in the development process. By continually validating our design through real-world tests, we ensured that every choice was backed by data and optimized for the mission. This structured, research-based method made NEPTUNE-X a high-performance, adaptable, and reliable ROV. It can efficiently complete mission tasks while maintaining stability and robustness.

Software Testing and troubleshooting: Software Testing

To ensure reliable operation during missions, NEPTUNE-X's software system underwent a structured testing process that combined controlled experiments with real-world trials.

Component Testing

Each software component was tested independently before integrating the system. The team validated the vision processing, telemetry, and control modules in test environments to confirm correct functionality and stable performance.

Sensor and Camera Validation

The ZED 2i stereo camera is crucial for perception and data processing, so it was tested in controlled underwater conditions. The camera was placed inside its enclosure and submerged prior to full ROV integration to check its sealing, image quality, and depth perception reliability.



System Integration Testing

After validating the individual modules, the team conducted full system integration tests to ensure proper synchronization between sensors, onboard computing, and control systems. These tests confirmed stable communication, real-time processing performance, and reliable telemetry transmission.

Problem Solving

For NEPTUNE-X, our approach to problem solving was guided by a simple principle: understand before acting. We never rushed to fix symptoms; instead, we first observed, analyzed, and mapped out the system's behavior.

Whenever an issue appeared, our first instinct was to ask: What is really happening, and why? By breaking challenges down to their root causes and considering how each subsystem interacted with others, we ensured that our solutions were precise, effective, and sustainable.

This mindset shaped everything we did. For example, when depth measurements fluctuated unpredictably underwater, we did not just tweak the algorithm. We examined patterns in the data, questioned the assumptions behind our stereo processing, and methodically tested adjustments. Through this process, we identified a combination of confidence thresholds and local averaging that stabilized measurements — a solution born from deliberate analysis rather than trial-and-error.

Similarly, when processing multiple streams of sensor and vision data threatened to overload our onboard computer, we approached the problem by stepping back and evaluating the flow of computation. By thoughtfully distributing tasks between NEPTUNE-X and a surface computer, and optimizing models for efficiency, we were able to maintain real-time performance without sacrificing functionality.

Across every challenge, our strategy remained consistent: observe, analyze, isolate, iterate, and validate. This structured approach allowed us to transform obstacles into opportunities for improvement, ensuring that NEPTUNE-X operates reliably and efficiently under complex mission conditions. In essence, our problem-solving process was not just about addressing issues — it became a guiding framework for the entire development, shaping how we designed, tested, and refined NEPTUNE-X.

Innovation

This year, the team implemented several key innovations to enhance NEPTUNE-X's performance, with a focus on computational capability, sensing accuracy, control efficiency, and task execution.

In an effort to achieve more stability and control in the harsh environments in Canada, we searched for a solution and found an option in ArduSub called position hold; this option required us to purchase a DVL sensor, but it costs near \$8,700 USD, so we utilized the ZED 2i's localization and a custom-implemented ROS2 node that enabled us to have the position hold functionality without buying a DVL.

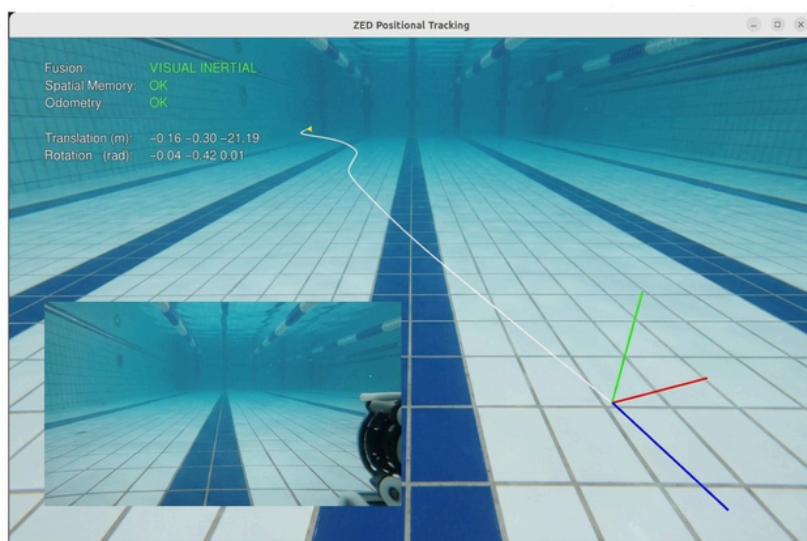


Figure 12: NEPTUNE-X's Path Tracking

Payload & Tools

1. Manipulators

After three prototypes, we finally found success with our current design. The first prototype made with PMMA (Acrylic) exhibited insufficient structural integrity, requiring a switch to a fiberglass-reinforced polyethylene in the second prototype, which also proved insufficiently rigid for operational loads. Finally, the third prototype, made with HDPE (high-density polyethylene), proved to be durable and effective. NEPTUNE-X has 4 horizontal (axial) grippers designed to provide greater accessibility, enabling the simultaneous handling of multiple objects to enhance efficiency and save time.



Figure 13: Gripper



2. Rotating tool

To clean the Holyrood subsea observatory camera, we designed a rotational tool using a bilge pump motor controlled by a Cytron motor driver for adjustable direction and speed. A copper coupler on the pump shaft interfaces with a custom 3D-printed U-shaped adapter that engages and rotates the inner plastic sheeting, ensuring the required color passes the window three full times to satisfy task completion criteria.



Figure 14: Bilge Pump

3. Rope tool

Carabiner-Based Mounting System.

A lightweight modular mounting system uses a metal carabiner with a T-joint interface for quick deployment and recovery, offering stable load distribution via a cylindrical extension for alignment. Heavy-duty cable ties replace rigid fasteners to minimize weight, simplify assembly, and provide corrosion resistance and shock absorption, resulting in a cost-effective, maintainable solution with minimal weight addition.



Figure 15: Metal Carabiner & T-joint

Vision System

NEPTUNE-X's vision system is designed to provide comprehensive situational awareness, centimeter-level spatial measurement, and real-time object detection through a multi-camera architecture consisting of one stereo depth camera and three auxiliary IP cameras.

ZED 2i Stereo Camera

Central to our depth-sensing architecture is a high-resolution stereo camera with dual 4-MP sensors (2688×1520 pixels), which facilitates real-time spatial mapping, positional tracking, and metric-accurate depth estimation. These functionalities are essential to our navigation pipeline and serve as the primary sensor driving our 3D reconstruction pipeline. Its stereo baseline allows for metric depth estimation, and onboard inertial sensing ensures stable positional tracking throughout the reconstruction and navigation processes.

Camera Configuration & Strategic Placement

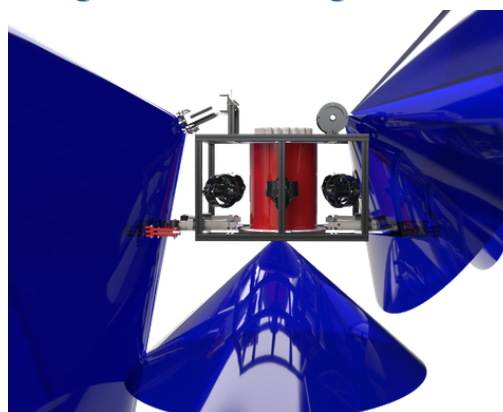


Figure 16: Cameras Viewing Angels

Each camera position was selected through deliberate analysis of task geometry, pilot visibility requirements, and subsystem coverage. The resulting configuration provides broad operational awareness while assigning dedicated sensors to the most critical task zones. This layout allows the pilot to maintain control during navigation, seabed inspection, reversing maneuvers, and manipulation, while also ensuring that the software team receives high-quality visual input for detection, measurement, and reconstruction.

Stereo Camera (Forward / Navigation)

Mounted on a high-torque servo motor, the stereo camera can tilt upwards to survey all five numbers on the iceberg (Task 2.2) and downwards for close-range structural inspection, while also allowing the pilot to clearly observe the two front grippers during manipulation tasks. It serves as the primary sensor for depth mapping, positional tracking, and dense point cloud generation.

IP Camera 1 — Bottom-Facing

Dedicated to crab detection and downward navigation, this camera provides a near-perpendicular view of the seabed, which is the preferred geometry for both AI-based detection and precise ground-plane awareness. This placement reduces perspective distortion and improves consistency between the dataset used for training and the live imagery used during deployment. It also gives the pilot a stable view for bottom-aligned maneuvering and target inspection.



IP Cameras 2 & 3 — Rear Enclosure

One camera provides a direct rear view for reversing maneuvers, while the second is angled to deliver a rear-down perspective for continuous monitoring of the frame structure and gripper mechanisms.

All three cameras are unified through a single Gigabit PoE switch, consolidating power delivery and data transmission into a single cable pathway. This architecture eliminates cable redundancy, minimizes signal overhead, and ensures stable, high-throughput feeds across all channels simultaneously.

Video Streaming

Our streaming system was designed around two separate pipelines, with each one optimized for the type of camera being used onboard. The stereo camera streams locally using RTP at 720p and 60 FPS, taking advantage of the Jetson Nano's hardware-accelerated encoding to provide real-time visual and spatial data while keeping computational load low. For the IP cameras, GStreamer pipelines are used to deliver low-latency RTSP streams with stable image quality. These streams can be accessed from multiple operator laptops at the same time, which gives the team more flexibility at the control station and ensures continuous visual feedback during operation. Using separate pipelines for stereo and IP cameras improves reliability across different camera types and network configurations.

Image processing & Color Restoration

Underwater photography suffers from light attenuation where red and yellow channels degrade with increasing depth, compromising object detection accuracy. A real-time color restoration pipeline using the Gray World Assumption filter was developed to address this. Gray World was selected over Histogram Equalization following a comparative R&D evaluation for its stability in low-light conditions and absence of visual artifacts

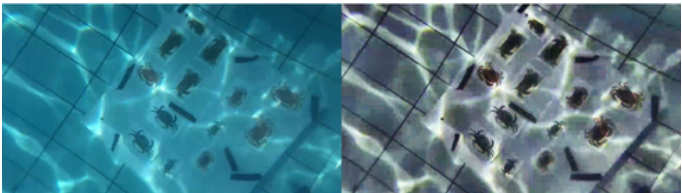


Figure 17 : Color Restoration Result

The initial Python implementation produced insufficient and inadequate frame rates on the Jetson Nano under concurrent AI workload. Rewriting the pipeline in C++ with optimized OpenCV recovered 5–10 FPS, resulting in a consistent 60 FPS output stream and eliminating pilot-facing latency.

Camera Calibration

Calibration was performed separately for each camera type to address their distinct optical characteristics. ChArUco marker-based calibration was applied to all IP cameras to eliminate fisheye distortion introduced by their wide-angle lenses. The stereo camera underwent dedicated calibration optimized for metric accuracy and depth consistency, establishing precise intrinsic and extrinsic parameters essential for stereo measurement tasks. All calibration data is pre-loaded and applied in real time throughout operations.



Figure 18 : Stereo Calibration Marker Detection

Crab Detection

Detecting European green crabs on a complicated seabed background faces two primary challenges: variable target orientation and high background noise. Standard axis-aligned bounding boxes fail to handle diagonally oriented crabs effectively, capturing excessive background and reducing confidence scores. Oriented Bounding Boxes (OBB) were implemented instead, aligning each detection window to the crab's principal axis and reducing background noise inside the detection windows by approximately 30%, resulting in sharper localization. A custom dataset of 600 images was built from NEPTUNE-X's camera footage to ensure domain-specific training data. It was expanded from 400 images using synthetic instance-pasting and geometric augmentation to correct orientation class imbalance, resulting in a 30% improvement in the Mean Average Precision over the initial baseline model, with the pipeline maintaining stable detection under low-visibility and complex seabed conditions.

Model performance Comparison

The following table summarizes the benchmark results across all evaluated YOLO architectures:

Metric	YOLOv11(Small)	YOLOv26(Nano)	YOLOv26(Small)
Precision (P)	99.9%	98.6%	99.2%
Recall (R)	100.0%	95.2	98.4%
mAP50 - 95	0.937	0.933	0.964
Parameters	9.41 M	2.37 M	~5.4 M
Inference Time	13.2ms	14.1ms	13.8ms

Table 5: Evaluation Metrics

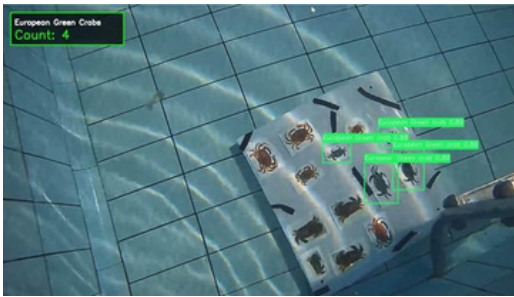


Figure 19: Crabs Detection

Depth Measurement Approach

Precise spatial awareness is achieved through a dual-panel interface that synchronizes high-fidelity RGB imagery with real-time depth maps. This system allows the operator to visually identify targets while the back-end architecture resolves 3D coordinates via stereo disparity computation. To ensure measurement integrity in challenging underwater conditions, we implemented a Confidence Thresholding Filter. This filter autonomously rejects depth samples affected by turbidity (stirred-up silt) or specular reflections, ensuring only high-reliability data enters the calculation stream. Furthermore, to counteract sensor jitter, we applied a Window-based Spatial Averaging algorithm. We selected this approach because it effectively suppresses noise while preserving the sharp geometric edges required for accurate structural inspection. The final output is processed through a Euclidean Distance Transform, yielding centimeter-accurate dimensions. This 'digital ruler' ensures our measurements remain well within the mission's 5 cm tolerance window, providing the pilot with a highly reliable metric for complex 3D tasks.

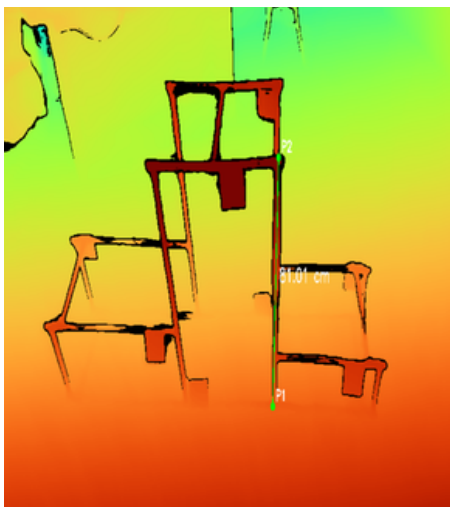


Figure 20: Stereo Depth-Based Measurement

Hardware Optimization

To remain within the Jetson Nano's constrained computational budget, we designed a distributed processing architecture that separates high-demand workloads from onboard real-time tasks. Stereo processing and computationally intensive AI operations are offloaded over the local network to a surface laptop GPU, while the Jetson Nano manages onboard data acquisition, stream handling, and lightweight inference. The crab detection model was further optimized using TensorRT with FP16 quantization, reducing latency and increasing throughput. This architecture allowed the system to sustain reliable real-time performance without overloading the embedded platform.

Coral Garden 3D Modeling

Reconstructing the coral garden in Task 1.2 demands a method that preserves true metric scale, captures all eight measurement targets within a single unified coordinate frame, and produces a point cloud dense enough to support accurate height and length estimation. After extensive evaluation of available reconstruction approaches, we selected stereo-based Spatial Mapping as our primary method, with instant-ngp as a validated backup pipeline. This choice provided the best balance between metric consistency, reconstruction speed, hardware compatibility, and mission practicality.

3D Reconstruction Tradeoff Matrix

The table below summarizes our comparative evaluation across three candidate reconstruction approaches:

Approach	Target Quality	Pipe Quality	Processing	Hardware	Edge
Spatial Mapping	Accurate	Moderate	Real-time	Stereo cam + GPU	Real-time accurate point cloud
DUST3R (Local)	Moderate	Moderate	Fast	6-16GB VRAM CUDA 11.8+	Local, multi-view best perf.
Instant-NGP (Local)	High	Moderate	Moderate	RTX 3060 CUDA	Fast training, no depth cam

Table 6 : 3D Approaches Evaluation

Electrical System

Electrical System Design

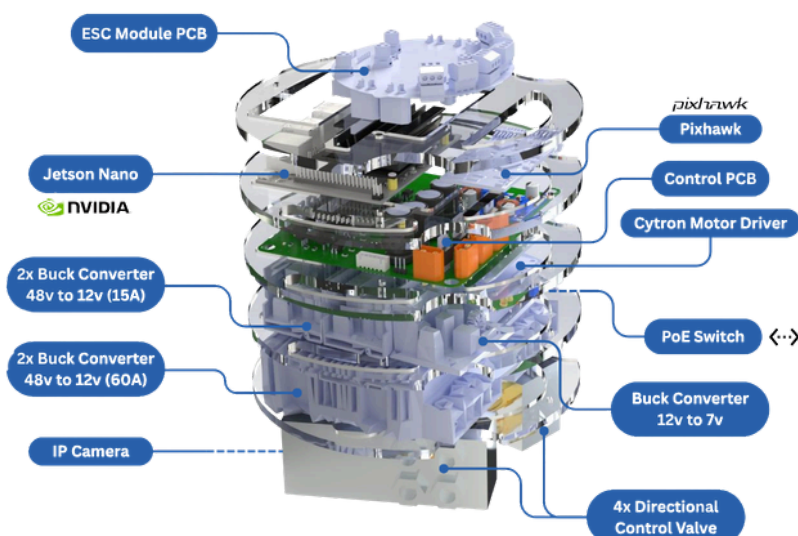


Figure 22: Electrical System Diagram

System Overview

NEPTUNE-X's electrical system was designed to ensure reliability, modularity, and operational safety in underwater environments. The system supports propulsion, sensing, actuation, and onboard computation while maintaining electrical isolation from the surrounding environment. The architecture emphasizes efficient power distribution, simplified maintenance, and stable operation under varying load conditions.

To achieve this, the electrical system is divided into three primary subsystems :

- Power Distribution
- Control Electronics
- Sensors and Actuators

This modular design allows individual subsystems to be tested, replaced, or upgraded without affecting the overall vehicle operation.

Power Distribution and Management

NEPTUNE-X utilizes a centralized power distribution architecture to efficiently deliver high current to propulsion systems while supplying stable low-voltage power to sensitive electronics.

High-current loads, including thrusters and auxiliary motors, are supplied through DC-DC buck converters rated at 120A. This rating was selected after evaluating the maximum

• Power calculation

The provided power supply delivers 48V at 30A, with a maximum available power of 1,440W. The table below presents the power consumption of the system.

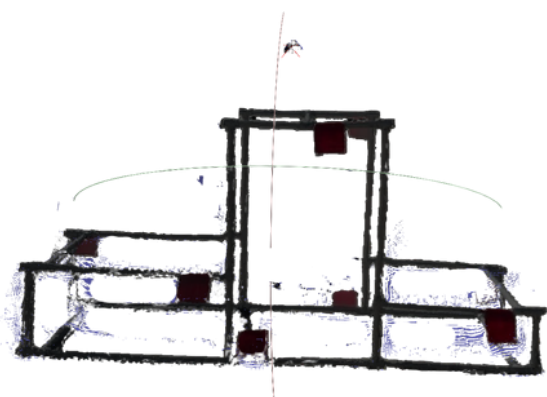


Figure 21: Dense Point Cloud Output

At Titans Robotics, safety is not an afterthought it is a core value embedded in every aspect of our work. We believe that innovation and safety must go hand in hand to achieve sustainable excellence. Our team adheres to industry best practices, international safety standards, and MATE ROV competition regulations, with a strong emphasis on proactive risk management and continuous preventive measures. Every team member is empowered and expected to take ownership of safety by identifying hazards, proposing mitigations, and maintaining compliance across all activities. We foster a culture of accountability through regular assessments, collaborative reviews, and open communication. This approach ensures that our work environment remains secure, efficient, and conducive to high-performance engineering



	Quantity	Voltage (V)	Current (A)	Power(W)	Total (W)
Thruster	6	12	15	180	1080
ESC	6	12	0.15	1.8	10.8
Bilge pump	1	12	4	48	48
Jetson Nano	1	5	3	15	15
Pixhawk	1	5	0.125	0.625	0.625
DCV	4	12	0.3	3.6	14.4
Z Camera	1	5	0.5	2.5	2.5
Underwater Servo	1	7	3	21	21
					1192.325

Table 7 : Power Calculation

Current Rating = $1192.325/48$. 22.95A
so we used fuse 25A

Control Electronics and PCB Design

NEPTUNE-X's control electronics are masterfully consolidated on a custom PCB, delivering a compact, efficient layout that slashes wiring clutter, enhances signal integrity, and eases maintenance amid testing and high-stakes competitions. By smartly segregating high-current power paths from delicate signal traces, we ensure rock-solid reliability and minimal electrical noise.

MOSFET control is flexible and proven:

1. Optocoupler Gate Drivers: Optocoupler gate drivers bridge Pixhawk's weak signals with electrical isolation and amplification, switching grippers (four DCVs), servos, and bilge pumps—directly carrying forward last year's battle-tested success.
2. Embedded Arduino Nano: A compact, reliable unit embedded directly into the PCB, streamlining low-level tasks, cutting wires, sharpening signals, and simplifying diagnostics that receives signals serially from the NVIDIA Jetson nano.

Power flows safely through fused lines, filtering capacitors, and protective circuits, stabilizing voltage for propulsion and auxiliaries without faults.

This elegant integration transforms complexity into confidence robust, adaptable, and primed to power NEPTUNE-X to victory.

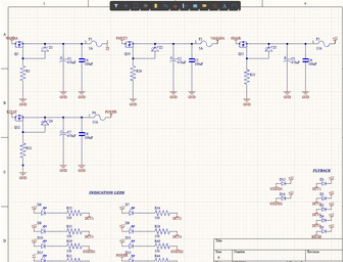


Figure 23: safety circuits

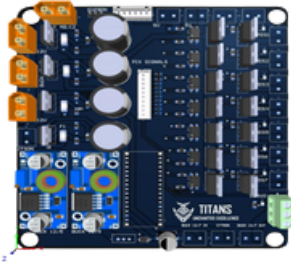


Figure 24: Control PCB

Power PCB

Power PCB consists of 6 ESCs and connectors for the thrusters; the input power to the ESC by the XT60 connector for high current rating can deal with 60A. As for the signal, there is a JST connector consisting of 6 pins that goes to the signal pin in the ESC and gets the signal from Pixhawk. The trace width in the PCB is calculated to transmit the current from the ESC to the thruster without heating.

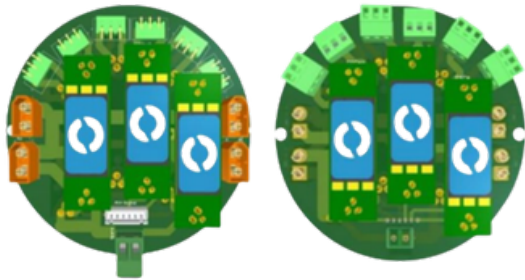


Figure 25: Power PCB

• ESC module

Each ESC is individually mounted on compact, removable PCB modules and connects directly to the Power PCB using robust, polarized MT-30 connectors. This modular approach simplifies maintenance, significantly reduces downtime, and prevents potential damage associated with traditional soldered ESC connections

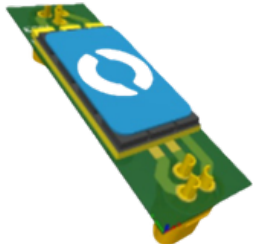


Figure 26: ESC Module

Actuation and Motor Control

NEPTUNE-X uses multiple electric actuators, including thrusters and auxiliary motors, to achieve full maneuverability and mission capability. Thrusters are controlled through Electronic Speed Controllers (ESCs), enabling precise control of speed and direction. A brushless DC (BLDC) motor is integrated to drive mission-specific tools and payload mechanisms. BLDC motors were selected due to their high efficiency, reliability, and compatibility with electronic control systems.

Tether

The tether serves as the ROV's critical lifeline, enabling power delivery, high-speed data transmission, and pneumatic control while maintaining the flexibility, buoyancy, and robustness required for effective underwater operation. Its design was developed to meet MATE's RFP specifications while ensuring safe, efficient, and streamlined operation under competition conditions. The tether consists of the following components:

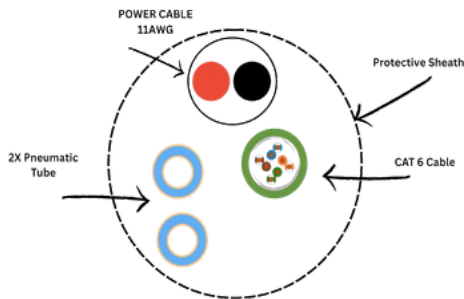


Figure 27 : Tether

• Power Cable:

An 11 AWG two-core power cable (4mm² in diameter) delivers 48V DC to the ROV. This choice is based on the current carrying capacity of the cable (up to 45A) and minimal voltage drop (approximately 0.4% over 25 meters), ensuring stable power delivery throughout the mission.

• Data Cables:

Cat6 Ethernet cable (23 AWG) are used for high-speed communication. This cable supports up to 10 Gbps, making it suitable for real-time video streaming and control.

• Pneumatic Tubes:

Two 6mm polyurethane tubes, rated for 10 bar, deliver air to the pneumatic grippers. This ensures that the system operates safely at the 2.75 bar required for the grippers while preventing overpressure or failure. The tether is 25 meters long, chosen to meet the 5.5-meter pool depth and the 10-meter horizontal distance from the poolside specified by MATE. The additional length provides extra slack, allowing the ROV to move freely without risk of entanglement or excessive tension. All cables are organized and protected within a braided cable sleeve to prevent abrasion and mechanical damage. The sleeve maintains flexibility and reduces tangling, ensuring the tether remains organized and secure during operation. A strain relief mechanism is implemented at the ROV side to absorb movement cable damage. This strain relief system minimizes mechanical stress, ensuring the tether's integrity and reducing the risk of operational failure. To maintain neutral buoyancy, sections of the tether are covered with closed-cell foam at strategic intervals along its length. This ensures that it remains manageable during ROV operations, reducing drag and minimizing potential entanglement or tension-related issues.

Tether Management System: The Tether Management System is designed to ensure efficient and safe handling of the Tether during deployment, operation, and retrieval.

Pre-Deployment: The tether is carefully inspected for wear or damage. It is coiled and stored in a manner that minimizes tangling, ensuring a smooth deployment process.

During Operation: A tether manager actively monitors the tether, ensuring that it remains untangled and has adequate slack for unrestricted ROV movement. The manager adjusts the length as needed to prevent the tether from becoming tangled, reducing the risk of snagging or damage.

Post-Operation: After mission completion, the tether is carefully retrieved, inspected for any signs of wear, and stored in a clean, dry environment to preserve its longevity. Proper storage ensures the tether's durability for future missions.

Control System

• Control System Architecture

NEPTUNE-X's control system follows a distributed three-layer architecture where mission processing, real-time flight control, and peripheral I/O are handled by comparatively selected hardware based on processing capabilities, power efficiency, features, and cost, ensuring stable flight communication, modular subsystem control, and structured data flow.

Purpose-built hardware was used for building this architecture: mission processing and command distribution are handled by the NVIDIA Jetson Nano, real-time flight control and stabilization are managed by the Pixhawk, while peripheral I/O and actuator control are handled by the Arduino Nano, ensuring that the execution of critical tasks is assigned to the most suitable processor.

Feature	NVIDIA Jetson	Intel NUC	Raspberry Pi 5
Processing Power	High	Very High	High
Power Consumption	Moderate	Very High	High
4K Video Streaming	Yes	Yes	Yes
CUDA Support	Yes	No	No
Integrated AI Capabilities	Yes	Yes	No
Hardware I/O	Good	Moderate	Extensive
Cost	Moderate	High	Low

Table 8 : Control System Architecture Comparison

Layer 1: Mission Processing & Perception Layer (Jetson Nano)

Topping the control hierarchy, Jetson Nano receives pilot commands by connecting to the topside surface station over Ethernet through the tether, supporting routerless operation with any Ethernet-capable laptop. The Jetson hosts the following software modules:

MAVLink Bridge (mavp2p): Relays Pixhawk feedback (depth, orientation, mode) to the surface GUI and manages flight mode switching.



Figure 28: NVIDIA Jetson nano



Heartbeat Failsafe Protocol:

Monitors the communication link between the topside station and Jetson Nano. A thruster disarm via MAVLink is triggered if no heartbeat is received within a defined timeout (default: 5 seconds), maintaining the NEPTUNE-X's current depth until control is restored.

Video & Depth Stream Relay:

Compresses and streams the ZED 2i RGB feed, depth data, and ML inference overlay to the topside GUI over Ethernet.

Serial Command Interface: Triggered by pilot controller inputs, it forwards gripper and servo commands to the Arduino over USB Serial.

Layer 2: Flight Control Layer (Pixhawk / ArduSub)

Running ArduSub firmware and operating independently of Jetson's compute load, the Pixhawk manages all time-critical flight operations. It receives MAVLink commands from Jetson Nano and generates PWM signals for the T200 thrusters.

The Pixhawk's EKF continuously fuses IMU and Bar30 data to estimate orientation and depth, driving PID corrections that actively oppose current-induced drift maintaining the position of NEPTUNE-X while Jetson Nano processes ZED 2i imagery.



Figure 29: Pixhawk

Layer 3: Peripheral I/O Layer (Arduino)

Low-level actuator operations outside the flight controller's scope are managed by the Arduino. The Arduino receives servo commands from the Jetson over USB serial and translates them into digital signals for gripper and actuator control.

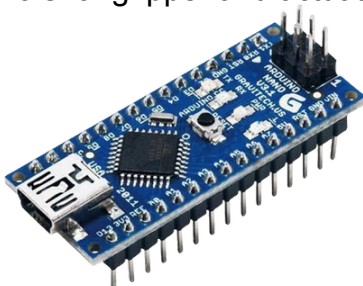


Figure 30: Arduino Nano

Control Modes and Mission Applications

To ensure precise maneuverability and stability during mission tasks, NEPTUNE-X utilizes multiple control modes tailored to specific operational requirements managed by the Pixhawk's ArduSub firmware. Each mode enhances NEPTUNE-X's ability to execute competition tasks efficiently and precisely, ensuring optimal performance in executing mission-critical tasks during the Competition.

Control Mode	Mechanism	Mission Application
Stabilize Mode	Pixhawk allows manual control while automatically correcting roll and pitch angles, preventing sudden tilts and ensuring smooth navigation.	Task 1.3: Hold position over coral garden in flume tank Tasks 2.5 & 3.2: Stable hover for fine manipulation.
Depth Hold Mode	Pixhawk locks the ROV at a fixed depth, ensuring consistent positioning while allowing free horizontal movement.	Task 1.2: Consistent altitude for photogrammetry image overlap. Task 2.2: Precise depth for iceberg keel measurement.
Manual Override	Full pilot authority; all stabilization disabled. Direct PWM control via topside joystick.	Scenarios that require full manual control.

Table 9 : Control Modes

The internal IMU provides real-time orientation data, while the external Bar30 pressure sensor accurately measures depth. This combination enhances navigation accuracy by ensuring precise depth control and stable maneuvering during mission tasks.



Figure 31: Bar30

Software Design

- Custom Topside app (Yester)



Our top side app reduced operational complexity. In the previous season, we encountered major issues that delayed our progress and caused considerable problems during testing. Therefore, we developed new features in our GUI that had not been introduced previously.

- One of our major issues was during the pilot selection phase. Each pilot had a unique preference for controller settings. Therefore, a dedicated menu was developed within the GUI to configure the controller settings for each pilot, and a dedicated profile was created for each pilot to simplify the transition instead of manually reconfiguring the settings before each operation



Figure 32: YESTER controller settings

The second major issue involved camera settings, frame rate, and quality. Since these parameters are dependant on water conditions and mission requirements, adjustments were necessary. For instance capturing a target demanded higher image quality and frame rate; however this required greater computational resources. consequently, a dedicated menu was developed within the GUI, enabling the operator to alter the frame rate and image quality of each camera based on mission requirements

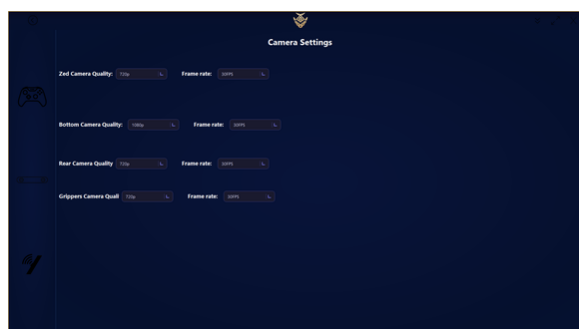


Figure 33: YESTER Camera settings

This major issue involved testing the motors individually, which was previously performed using QGroundControl. This process was time-consuming, as every time an issue occurred, the GUI had to be closed in order to launch QGroundControl, resulting in significant time and effort expenditure. Consequently, a designated menu named Yester was developed within the GUI, enabling individual motor testing and parameter configuration



Figure 34: YESTER motor test

- We developed an interactive 3D model that responds according to IMU readings and depth to detect NEPTUNE-X's orientation .

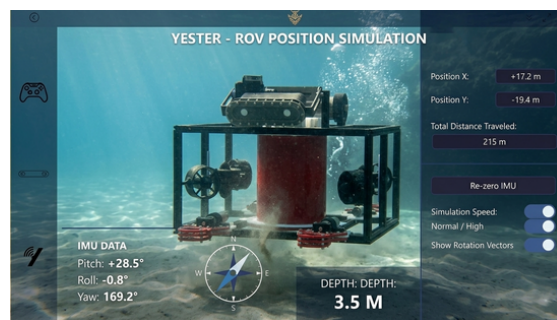


Figure 35: YESTER ROV position simulation

A proactively identified issue involved the integration of four grippers into the design, raising the challenge of ensuring efficient utilization of all four. Consequently, a feature was developed within the GUI enabling the operator to switch the camera feed from the main ZED camera to the two rear IP cameras while simultaneously reversing all controller settings, ensuring effective operation of the rear grippers

Custom Downside OS



One of the major issues that had not been encountered previously, and was addressed proactively before it developed into a critical issue this season, involved the integration of four grippers into the design. Since the pilot now operates four grippers, ensuring efficient utilization of all four presented a significant challenge. Consequently, a feature was developed within the GUI enabling the operator to switch the camera feed from the main ZED camera to the two rear IP cameras, while simultaneously reversing all controller settings, ensuring that the two rear grippers could be operated effectively and that navigation and task execution remained straightforward.

Vertical Profiling Float

Building upon last year's validated float design, we enhanced precision by increasing the pneumatic cylinder capacity to 150ml (from 60ml), enabling greater buoyancy control precision while retaining the unified aluminum extrusion core, stepper actuation, IR sensing, ESP32 integration, Bar30 for depth sensing, and lead-acid power. This targeted evolution eliminates past granularity limitations, enhances reliability in harsh underwater environments, and positions the system for optimal competition performance.

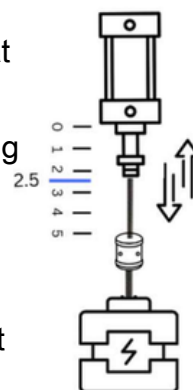


Figure 36: Floatilla mechanism



Build vs. Buy, New vs. Used

When designing NEPTUNE-X, we focused on achieving an optimal balance between reusing what already works, improving performance, and adding new ideas. Any component that demonstrated reliability in previous testing and was not limiting performance was reused to save time, reduce cost, and lower risk. This allowed us to focus more on developing and improving the systems that really impact how well the ROV performs during missions.

This year, our main focus was improving the ROV's intelligence, control, and overall efficiency. We upgraded the system by integrating Jetson Nano for better onboard processing, and expanding our manipulation capabilities. At the same time, we developed several custom-built components to better match our specific mission needs while keeping the system modular and easy to maintain.

By combining reused components, newly purchased technologies, and parts we built ourselves, we were able to create a system that is both reliable and capable of handling more advanced tasks, while staying flexible for different mission requirements.

Pixhawk Flight Controller	precise control system, enabling PID tuning and advanced features such as depth hold and stabilization modes
NVIDIA jetson nano	providing sufficient processing power for system control and data handling.
Thrusters (6 Units)	ensure full maneuverability with proven performance
Underwater Servo Motor	controlled rotation of the ZED2i, increasing field of view without moving the entire ROV.
Bilge Pump	durable and efficient mechanism for task 2.5

Table 10: reused (Purchased Systems)

Electronics Pod	waterproof enclosure that ensures protection of internal electronics, reduces risks
IP Cameras Enclosure	transparent waterproof enclosure enabling full camera visibility while ensuring protection
Manipulators (2 Units)	object handling, ensuring dependable performance while minimizing redesign effort.

Table 11: reused(In-House Systems)

ZED2i Camera	depth perception and vision capabilities for improved navigation and task accuracy.
Depth Sensor	accurate real-time depth data, essential for stable depth hold and precise control.

Table 12: New (Purchased Systems)

ZED Camera Enclosure	Waterproof housing ensuring protection and full rotational functionality
ROV Frame	Newly designed structure optimized for strength, stability, and modular component integration.
Manipulators (2 Units)	allowing multiple tasks to be completed in a single dive, reducing mission time.

Table 13: New(In-House Systems)

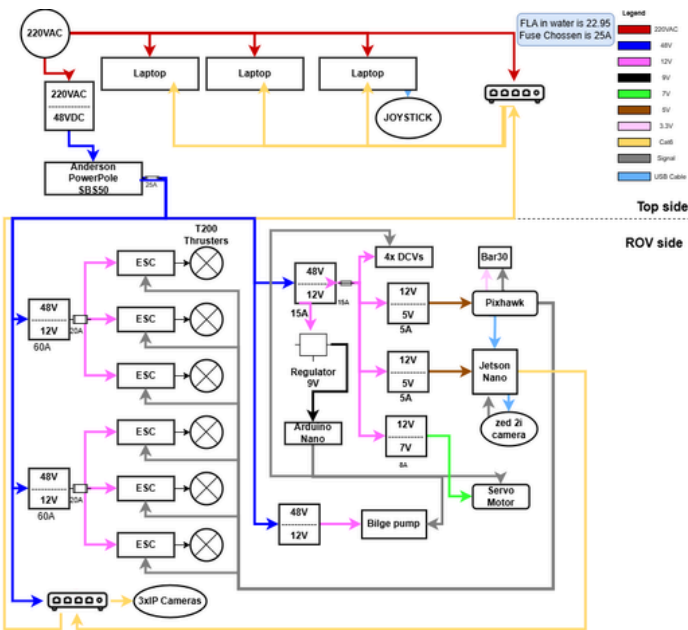


Figure 37: Electrical SID

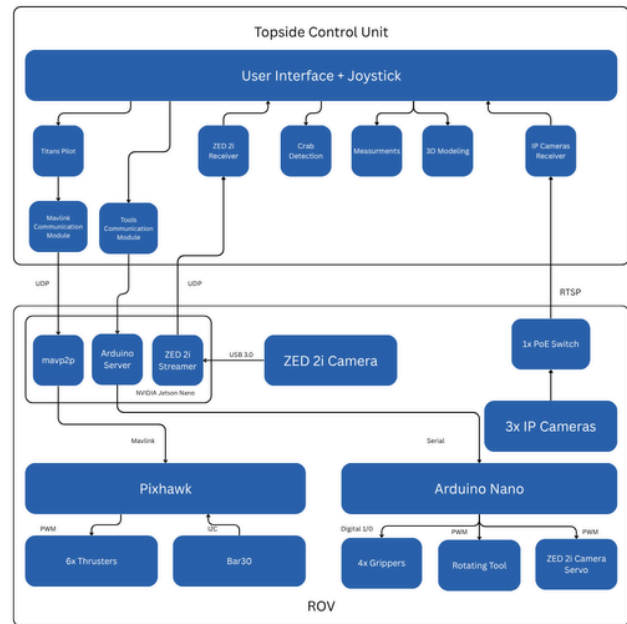


Figure 39: Software SID

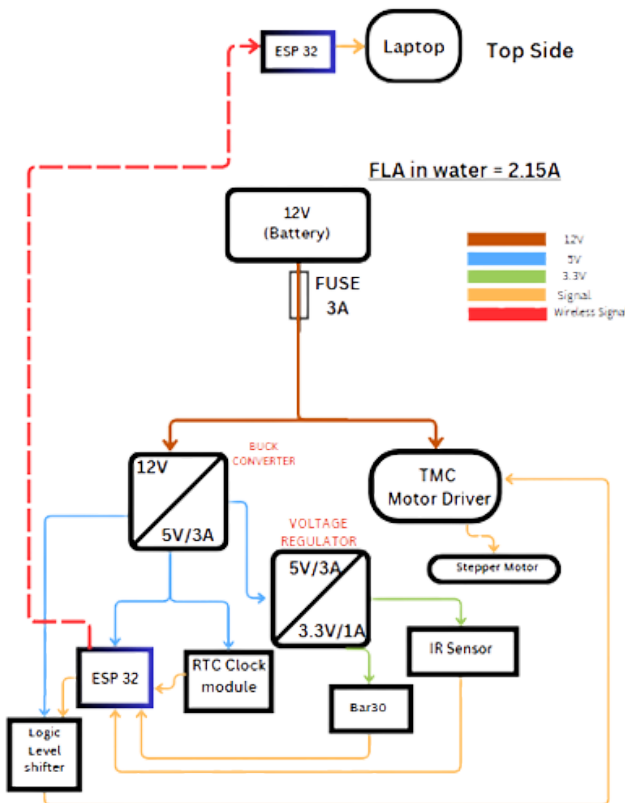


Figure 38: Float SID

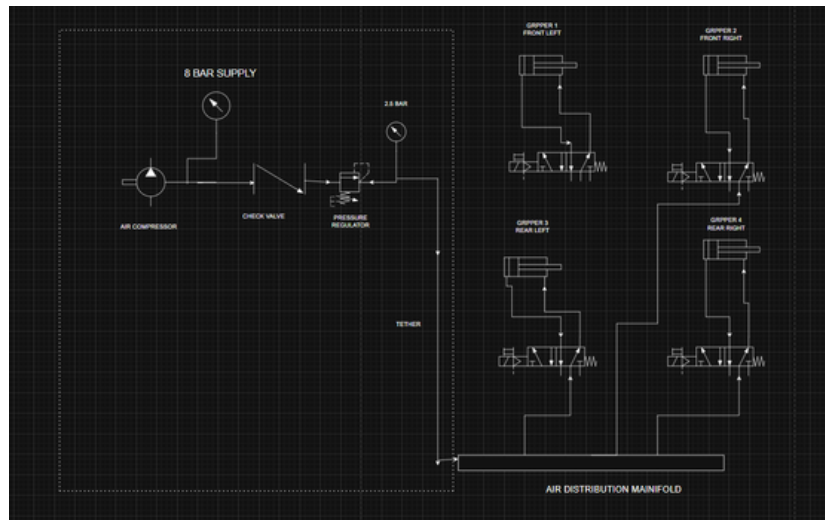


Figure 40: PneumaticSID



Philosophy Standards Lab Protocols

Strict lab protocols are enforced to maintain a hazard-free workspace. Key elements include:

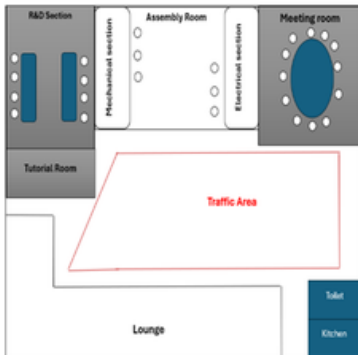


Figure 41: Titans Workshop

Job Safety Analysis (JSA):

Conducted before each task to assess potential risks and define mitigation strategies.



Figure 42: Titans employee wearing proper PFDs during in-test pool

Mandatory PPE:

Use of safety goggles, gloves, anti-static gear, and protective clothing when handling tools or equipment.

Tool Inspections and Maintenance:

All tools and test setups undergo scheduled checks to ensure functionality and safety compliance.

Clean Bench Policies:

Workstations must remain uncluttered and organized to reduce accident risks and improve workflow. By strictly adhering to these procedures, we reduce the likelihood of injury, equipment damage, or system failure during both lab work and field testing.

Training:

To ensure a uniformly high level of safety awareness and operational readiness, all Titans Robotics team members complete a structured safety training program. This includes :

Initial Safety Inductions:

Covering lab rules, risk assessments, emergency protocols, and proper use of Personal Protective Equipment (PPE).

Hands-On Supervised Sessions:

Members practice safe handling of electrical, mechanical, and pneumatic systems under mentor supervision.

Refresher Workshops:

Periodically conducted to review procedures, introduce updated safety protocols, and address any past incidents.

Safety Drills and Peer Reviews:

Simulating emergency scenarios to reinforce preparedness and encourage mutual oversight

Critical Analysis

As Titans, we upheld a methodical testing approach throughout the development of each subsystem to guarantee The ROV's robustness and optimal performance. As for proactive mitigation, a systematic troubleshooting protocol has been employed to detect and resolve anomalies expeditiously. Adhering to this methodology, we strive that the ROV performs efficiently under operational conditions with minimized failure probability.

Testing Methodology

Our testing methodology transitioned from individual component inspection to extensive system benchmarking to ensure the NEPTUNE-X surpasses all efficacy, safety, and competition requirements.

Mechanical Testing:

Structural Integrity Assessment

Stress analysis simulations using Ansys software are conducted to predict the ability of NEPTUNE-X and its components to withstand different stress distributions. Subsequently, the ROV and its components are verified in isolation using physical load testing techniques to validate the structural durability on shore, and more importantly, in underwater environments.

Enclosure Hydrostatic Pressure Test

We conducted this test by applying 0.5 bar pressure inside the enclosure using a free pneumatic cable to simulate underwater depth pressure. It is used to ensure the ROV's electronic components can withstand deep water conditions, combined with bubble observation to check sealing leakage.

Buoyancy and Stability

NEPTUNE-X undergoes different test trials to verify optimal weight distribution and to achieve neutral buoyancy



Pneumatics

We check Pneumatic circuits most importantly for proper airflow, and Pneumatic components are tested for proper actuation response and consistent pressure regulation.

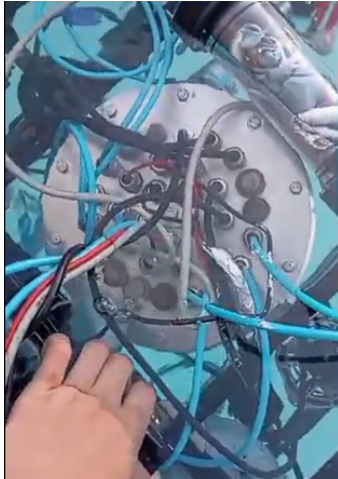


Figure 43: Seal Testing

Electrical Testing: Power Distribution Analysis

The electrical subsystems are tested for voltage regulation and current draw using oscilloscopes and multimeters to ensure proper operation under peak loads.

Component Verification

Individual electrical components undergo meticulous testing to confirm their functionality. Prototypes, such as double-layer PCBs, are used to verify the system design.

System Integration Testing

Once individual components pass testing, they are integrated into the full electrical system, and power flow, data transmission, and response times are verified under real-world conditions.

Software Testing: System Integration Testing

To evaluate NEPTUNE-X's software and control systems' efficiency and performance under real-time conditions, we assessed them using hardware-in-the-loop (HITL) simulations.

Fault Injection Testing

Simulated aberrations like data deterioration help examine how well the software can remediate malfunctions. It exhibits how the system detects, identifies, and recovers from these issues. We selected communication protocols such as RTSP and TCP to ensure they provide reliable data transfer.

Component Validation and Simulation

Before being assembled, all components undergo testing on a test bench to diagnose their function and reliability in a controlled environment. Key hardware parts, like the NVIDIA Jetson Nano, are subjected to make sure they comply with the system's requirements. We used Ardupilot SITL simulator to simulate the Pixhawk, which aided us in finding the problems at the outset and making sure the system functions properly before the hardware is actively implemented.

Structured Testing Approach

• Test Package Design

During the design phase, we created custom test modules to match the system's requirements. This ensures every part meets the set functional and performance standards.

• Module Integration Testing

Once the components are checked, we put them together and test them as a group to make sure they integrate perfectly.

• Full System Integration

The entire NEPTUNE-X is tested from start to finish to check how well all parts perform efficiently.

• System Stress Testing

NEPTUNE-X is tested under heavy load conditions to make sure it can operate reliably in tough situations.

Troubleshooting

When problems arise, we follow a structured framework to diagnose and rehabilitate the issues efficiently, safeguarding other parts of the system from being disrupted.

• Issue Identification

System logs and performance data are monitored to spot any unusual behavior. By evaluating against the current data with the expected baseline, we can accurately pinpoint where the problem is developing and focus on the specific part of the system that is affected.

• Fault Isolation and Diagnosis

We categorize problems based on whether they are related to mechanical, electrical, or software systems which helps us in organizing the troubleshooting process. For electrical issues, tools like oscilloscopes are deployed, while software debuggers are used for control system problems. Hence, we follow a logical, step-by-step process to find out exactly the defective element.

• Corrective Actions and Verification

Once the cause is uncovered, the right fix is implemented, such as replacing a faulty part or updating the software. We then test the fixed part autonomously to make sure the problem is solved and no other areas are affected. Each case is meticulously documented, including the telltales, the root cause identified, and the steps taken to fix it, which helps elevate subsequent diagnostic efficacy



Budget

Our budget covers all subsystems and logistics for the season. Funding came from a Faculty of Engineering grant and team member contributions, giving us a total of \$6,795. We focused on reusing parts from last year where possible, keeping total spending down to \$3,704.

Source	Description	Amount (USD)
Faculty of Engineering Team	Faculty grant for ROV project	\$823
Member Contributions	Individual contributions from team members	\$5,972
Total		\$6,795

Table 14: Funding sources, September 2025 – April 2026.

Budget Allocation

Budget divided across each subsystem. Projected costs include the market value of reused parts to show the full worth of the build.

Category	Items	Projected Cost (USD)
Tether	Cables, sheath	\$131
Float	Microcontrollers, sensors, battery, PCB	\$252
Topside	Switch, microcontroller, joystick	\$102
ROV	Structure, thrusters, electronics, cameras	\$4,104
Logistics	Transportation, accommodation, registration	\$700
Total		\$5,289

Table 15: Budget breakdown by subsystem.

For a comprehensive breakdown of individual component costs, market values of reused parts, and actual spending, please refer to **Appendix B: Cost Accounting**



Acknowledgements

We would like to extend our heartfelt appreciation to the MATE Center and the Marine Technology Society for organizing and sponsoring the MATE ROV competition, and to AASTMT and AASTMT Stadium for hosting the MATE regional competition in Egypt and providing an inspiring venue for our ROV journey.

Our warmest gratitude goes to the members of Vortex Company for their hardware equipment, and to our respected mentors Abdelrahman AbouKlila, and Abdelaziz Yousry, whose invaluable guidance and insight throughout the process helped this project reach its current success.

We also extend our sincere thanks to the Vortex Explorers 2025 team for their continuous technical support, with special appreciation to Mahmoud Reda, Ahmed Kamel, and Habiba Hatem for their dedicated assistance and expertise.

We recognize the following companies and platforms for their significant contributions: Pixhawk, Blue Robotics, Hikvision, NVIDIA, and Stereolabs for providing advanced hardware and robotics technologies; GitHub, ANSYS, SolidWorks, VS Code, Qt, ArduPilot, and Ultralytics for supporting our software development and engineering processes; and platforms such as Flaticon and GStreamer for enhancing our design and system integration. We are also thankful to Makers Electronics, Ampere Electronics and Morphiq for providing us with the resources and facilities that enabled us to successfully complete this project.

We extend special appreciation to Alexandria University for being our official entity, for their continuous support, and for covering the registration fees, which greatly facilitated our participation in this competition.

Lastly, sincere appreciation goes to our families, friends, and company employees for their unwavering support and encouragement. We also extend our gratitude to the competition sponsors—Innovators Support Fund, NTRA, Fugro, MTS, and NSF—as well as the volunteers and judges, whose commitment played a vital role in the success of this event.

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Pre-Operational Safety Checklist

- ☐ General Workspace Safety
- ☐ Confirm a secure and clutter-free workspace.
- ☐ Ensure no obstacles or trip hazards.
- ☐ Verify no personnel running around the pool area.

Equipment Inspection

- ☐ Check the sealing of electronics housings.
- ☐ Verify unobstructed thrusters.
- ☐ Confirm power source is securely connected to ROV.
- ☐ Ensure cables are secured and leakproof.
- ☐ Check for protective gear availability.

Communication

- ☐ Establish clear and audible communication protocols.
- ☐ Test all communication devices.

Power Verification

- ☐ Ensure the ROV is receiving the correct nominal voltage.
- ☐ Test power systems for proper operation.

Thruster Testing

- ☐ Test all thrusters for proper operation.
- ☐ Confirm controller movements correspond with thruster activity.

Camera and Sensor Checks

- ☐ Verify functionality of all cameras and sensors.
- ☐ Test camera positioning and video feeds.

Leak Tests

- ☐ Perform leak tests on the pressure hull.

Pre-Dive Preparations

- ☐ Prepare the dive site, including clearing any hazards.

Pre-Water Safety Checklist

- ☐ Power up the system by connecting the tether cable to the control station.
- ☐ Set electronics enclosures' pressure to the rated depth.
- ☐ Test camera functionality and sensor readings.
- ☐ Confirm thrusters operate correctly with controller inputs.
- ☐ Announce "Water Ready" after confirming system readiness.
- ☐ Lower ROV into pool with tether handler and team.

During Operation Safety Checklist

Operation Monitoring

- ☐ Continuously monitor systems and operations.

Tether Management

- ☐ Ensure proper tether management to avoid entanglement.

Communication Continuity

- ☐ Maintain clear communication with surface team.

Tool Deployment

- ☐ Follow protocols for tool deployment and retrieval.

Post Operation Safety Checklist

ROV Retrieval

- ☐ Safely retrieve ROV from water.

System Power Down

- ☐ Power down system and announce "Crew in Command."

Full cost accounting for the Titans ROV project, September 2025 – April 2026. Parts marked as Purchased or Reused. Reused parts listed at current market value. All figures in USD.

Available Funds

Category	Source	Amount (USD)
Faculty Grant Team	Faculty of Engineering — Titans ROV Project	\$823
Contributions	Individual contributions from team members	\$5,972
Total Available Funds		\$6,795

Table 16: Available funds.

ROV Total Cost

Cost split by subsystem. Reused parts shown at market value — no money was spent on them this season.

Category	Components	Reused Value	Purchased Cost (USD)	Total (USD)
Tether	Power cable, pneumatic cables, Cat6 cable, tether sheath	\$131		\$131
Float	Microcontrollers, IR sensor, motor driver, PCB, battery, pressure sensor, RTC module Microcontroller, TP-Link	\$195	\$139	\$334
Topside	network switch, Xbox joystick	\$72	\$30	\$102
ROV Structure	Camera boxes, grippers, aluminum extrusion, O-rings, 3D printed parts, enclosure, face glands Thrusters,	\$459	\$195	\$654
ROV Electronics	ESCs, cameras, Jetson Nano, Pixhawk, ZED 2i, PCBs, buck converters, Cytron, pressure sensor	\$3,214	\$1,240	\$4,454
ROV Pneumatics	DCV x4, pneumatic pistons x4, compressor, bilge pump	\$375	\$279	\$654
Logistics	pool rental, villa rent, villa expenses, competition registration	—	\$2,100	\$2,100
Total		\$4,446	\$3,983	\$8,429

Table 17: Cost by subsystem — reused value vs. new purchases.



Expenses (September 2025 – April 2026)

Budgeted vs. actual spending per category for purchased items and logistics.

Category	Example Items	Budgeted (USD)	Actual Expenses (USD)
Float	ESP32, IR Sensor, Motor Driver, Battery, Bar30	\$180	\$139
Topside	ESP32, TP-Link Switch	\$35	\$30
ROV Electronics	Control PCB, Buck Converters, Cytron, ZED 2i, Jetson Nano	\$1,595	\$1,135
ROV Structure	Grippers, Extrusion, O-Rings, 3D Parts, Face Glands	\$225	\$195
ROV Pneumatics	DCV x4, Pneumatic Pistons x4	\$320	\$279
Logistics	Transport, pool rent, villa, registration	\$2,100	\$2,100
Total		\$4,455	\$3,704

Table 18: Budgeted vs. actual expenses.

* Purchased: bought new this season. Reused: carried over from previous builds, listed at market value.

Total Income: \$6,795

Total Expenses: \$3,704

Reused Components Value: \$3,689

Remaining Balance: \$3,091