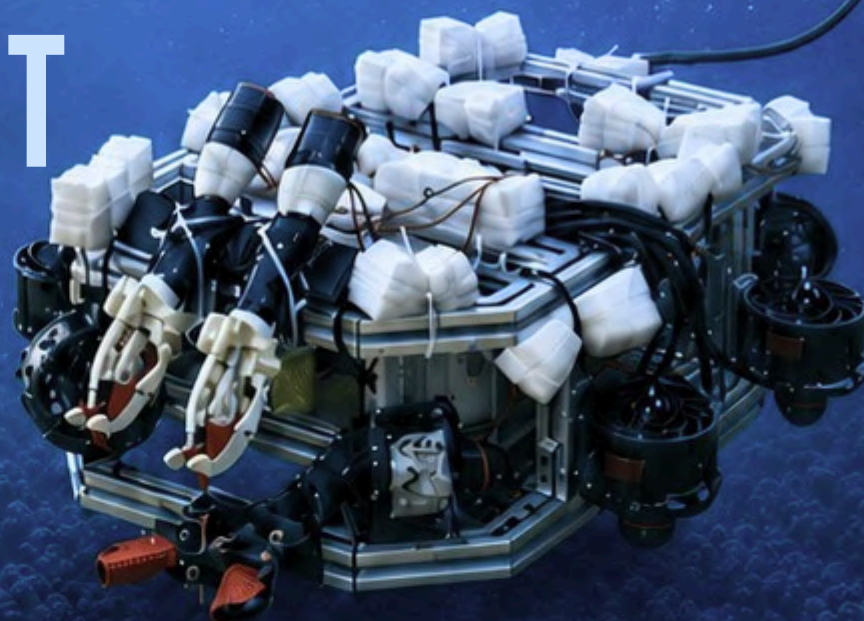


MATE ROV '26 TECHNICAL REPORT

UIU Mariner
Bangladesh



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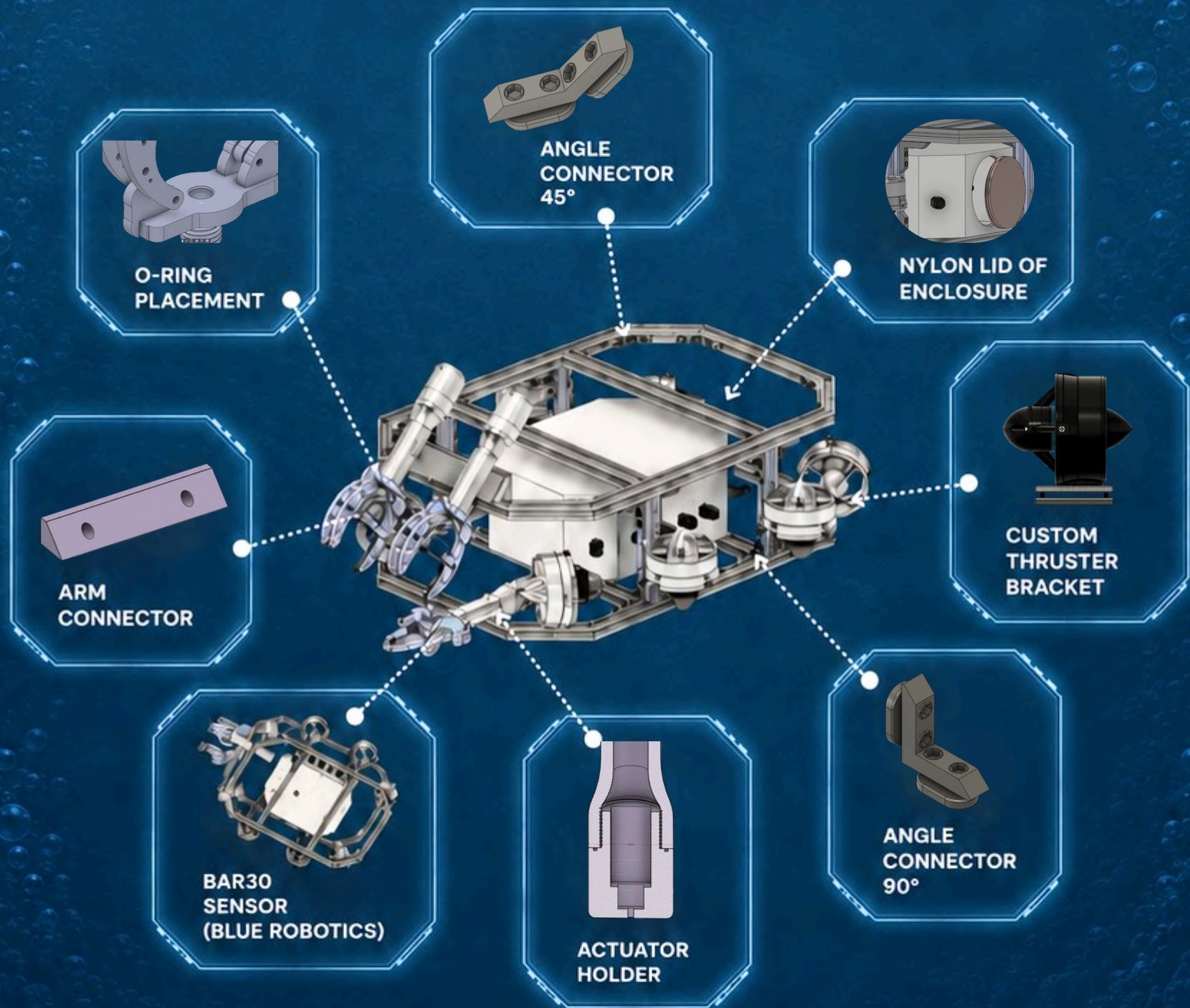
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ABSTRACT

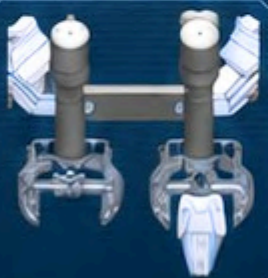
In response to the MATE Center's Request for Proposals (RFP), UIU Mariner at United International University, Bangladesh, proudly presents its newly built remotely operated vehicle (ROV), namely Kraken. Kraken is a ROV developed over eight months by a cross-functional team of 35 members. It is designed to perform various tasks e.g., underwater manipulation, environmental monitoring, float deployment, marine infrastructure inspection, etc. Kraken's design philosophy centers on modularity, adaptability and precision. A dual-tier octagonal aluminum T-slot frame allows it to rapidly reconfigure without permanent welds. All onboard electronics are protected within an octagonal acrylic pressure housing sealed with Nylon end caps and Blue Robotics Wetlink Penetrators. Eight Blue Robotics T200 thrusters arranged in a vectored 6-DOF propulsion array deliver significantly greater thrust efficiency over conventional configurations. The software suite is a custom ground-station-centric platform built on Python, React.js, and OpenCV, where a V-Matrix thruster mixer computes all outputs in software to support any frame geometry without firmware modification, and a cascaded dual-loop PID controller with multi-stage depth signal filtering ensures stable depth hold, complemented by a computer vision engine supporting multiple detection modes and a stereo vision system for accurate real-world 3D measurement. The GripperX manipulator system uses three waterproofed 3D-printed grippers driven by linear actuators, handling both large object retrieval and precision tasks. Equipped with thruster guards, a software emergency stop, and a custom tether strain relief system, Kraken is engineered to tackle all RFP tasks with precision and efficiency.

THE KRAKEN ARCHITECTURE



ADAPTIVE MULTI-MANIPULATOR SYSTEM

Intelligent and modular manipulator system built for complex, real-world mission tasks.



GripperX Claw-1



GripperX Claw-2

COMPARATIVE CLAW DESIGNS FOR TASK OPTIMIZATION

Evaluating performance, precision, and adaptability to select the optimal claw for mission success.



PLANNED STEREO VISION SYSTEM (OAK-D POE)

Enabling accurate spatial measurement and photogrammetry for enhanced navigation and object mapping.

Fig 1 : Kraken Architecture

Design Rationale

Engineering Design Rationale

Kraken is the next-gen ROV to UIU Mariner's line after the Scorpion 2.0 model (2025). The Kraken was conceived with the consideration of two unchanging necessities: (1) The chassis should be flexible, allowing for changes in size without remachining; and (2) The propulsion system needs to be fault-tolerant, ensuring that failure of a single prop does not stop the operation of the entire vessel.

Overall Vehicle Design

Our *Kraken* is made up of three layers that work together as one: a **double-layered** octagonal **aluminum** frame (structural skeleton), a **single-layered** **acrylic** frame housing for electronics (electronic brain), and a three-tiered software system that works through the ground station. Each of these layers could operate independently due to its standardized interface. The octagonal shape (**440 mm x 359.8 mm**) makes it possible for all three conflicting requirements to be met simultaneously.

Planning and Design Process

The design process went through more than five phases of design iterations.

- Phase 1 (Mission Analysis):** MATE 2026 RFP requirements were reduced to a subsystem level for propulsion, manipulation, sensors, and controls.
- Phase 2 (Conceptual Trade-off Study):** Conducted trade-off study between **H-Frame**, rectangular and octagonal frames via bending moment calculations; selected octagonal frame architecture based on the existing ROV literature [2, 3].
- Phase 3 (Digital Twin by SolidWorks):** All the components are designed using Fusion 360/SolidWorks software and simulations on buoyancy/structure have been performed before fabrication.
- Phase 4 (Iterative Fabrication and Pool Testing):** We built hardware in parallel sub-team sprints and validated each subsystem individually before system integration.
- Phase 5 (Troubleshooting and Optimization):** Proposed solutions to depth-hold oscillation (cascaded PID), thruster mapping (V-Matrix / RCPassThru), and power ripple (dual buck converter stages).

Design Decisions and Trade offs

Octagonal vs. Rectangular frame: Octagonal frames are a common choice for open-frame ROVs, selecting this geometry for its ability to withstand the collision of obstacles while maintaining navigational stability for station keeping and attitude tracking [3]. A pattern of design ubiquitous across the work-class ROV literature [2, 4]. A rectangular frame has four right-angle corners. Each corner is a **stress concentrator**, a moment applied across the frame produces **peak bending right at the joint**. Replace each **90° corner** with two **135° corners** (which is

what the octagonal chamfer does), and the same total moment is now shared across eight joints instead of four. The simplest way to write the comparison is:

$$M_{rect} = P \cdot L / 4$$

vs

$$M_{oct} = P \cdot L / 8$$

Where,
P: Applied load
L: Characteristic span

The peak bending moment at any single joint is roughly halved relative to the rectangular case. The octagonal ring is therefore more impact-tolerant for the same extrusion.

The bigger reason for going **octagonal** is that the four chamfered faces sit at **exactly 45°** to the longitudinal axis. This is the **optimal angle for vectored horizontal thrusters**, and it means the thruster brackets **bolt directly to flat aluminum faces** no wedges, no shims, no machined adapter blocks. A rectangular frame can do 45° vectoring too, but only with **custom angled brackets**, which add mass, complexity, and another set of fasteners that can loosen. **That's why 45° matters more.**

8 thrusters vs. 6 thrusters: It's the published configuration that retains full 6-DOF control under any single-thruster failure [5, 6, 7]. Eight thrusters at this scale is the standard for **fault-tolerant**, over-actuated ROVs. That's why we chose **8 thrusters over 6 thrusters**.

The 45° horizontal vectoring: Each of the four horizontal thrusters is mounted on one of the four octagonal chamfer faces. Each thrust vector points horizontally and sits at 45° to the surge (forward) axis. For a single thruster producing thrust T.

$$F_x = T \cdot \cos(45^\circ) = T\sqrt{2} / 2 \approx 0.7071 T$$

$$F_y = T \cdot \sin(45^\circ) = T\sqrt{2} / 2 \approx 0.7071 T$$

Where , F_x (Surge): The Forward/Backward Force along the longitudinal axis
 F_y (Sway): The force along the lateral axis
T (Thrust): Individual Thrust

For pure forward motion at full throttle, all four thrusters contribute their X-component:

$$F_{surge} = 4 \cdot T \cdot \cos(45^\circ) = 2\sqrt{2} \cdot T \approx 2.828 T$$

Where , F_{surge} : The Forward/Backward Force

The single-thruster X- and Y-projections are equal, which means surge and sway thrust are also equal, neither direction is preferred.

Ground station mixing vs. firmware: Thruster mixing via Python GCS can be changed in real time without any recompiling; works with any user-defined frame.

Threaded nylon caps vs. bolted flanges: O-rings compress evenly from one tightening operation; no leak path through varying differential torque applied by bolts.

Enclosure made of acrylic instead of aluminum: Visual pre-dive checks without disassembly of the case; enough compressive resistance at <20 m depth.

ABS material instead of metal for grippers: Enough force resistance at **60 N**; much lighter and quicker change between dives.

Innovation

Some of the original improvements implemented in our UIU Mariner to improve functionality while reducing cost include:

V-Matrix Thruster Mixer: All thrust allocation is computed on the ground station using UIU Mariner's proprietary V-Matrix Mixer. Rather than relying on fixed firmware frame types, PWM outputs are calculated entirely in software via a configurable 6-DOF mixing matrix stored in **config.json**. The formula applied to each motor is:

$Motor_PWM[n] = Base + \sum (Input[j] \times Matrix[n][j]) \times Scale$

Where , Input[j]: The six DOF commands (Surge, Sway, Heave, Roll, Pitch, Yaw)
Matrix[n][j]: The signed contribution coefficient for thruster n

This software-defined approach supports any frame geometry, **H-Frame**, **Vector-6**, **Vector-8**, or custom **asymmetric** layouts simply by editing the configuration file, with no firmware recompilation required.

Table 1: 8-Thruster Vector-8 Mixing Matrix

Motor	Surge	Sway	Heave	Roll	Pitch	Yaw
Motor 1	+0.7	-0.7	0	0	0	-1
Motor 2	+0.7	+0.7	0	0	0	+1
Motor 3	-0.7	+0.7	0	0	0	-1
Motor 4	-0.7	-0.7	0	0	0	+1
Motor 5	0	0	+1	-1	+1	0
Motor 6	0	0	+1	+1	+1	0
Motor 7	0	0	+1	-1	-1	0
Motor 8	0	0	+1	+1	-1	0

Custom Connectors and Brackets: The frame can only be as modular as the joints holding it together. We did not want bolted gussets that pin extrusion ends to fixed positions, and we did not want welded joints that lock the geometry forever. So we machined our own. The **45°** (Fig: 1) and **90°** (Fig: 2) connections of aluminum that include captive steel biscuits are used instead of welds. The 90° “**L-block**” connection with **two bolts** prevents the vertical posts from rotating when subjected to impact loads, a unique application compared to commercial T-slot accessories.

The Angle Connector 45°: An octagon needs corners that meet at **135°** on the inside. Instead of cutting every rail end at an angle, we put the geometry in the connector itself. Every rail on *Kraken* is a plain straight cut. Reconfiguring the frame shape takes four bolts and about **a minute**. The load path through this joint was also a deliberate choice: bolt to connector body to steel biscuit to T-slot wall, all in shear and compression. Nothing relies on **threads cut** into soft aluminum, which is how most modular frames

eventually strip out and fail.

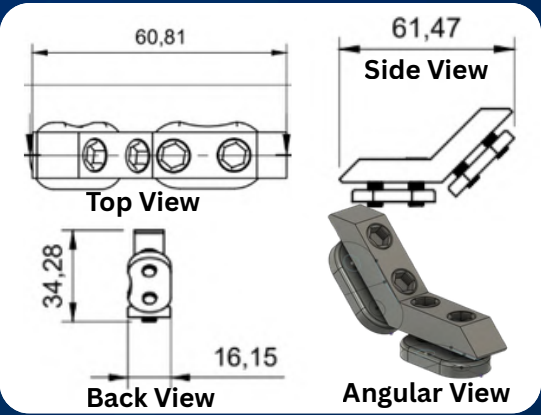


Fig 2 : Angle Connector 45 °

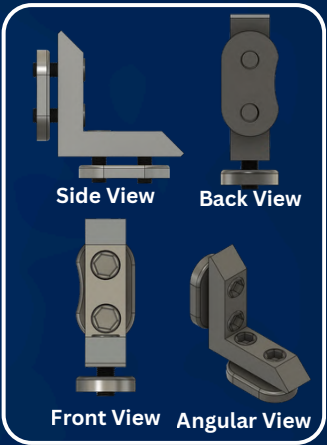


Fig 3 : Angle Connector 90°

The Angle Connector 90°: This connects the four vertical posts between *Kraken's* upper and lower octagonal rings, turning **two flat rings** into one rigid cage. We CNC-machined it from aluminum billet as an L-block with **two bolts per leg**. One bolt per leg would create a pivot point under impact. Two bolts eliminate that completely.

The two bolt per leg decision came from a specific failure we thought through. A single bolt at a **vertical** post creates a rotation point. When the frame gets bumped, and it will get bumped, a single bolt post pivots. Two bolts lock the geometry completely. Same biscuit system inside the slot, same load path as everywhere else on the frame.

Thruster Brackets: We used the exact same biscuit and rail logic for the thruster mounts. Each bracket has a curved cradle that holds the thruster body and a flat face that sits against the T-slot rail. Because it uses biscuits to attach, you can slide the thruster along the rail to adjust the vehicle's balance after adding or removing a payload. No unbolting, no reassembly, just slide and lock.

How This Compares to What Already Exists: T-slot aluminum framing is not a new idea. Industrial robotics has used systems like 80/20 for decades because of how easy they are to reconfigure, and because anodized aluminum holds up in tough environments far better than welded steel. And similar systems are documented across the industrial-robotics design literature [8, 9]. What we actually contributed here is the connector geometry that makes this system work for an eight-sided underwater frame. That specific combination of octagonal layout, marine environment, fully reconfigurable joints, and purpose-built hardware is what we designed and built ourselves. What they offer, repeatedly, is the same set of properties: tool-less reconfiguration, cable channels integrated into the profile, and critically for marine work, anodized aluminum's corrosion resistance compared to welded steel [9, 10].

Problem Solving

Our team developed a planning process that was systematic and collaborative by creating a Discord server

where our sub-teams of mechanics, electronics, software, and logistics worked independently in their assigned groups on a more specialized level (Fig: 3). Sprint reviews every week were held as the main avenue for highlighting issues, which were sorted based on their urgency in our Notion board. Ideas were brainstormed in a discussion among the team and filtered through two major criteria, whether the problem was solved at the core or just the symptoms, and whether it could be executed during the current sprint cycle.

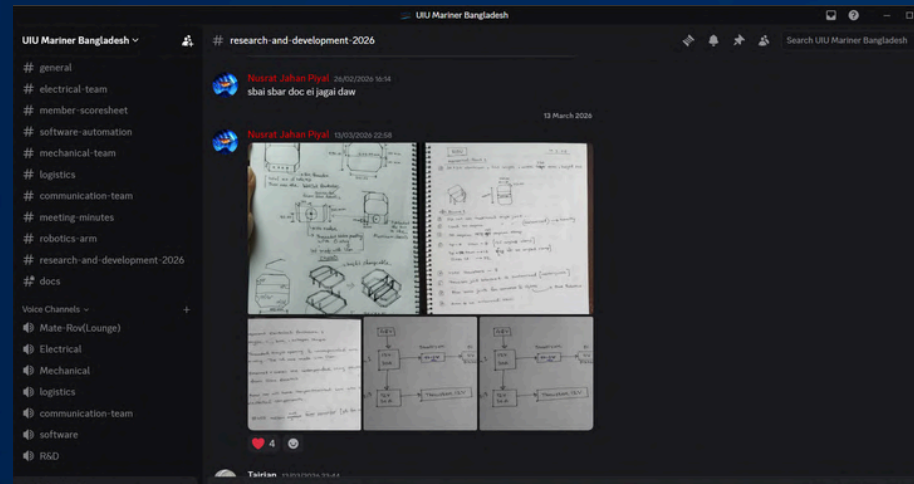


Fig 4 : UIU Mariner Discord Server

Systems Approach

UIU Mariner’s *Kraken* ROV utilizes a modular, ground station-centered systems engineering method tailored for MATE competition objectives, delivering complete 6-DOF control, accurate object manipulation, and computer vision capabilities within real-time up to 20m depths through iterative development in mechanical, electrical, and software sub-systems. These computations include thruster mixing with the V-Matrix system, cascading PID depth control, and stereo vision. Computations are done on a Windows-based ground control station (GCS) (Python/FastAPI backend and React.js frontend with OpenCV library), which consists of three-tier architecture with GCS for joystick control and 20Hz WebSocket telemetry, a Raspberry Pi 5 inside for MJPEG video stream and sensor data communication with Pixhawk (RCPassThru mode), and eight vectored T200 thrusters powered by 48V/30A architecture that can manage 955W peak power consumption. Specific features of this ROV include a two-tier octagonal T-slot aluminum frame with custom connectors(45°/90°) for quick changes, neutral buoyancy obtained using optimized foam configuration based on the Archimedes principle (a displacement of 10.50 kg means a weight of 4.26 kg), marine grade components with 13 Wetlink connectors, thruster protection as a safety feature, and GripperX manipulators for sampling confirmed using Digital Twin Simulations from SolidWorks.

Vehicle Structure

Frame Structure and Materials Trade-offs

This dual-tier octagonal frame (Fig 2) is made up of 30 × 30 mm aluminum T-slot extrusion forming two octagonal frames each measuring 440 mm × 359.8 mm separated by 150 mm vertical standoffs. Structural dimensions include:

Table 3: Materials Trade-offs

Dimension	Value
Overall width (flat-to-flat, X)	359.80 mm
Overall length (flat-to-flat, Y)	440.00 mm
Top flat edge width	240.00 mm
Corner chamfer (projected horizontal)	45° cut from rectangular corner
Inter-ring height	150.00 mm (enclosure 115 mm + 35 mm clearance)
Extrusion cross-section	30 × 30 mm standard T-slot profile

Cost trade-off: Aluminum T-slot extrusion with modular connectors was chosen over welding and steel or using HDPE sheets. Although the cost of machining the initial

Table 2: Rational Evaluation of Alternatives

Problem	Alternatives Evaluated	Selected Solution & Rationale
Depth hold oscillation	Single-loop PID; Increase damping gains; Cascaded PID	Cascaded PID separates position and velocity control; eliminates oscillation at root cause rather than masking it.
Thruster mapping failure	Default ArduSub frame; Custom firmware; RCPassThru + software mixer	RCPassThru + V-Matrix zero firmware risk; real-time tuning; geometry-agnostic.
Power ripple on Pi/Pixhawk	Single buck converter; Linear regulator; Two-stage buck convertor	Two-stage buck (48V→12V→5V) ripple-free DC supply; protects sensitive digital boards.
Frame rigidity at joints	Welded joints; Off-shelf gussets; Custom captive-nut connectors	Custom angle connectors reconfigurable, no weld distortion, double-bolt anti-pivot design.

connectors was more than that in both alternatives, the cost savings incurred by not having to remachine the connectors for any adjustments to the frame, which requires removing four bolts and adjusting back the frame (zero cost), outweighed this expense.



Fig 5 : 30×30 mm aluminum T-slot extrusion

Size trade-off: The smallest size that can accommodate the octagonal acrylic chamber (339.99 mm x 241 mm) and still allow 9.9 mm clearance on all sides is 440 mm x 359.8 mm.

Weight trade-off: The aluminum connectors replace the previous iteration's stainless steel connectors, which were heavier. 316 grade stainless steel will be used exclusively in the internal locking mechanism parts because tensile strength is necessary in these components.

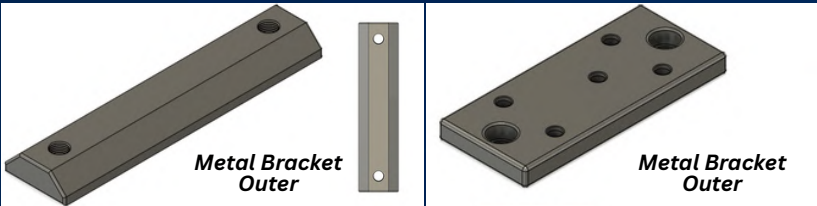


Fig 6 : Custom Thruster Metal Bracket Outer and Inner

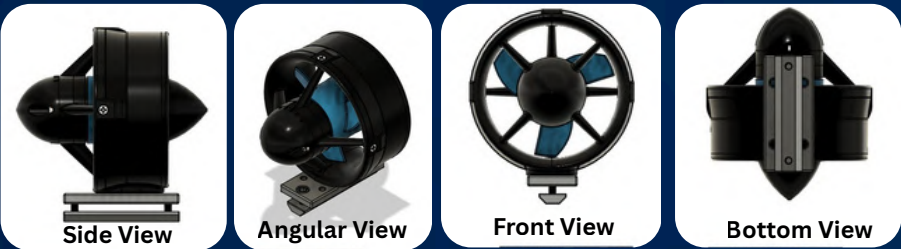


Fig 7 : Custom Thruster Metal Bracket With Thruster

Table 4: Angle Connector dimensions

Feature	Value	Function
Overall length	59.75 mm	Spans the corner joint along the chamfer face
Bend angle	135°	Matches the interior angle of the octagonal corner
Mounting height	35 mm	Engages the full 30 mm extrusion face plus an overlap
Through-hole	Ø 7.2 mm	Clears M6 / M8 bolt heads — fits standard T-nuts
Plate thickness	8.57 mm	Stiff enough not to flex under thruster reaction torque
Material	Aluminium	Strength and rigidity at the joint

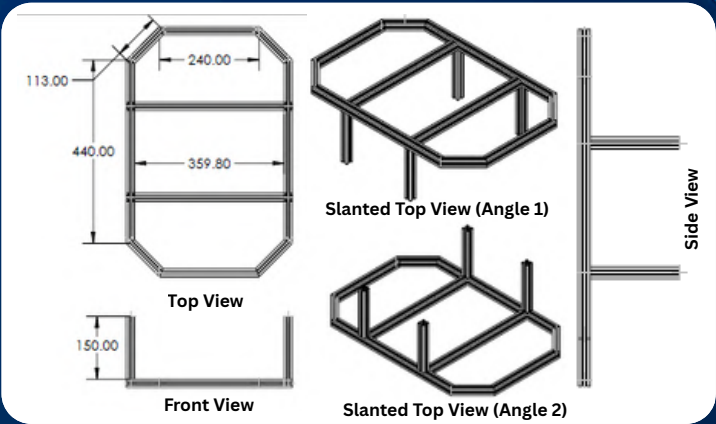


Fig 8 : Frame Structure , Chassis

Centralized Octagonal Enclosure

It is also important to note that acrylic was used for the octagonal case since it allows for pre-dive inspection while being inside the housing without removing any parts. The preferred solution is to use threaded caps rather than bolted flanges since the former does not require equal tightening of all the screws simultaneously in order to achieve a watertight seal; whereas a single improperly torqued screw would cause a leak. The proposed solution utilizes the same principle applied by Blue Robotics in commercial housings [1] and is similar to ROV implementations in references [2, 4].

Table 5: The structural specs of Enclosure

Parameter	Value
Plan-form	Octagonal prism (matches frame geometry)
Dimensions (W × D × H)	339.99 × 241.00 × 115.00 mm
Wall material	Acrylic
End-cap material	Nylon
Sealing	Threaded interface with face-seal O-ring
Side penetrations	Ø 100 mm (left, right, bottom)
Frame clearance per side	≈ 9.9 mm
Mounting	T-slot biscuits through extrusion channels

Enclosure Material Rationale: Nylon end caps as they do not gall against the acrylic threads are electrical insulators so that the caps will never be able to conduct electricity unintentionally and are easily machined to properly form O-ring grooves. Acrylic for body parts as the material needs to be clear for the pre-dive inspection and because the compressive strength of acrylic is sufficient for our depths.

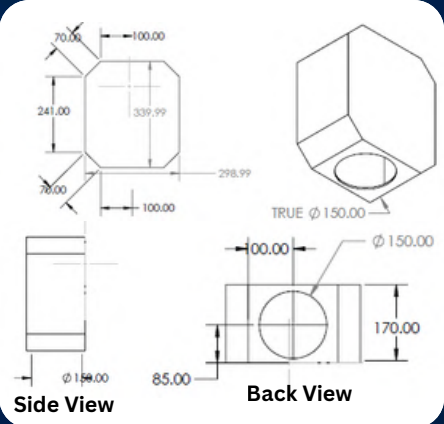


Fig 9 : Sketch of Octagonal Acrylic Enclosure

Thruster Guard Design

In order to avoid any harm to the thrusters of the ROV caused by debris and vegetation in the water, as well as to avoid coming into contact with any loose cables, a specialized guard was made specifically for use on the ROV through the process of 3D printing. It was chosen to have a spiral rib design because it creates a stream of water while preventing other objects from touching the propellers. It is positioned using the hub ring, which exists in the center of the thruster. The mounting tab makes it simple to bolt onto the ROV through the mounting tabs.



Fig 10 : Top and Bottom side Thruster Guards

Vehicle Systems

Evolution of Design Based on Mission Requirements

We followed three main iterations before reaching the final design:

- Iteration 1 (rectangular frame and six thrusters): Pool tests showed unequal thrust along the sway axis and poor stability of depth hold. And cause thruster array aligned on axes provides 2T surge versus 2√2·T diagonally unequal thrust felt by pilots.
- Iteration 2 (octagon frame and eight thrusters with onboard mixer): Isotropy of thrust was accomplished. Oscillation in depth hold persists due to one-loop PID controller responding to positional error alone. The onboard ArduSub mixer did not support custom arrangement of thrusters.
- Iteration 3 (final) (octagonal frame and eight thrusters with GCS mixer and cascaded PID): Cascaded PID control (outer loop – position → velocity setpoint, inner loop – velocity → PWM) eliminated oscillations. GCS Python mixer using config.json for real-time tuning.

Electrical System

Electronic Design and Cabling

Kraken’s power system utilizes a 48 V / 20 A power source located on the surface and fed directly to the ROV using one Anderson SBS50BLU 50A connector, which serves as the only physical interface between the MATE power source and Kraken itself. The power flow within the octagonal acrylic box takes place according to this scheme:

- 48V to 12V Buck Converters (1,2,3 to 8 ESCs to 8 thrusters)
- 48V to 12V Buck Converter(4) to 5V Buck Converter to Raspberry pi 5 & Pixhawk
- 48 V to Buck converter 3 (48V→12V) to 3 × linear actuators + gear motor (12 V)

- 12 V rail to Pixhawk 4 (5 V via internal regulator)
- 3.3 V: Bar02 depth sensor by means of Raspberry Pi GPIO I2C rail

The power cables employ only crimped connectors with no exposed copper. There are 13 Blue Robotics Wetlink Penetrators used for cable ingress into the acrylic housing. The special strain relief prevents mechanical stress propagation from the tether into the penetrators and the internal wiring.

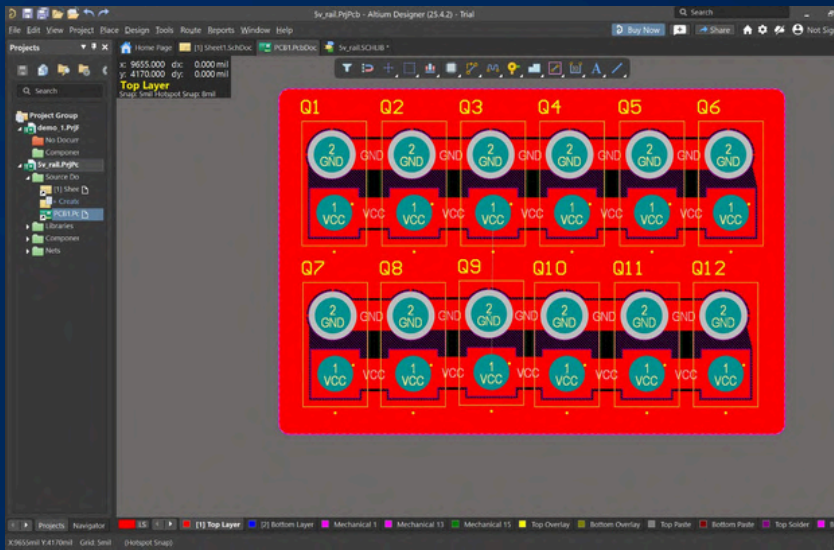


Fig 11 : 5 volt and 12 volt rail

Table 6: ROV Electrical Power Budget

Component	Model	Qty	V (V)	I (A)	Power (W)
T200 Thrusters	T200	8	12.0	7.5	720.0
ESC	Basic 30A	8	12.0	0.5	48.0
IMX322 Camera	IMX322	2	5.0	0.35	3.5
Flight Controller	Pixhawk 4	1	5.0	0.5	2.5
Onboard Computer	Raspberry Pi 5	1	5.0	5.0	25.0
Depth Sensor	BAR02	1	3.3	0.1	0.33
ARM Linear Actuators	Miniature LA	3	12.0	3.0	108.0
ARM Gear Motor	Gear Motor	1	12.0	4.0	48.0
TOTAL	—	—	—	20.95 A	955.33 W

Power Consumption of ROV:

Now,

$$P=VI,$$
$$I = P/V = 955.33 \text{ W} / 48 \text{ V}$$
$$\therefore I=19.903 \text{ A (approx)}$$

Where ,
P: Power
V: System Voltage
I: Current

Maximum Current Draw: 19.903 A
Primary Fuse Rating Used: 20 A

Tether Design and Management

Tether Management Protocol: The tether must be neatly arranged at all times, free of loose coils. It is important for secure and organized routing.

Entanglement prevention: The cable must not pose entanglement risks to the ROV, team members, or any environmental structures during deployment or retrieval.

Strain relief: Teams are expected to implement strain relief mechanisms to protect the tether connection points from excessive tension or pull. We built a new strain relief system design.

Dedicated tether manager: A designated team member monitors and guides the tether throughout the run, managing drag and preventing snags during operation.



Fig 12 : Strain Relief Design

Length compliance: The tether must stay within the length limits specified by MATE competition guidelines at all stages of use.

Operational benefit: Reduces drag on the ROV, improves pilot control, and contributes to smoother, more reliable mission performance.

Navigation: Pixhawk

The Pixhawk is responsible for interpreting the commands from the pilot and combining them with data collected from various onboard sensors to propel the thrusters to ensure steady and accurate movement in the water.

In conjunction with ArduSub, the Pixhawk controls depth-holding operations by using Bar02 sensors, stabilizing orientation, and maneuvering the vehicle with minimal manual control required.



Fig 13 : Pixhawk



Fig 14 : Bar02 sensor

The Bar02 sensors are compact, high-resolution pressure sensors for under-water pressure and depth sensing. This automation relieves a substantial portion of the pilot's workload and improves the ROV's operational reliability.

Control Station

The control station is what the pilot uses to operate the ROV. *Kraken's* control station consists of a laptop and an Xbox controller, connected to the ROV via ethernet. The ROV's Raspberry Pi with ground station through ethernet cable, which means no router,(as underwater communication is not possible). The whole setup was built to be quick to deploy and quick to pack up, which matters a lot during MATE operations. No control box used.



Fig 15 : Control Station

Control System Design

The team utilizes a software control system. The control system's requirements were developed based on the required mission operations, the ROV should maintain its depth to within ± 50 mm, move horizontally with equal maneuverability in all directions, and allow slow mode manipulation.

A control requirements matrix was created before any configuration of the firmware, and tested using pass/fail criteria at a pool test after configuration.

Software System Design

The GCS software stack: Python/FastAPI backend, React.js frontend, OpenCV vision engine, communicating via WebSocket at 20 Hz.

Advantages: Geometry-agnostic (any thruster layout configurable via JSON), browser-based dashboard allows feature addition without recompilation.

Limitations: Requires stable Ethernet connection; adds ~8 ms GCS-to-ESC latency vs. onboard mixer.

Development: Git-controlled source code hosted on GitHub. Feature branches, pull requests, integration testing on pool setup before merging. Software components: joystick_handler.py, mixer.py (8x6 V-Matrix), pid_controller.py (cascade depth hold), vision_engine.py (5 CV Modes), stereo_measure.py.

Operational Performance Features: Two speed settings (FAST: max 364 PWM; SLOW: max 150 PWM units using Button 6). PID controller real-time adjustment dashboard; Telemetry update at 20 Hz (Depth, Heading, Pitch, Roll, Armed status, Mission time). Digital zoom 1x-4x by L3/R3 stick click.

Table 7: Three-Tier Architecture

Layer	Hardware	Software Responsibilities
Ground Station (GCS)	Operator Laptop (Windows)	Joystick input processing, thruster mixing, PID stabilization, telemetry dashboard, computer vision, REST/WebSocket API
Onboard Computer	Raspberry Pi 5	High-speed serial relay to Pixhawk, MJPEG camera streaming, sensor data forwarding
Flight Controller	Pixhawk (RCPassthrough mode)	Receives pre-computed PWM signals; no mixing logic performed onboard

Version Control (GitHub)

All software for UIU Mariner ROV is hosted on GitHub under the repository UIU Mariner ROV Software. The team follows an Agile workflow. When a new feature is required, such as camera streaming, MAVLink setup, or arm control, a dedicated feature branch is created, developed, and submitted via pull request. A peer code review is mandatory before merging into the dev branch. Once hardware-tested, dev is merged into the protected main branch and tagged as a competition release. This ensures stable, reviewable, and iterative software delivery throughout the build cycle.

Computer Vision Engine

The multi-mode CV engine we designed is incorporated into the MJPEG stream processing pipeline using OpenCV. Five direction modes can be accessed by operators through our dashboard interface. Our engine uses adaptive pre-processing before applying the detection algorithms, starting with Gaussian blurring followed by dilation to mitigate backscatter effects on object detection.

Stereo Vision Measurement System: Beyond the real-time CV modes, the team developed a standalone Stereo Vision Measurement System capable of computing precise real-world 3D dimensions of objects in the field. This system uses two synchronized USB cameras, a custom stereo calibration pipeline, and depth reprojection to produce centimetre-accurate measurements from camera images alone.

Depth Computation of the Stereo Formula: The core depth equation underpinning all measurements is:

$$Z = (focal_length_px \times baseline_m) / disparity_px$$

The Q matrix generated during calibration encodes this formula. Calling `cv2.reprojectImageTo3D(disparity, Q)` applies it simultaneously to every pixel, producing a full 3D point cloud. For each clicked measurement point, the script samples an 11x11 pixel neighbourhood and takes the median depth for stability against noise.

Real-Time WebSocket Stream: The GCS broadcasts telemetry at 20 Hz to `ws://localhost: 8000/ws`. The JSON packet format is:

```
{ "depth": 1.25, "temperature": 24.5, "heading": 182.0,
  "pitch": 4.5,
  "roll": -1.2, "armed": true, "is_recording": false,
  "timer_running": true, "mission_timer": 420 }
```

The WebSocket stream is the primary data source for the React dashboard and can also be consumed by external logging applications or analysis scripts.

Photo To 3D Flow Chart

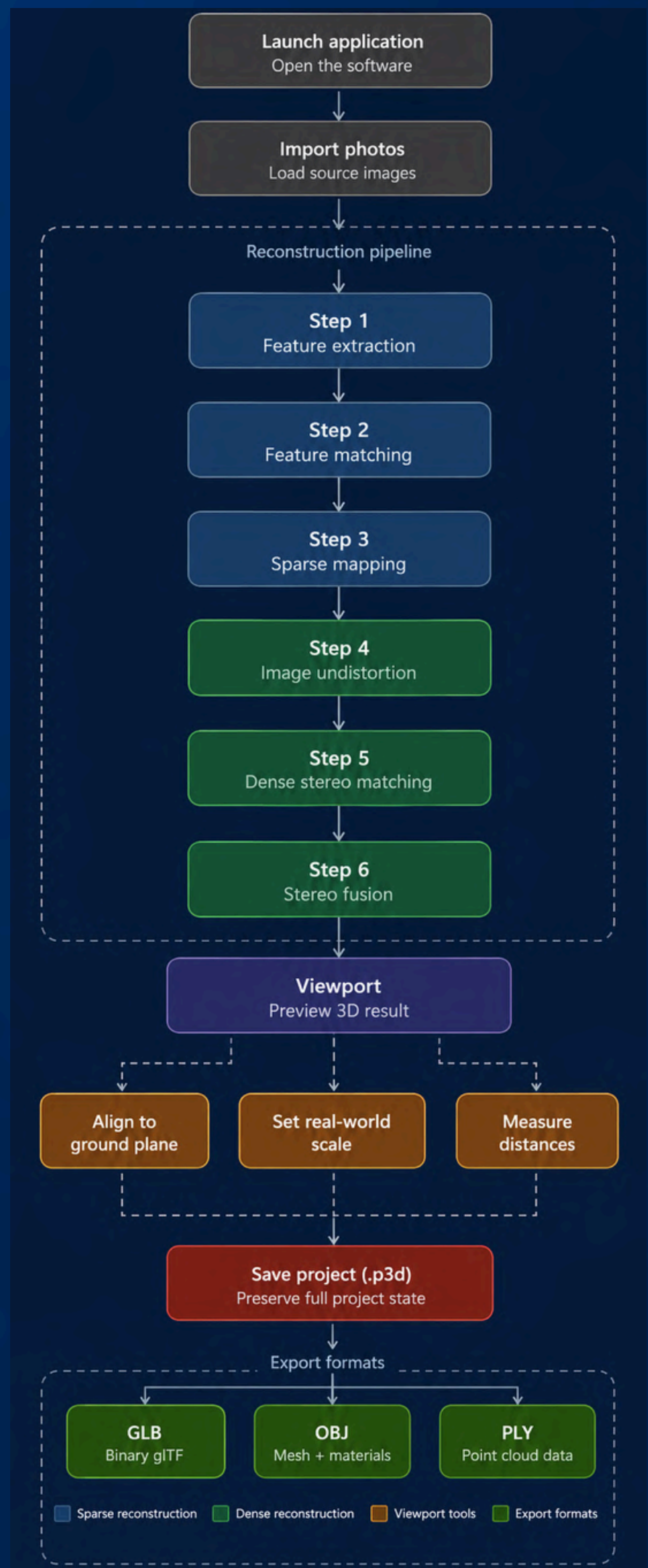


Fig 16 : Flow chart of Photo TO 3D

PhotoTo3D: The PhotoTo3D engine is perfectly embedded within the ROV app in order to provide a robust photogrammetry pipeline for the subsurface context through the utilization of the Python 3.12 + PySide6 stack that manages the COLMAP structure-from-motion (SFM)

and multi-view stereo (MVS) backend with the help of its native Qt6 API. The design is built upon the layered architecture of the engine including the GUI, core, utils, and stateless tool packages, enabling conversion of unordered underwater images to dense colored point clouds with the help of the processing of their features, matches, maps, and fusions, respectively. In cases of emergency missions, all of the advantages of the framework such as the embedded PyVista 3D viewport, automated image blur detection based on Laplacian variance scores, and EXIF/GPS metadata parsing are fully exploited. Along with those, the pipeline performs precise measurements related to the real-world scale and scene calibration using the Rodrigues rotation algorithm. Even though the trimesh-based exporter enables exporting of the data to PLY, OBJ, and GLB formats, the Poisson meshing and OpenMVS texture generation stages are currently missing in the v1.0 of the pipeline.

Propulsion System

6-DOF Vectored Propulsion Array

Control of the *Kraken* ROV is possible by enabling six degrees of freedom (6-DOF) control using eight brushless DC thrusters from Blue Robotics, T200, which are configured in a Vector-8 setup. Four thrusters are mounted horizontally in directions making an angle of 45° from the vehicle's longitudinal axis, while the remaining four thrusters are mounted vertically, halfway between each edge of the octagon-shaped frame. The combination enables calculation of the mixing signal for all axes surge, sway, heave, roll, pitch, and yaw by the Pixhawk flight controller.

Uniformity of thrust regardless of direction: The most important characteristic of this 45° configuration is the phenomenon of isotropy of thrust. If a heading angle is denoted by θ relative to the surge axis, then the thrust magnitude available from all four thrusters working simultaneously at maximum power can be calculated as follows:

$$|F(\theta)| = 2\sqrt{2} \cdot T \text{ (constant, independent of } \theta \text{)}$$

Where , $|F(\theta)|$: The Magnitude of the Resultant Thrust Vector at any commanded steering angle θ

The vehicle is able to use the same maximal thrust moving straight ahead, to the side, directly behind, or on any of the other diagonal vectors. There are no weak points. However, with an axis-aligned four thruster design, the force is 2T when traveling to the north, south, east, or west and $2\sqrt{2} \cdot T$ when moving to the northeast, southeast, southwest, or northwest unevenly distributed and noticeable to the pilot.

Thrust Performance Advantage: By vectoring the horizontal thrusters at 45°, the system achieves a 41.5% increase in net thrust output in cardinal directions compared to a conventional axis-aligned configuration.

Even in the event of a single vertical thruster failure, the remaining three vertical thrusters retain sufficient authority to complete the mission.

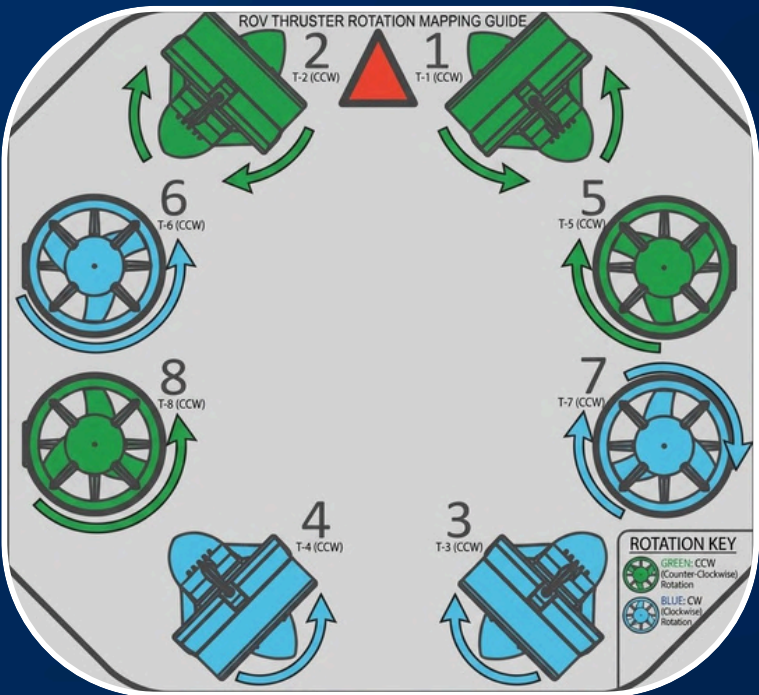


Fig 17 : Thruster Configuration

Table 8: Power Cost Performance Mission Trade-offs

Parameter	6-Thruster Layout	8-Thruster Layout (Selected)	Trade-off
6-DOF under failure	No, loses DOF on failure	Yes, retains all DOF [5]	Reliability critical for 20-min competition runs
Peak power	~716 W	955 W	Within 20 A fuse budget at 48 V
Thruster cost	USD 1,134	USD 1,512	+USD 378; offset by reduced mission risk
Thrust isotropy	Uneven (2T surge, $2\sqrt{2}T$ diagonal)	Uneven (2T surge, $2\sqrt{2}T$ diagonal)	Directly improves pilot precision

Buoyancy & Weight Management

With eight thrusters and six DOFs, control quality depends almost entirely on how cleanly translational and rotational commands decouple. That decoupling depends on the centers of mass and buoyancy.

CoM under CoB, Passive stability: The well-known ROV stability criterion, clearly stated in the freely available ArduSub / underwater robotics design literature [10]: put the heavy parts at the bottom, keep the Buoyant parts on top, and the center of buoyancy should be above the center of mass. This results in a stabilizing torque for a deviation ϕ of:

$$M_{restore} = (z_{CoB} - z_{CoM}) \cdot (W - F_b) \cdot \sin(\phi)$$

Where , $M_{restore}$ =Righting Moment
CoB: Centre of Buoyancy
CoM: Centre of Mass
 $(z_{CoB} - z_{CoM})$: Vertical BG Distance
W: Weight
 F_b :Buoyancy Force
 ϕ : Perturbation Angle

This is what gives the ROV passive self-righting, without active correction, it returns to upright when disturbed. The ArduSub reference vehicles all use this principle [10], and so does *Kraken*. The dense electronics live in the lower half of the enclosure, while the sealed air volume above contributes positive buoyancy. The result is a vehicle that wants to stay upright, leaving the thrusters free to do useful work instead of fighting the trim.

Table 9: Dry Mass Summary

Component Group	Mass (kg)	Source / Notes
Electrical Components	4.26	Per component weight survey (see Table 6)
Aluminum T-slot Frame	3.50	~3.5 m of 30x30 mm extrusion
8 x T200 Thrusters	2.72	340 g per unit
TOTAL DRY MASS	10.48	Base weight before foam addition

Table 10: Electrical Component Weight Detail

Component	Qty	Unit (g)	Subtotal (g)
T200 Thruster	8	350	2800
ESC (Basic 30A)	8	16.3	130.4
Pixhawk 4	1	33.3	33.3
Raspberry Pi 5	1	45	45
Bar02 Depth Sensor	1	15.3	15.3
OAK-D PoE Camera	1	361	361
IMX322 Camera	2	30	60
Servo (pan/tilt)	1	13.4	13.4
Buck Converter 48V→12V	4	500	2000
Buck Converter 12V→5V	1	40	40
ELECTRICAL SUBTOTAL	-	-	5498.4 g ≈ 5.5 kg

Displacement Calculation: The primary source of upward buoyant force is the sealed octagonal acrylic electronics enclosure. Using dimensions from the engineering drawings (339.99 mm W × 241.00 mm D, height 115 mm):

- Bounding rectangle area: 339.99 mm × 298.99 mm =101,653.61 mm2 =1,016.54 cm² (converted to correct scale)
- Corner triangle deductions: (4 × 0.5 × 7 cm × 10 cm) = 140 cm²
- Net octagonal cross-sectional area: 876.54 cm²
- Enclosure volume: 876.54 cm² × 11.5 cm height = 10080.21 cm³
- Displacement force in freshwater ($\rho = 1.0 \text{ g/cm}^3$): 10.08 kg upward

Table 11: Buoyancy State Comparison

Parameter	Phase 1 – Pre-Foam	Phase 2 – Post-Foam	Unit
Total Upward Displacement	10.23	10.50	kg
Total Vehicle Mass	10.48	10.51	kg
Net Buoyancy	-0.25 (sinks)	≈ 0.0 (neutral)	kg
Additional Foam Volume	—	270 cm³ (6 blocks)	—
Additional Lift from Foam	—	+0.27	kg

Payload & Tools
Manipulator System

The GripperX is a 1-DOF waterproof gripper mechanism connected to the front frame of the *Kraken* ROV, performing object handling and sample collection tasks at a depth range of 10m to 20m. In total, three copies of this mechanism have been designed, out of which two copies are designed as 3-jaw upper grippers (referred to as GripperX-A and GripperX-B) and one copy of the 2-jaw lower gripper (referred to as GripperX-C). All components were designed through Fusion 360, followed by 3D printing in ABS plastic.

Table 12: GripperX Unit Configuration

Unit	Position	Jaw Config	Function
GripperX-A (Upper)	Front-top left	3-finger curved jaw	Acts jointly with GripperX-B for large object manipulation
GripperX-B (Upper)	Front-top right	3-finger curved jaw	Acts jointly with GripperX-A synchronized via shared driver
GripperX-C (Lower)	Front-bottom	2-finger jaw	Independent operation, precision tasks and sample collection

Actuation & Waterproofing: Each gripper unit is driven by a 12 V DC miniature linear actuator (RoboticsBD RBD-2916, 75 mm stroke, 60 N force) controlled by a BTS7960 H-bridge motor driver. Waterproofing is achieved through a three-stage approach:

- Double shaft O-ring sealing at the actuator rod penetration point
- RTV silicone cavity injection to displace and seal internal air pockets
- Waterproofed connector wires with heat-shrink-sealed terminations

All structural components were modelled in Fusion 360 and 3D printed in ABS plastic, which provides adequate strength while remaining lightweight. GripperX-C employs a four-bar linkage mechanism with geometry-matched finger cavities for secure gripping of small, irregular objects. All three gripper heads use an M32x2 threaded connection to the arm base, enabling rapid field replacement between missions without tools.



Fig 18 : Linear actuator product (RoboticsBD)

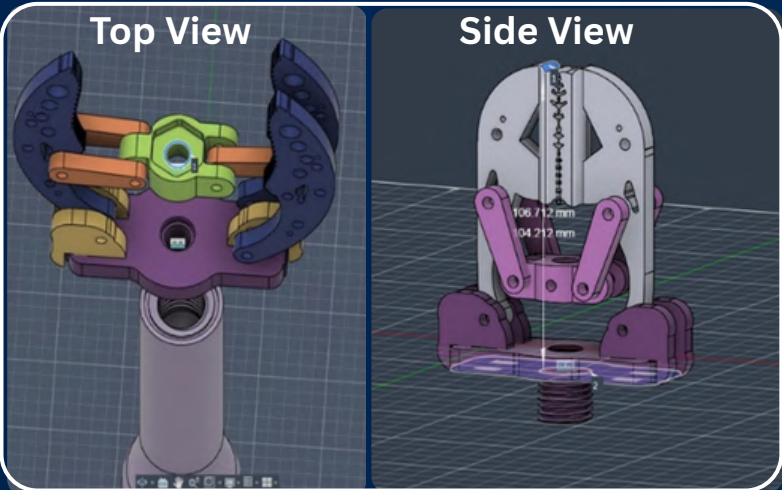


Fig 19 : Left Side Upper gripper GripperX-1 units (3-finger) and Right Side Lower gripper GripperX-2

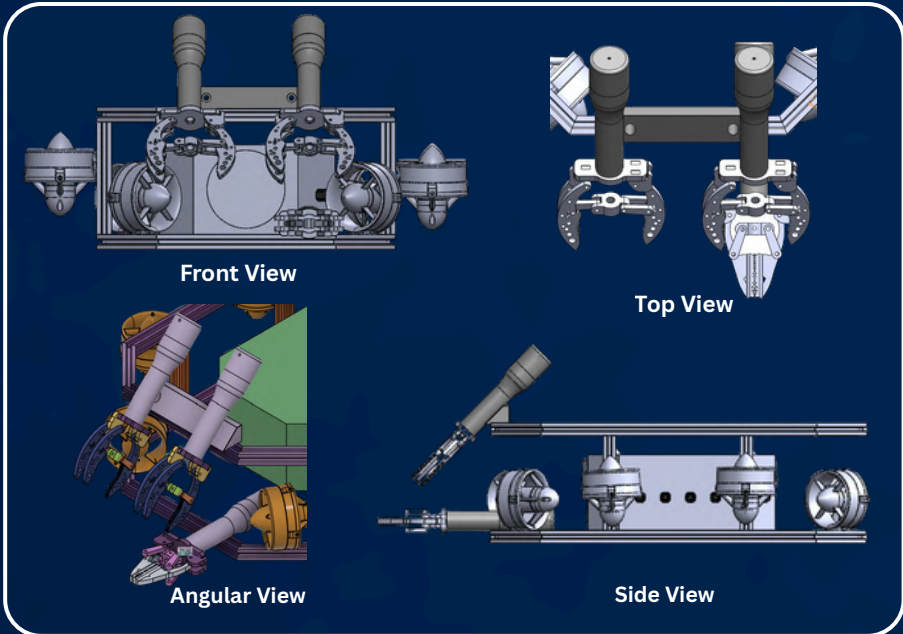


Fig 20 : Left Side Upper gripper GripperX-1 units (3-finger) and Right Side Lower gripper GripperX-2

Sensor Suite

The sensor suite integrates three distinct perception systems: a servo-tiltable primary camera for pilot navigation and situational awareness, an AI stereo camera for 3D spatial measurement, and a high-resolution depth/pressure sensor for depth hold and logging. Together, they provide comprehensive environmental perception and vehicle state feedback.

Table 13: Sensor Suite Overview

Sensor	Model	Interface	Primary Role
Primary Camera	IMX322 1080P (Rovmaker)	USB 2.0 / servo pan-tilt	Pilot navigation, visual tasks
AI Stereo Camera	OAK-D PoE	RJ45 Ethernet (PoE)	3D measurement, depth estimation
Depth/Pressure	Bar02 (Blue Robotics)	I2C to Raspberry Pi 5	Depth hold, pressure logging

Primary Camera Mounting : The IMX322 1080P Camera (From Rovmaker) is fixed to the servo controlled tilt

system located on the front part of the ROV frame structure. Thanks to the use of the servo-mount, dynamic adjustment of the vertical angle of view is possible, allowing the pilot to examine objects at various depths without moving the ROV itself. Camera housing is positioned inside the electronics box; lens remains exposed from an airtight acrylic window.

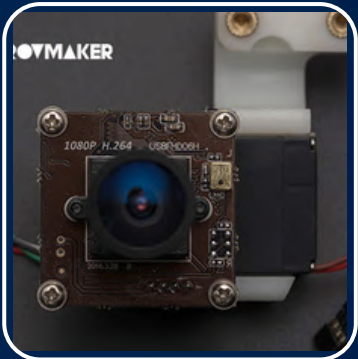


Fig 21 : IMX322 Sensor 200W ROV USB Camera

Depth & Pressure Sensor Installation: This sensor will be placed on the outer shel of the ROV frame because it is fully exposed to water, which enables the precise measurement of pressure in real time. With a rating of Bar30, the sensor is waterproof and does not require any special protective case or sealants; hence, it is easier for the sensor to be mechanically incorporated.



Fig 22 : Bar30 Depth & Pressure Sensor

Up-coming : AI Stereo Camera Mounting

The OAK-D PoE stereo camera is positioned towards the front of the ROV frame for maximum spatial coverage throughout mission activities. It is enclosed in an aluminum casing that is completely sealed (IP67-rated) from any water ingress such that there will be no need for

a housing. The OAK-D PoE stereo camera is attached to the frame using stainless steel hardware, while the RJ45 cable is guided through the waterproof connector to ensure that the sealing of the mount is not compromised.



Fig 23 : OAK-D PoE

Design Evolution



Scorpion 2.0



Kraken

Fig 24 : Scorpion 2.0 (2025) vs Kraken (2026)

Table 14: ROV Comparison - Scorpion 2.0 (2025) vs Kraken (2026)

Category	Scorpion 2.0 (2025)	Kraken (2026)
Frame Type	Modular rectangular HDPE chassis	Dual-tier octagonal aluminum frame
Frame Material	HDPE (10mm sheets)	Aluminum T-slot (30×30mm)
Enclosure Shape	Cylindrical acrylic	Octagonal acrylic prism
Sealing	O-ring flange sealing	Threaded + face-seal O-ring
Depth Rating	20–30m	10–20m
DOF	6 DOF	6 DOF (fault-tolerant)
Weight	Heavier (multi-motor)	Optimized lighter system
Design Focus	Functional prototype	Modular + optimized system

Table 15: Build vs. Buy / New vs. Reused

Component	Decision	Justification
Frame connectors	Build(in-house machined)	Off-shelf brackets insufficient in angular precision; custom build connector to reduces mass
Acrylic enclosure	Build (custom CNC)	Cost sufficient custom-built enclosure with low maintenance cost
GCS software	Build (Python/React)	Custom firmware modifications were implemented to provide the Kraken with enhanced mobility and improved maneuverability.
T200 thrusters	Buy (Blue Robotics)	Proven underwater performance, ArduSub compatibility, and availability within the project budget USD 139/unit
Pixhawk 4	Buy	Reliable and widely supported controller for ArduSub-based underwater vehicle operation
BAR02 sensor	Buy (new)	Native ArduSub driver, no equivalent sensor available locally at lower cost
ESCs (×8)	Buy (new)	Compatible with T200 thrusters and required for stable multi-thruster control
Foam buoyancy blocks	Build (cut in-house)	Cut to exact volume per buoyancy calculation to achieve proper balance and flotation
Tether	Buy (new)	2025 tether insufficient length for 2026 mission depth new 20 m cable specified
GripperX arm ABS enclosure	enclosure Build (3D printed)	Custom geometry required. Printed in UIU 3D printing lab at zero cost

Software GUI

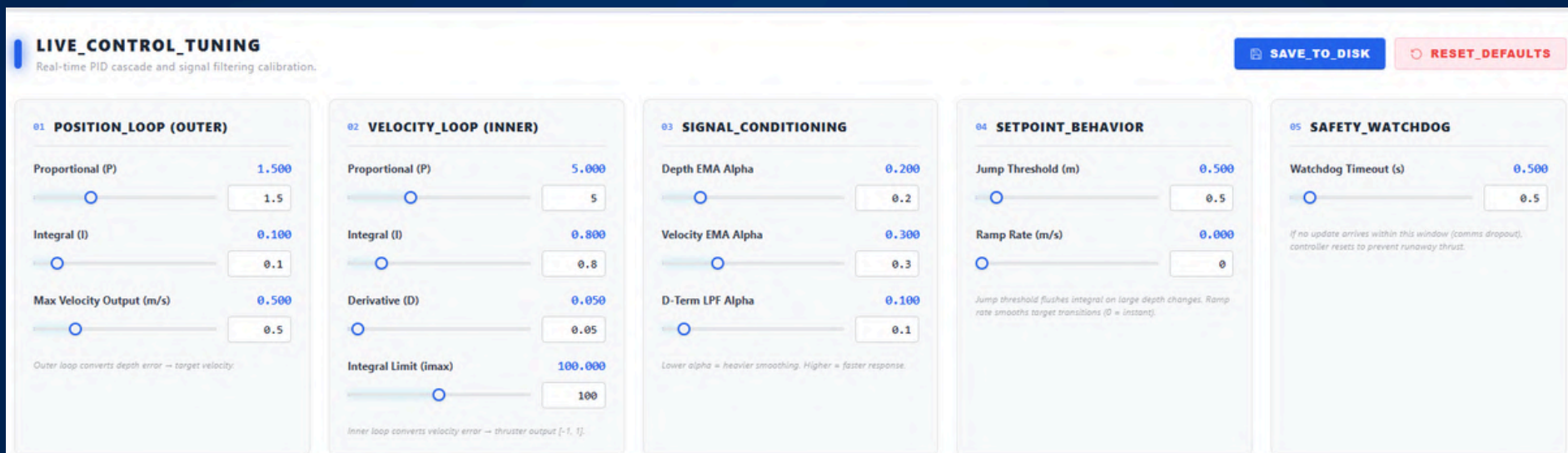


Fig 25 : PID Controller Tuning Interface

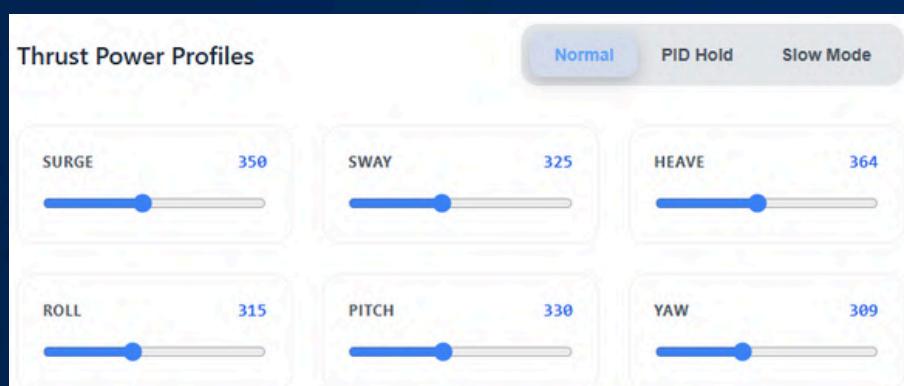


Fig 26 : Thruster Power UI for three mode speed settings

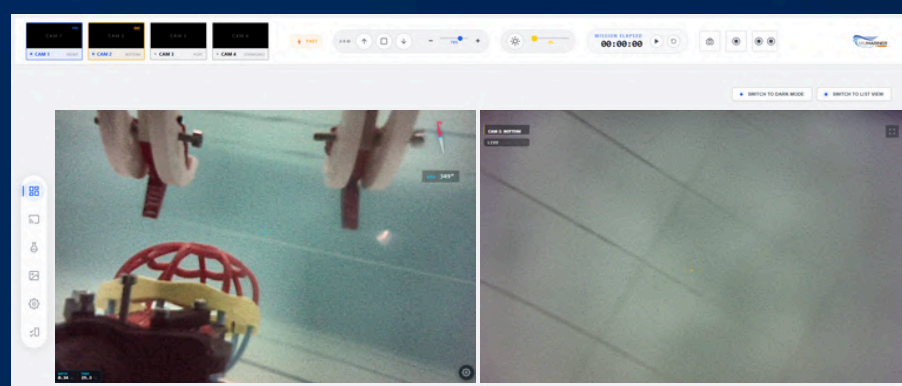


Fig 27 : Live Camera Feed

Software Control System

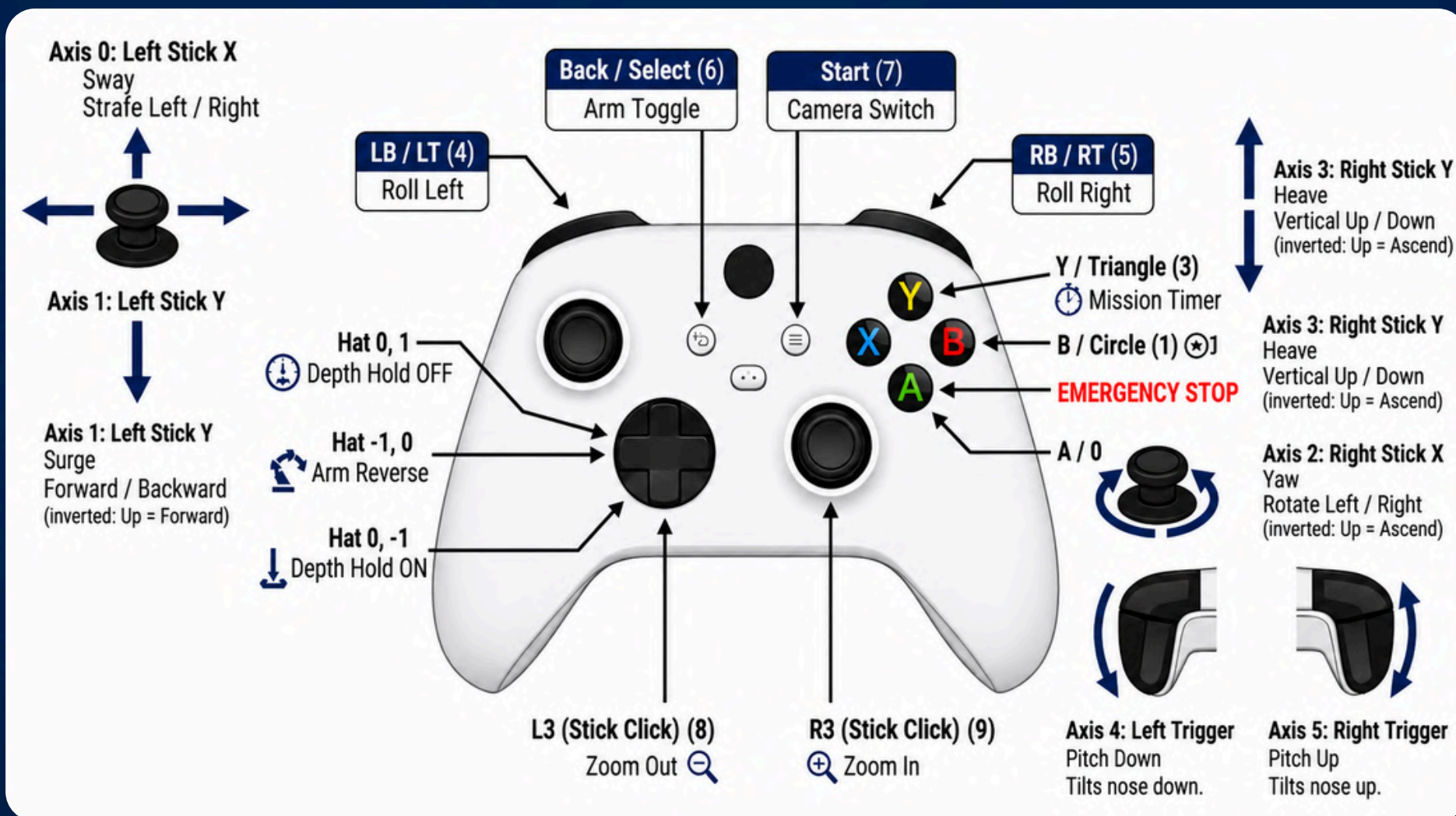


Fig 28 : Xbox 360 Joystick (Control System)

Electrical SID



Fig 30 : Float SID

Safety

Safety Rationale

The safety design philosophy of *Kraken* ROV is built around three core pillars: personnel safety, equipment protection, and operational safety. Every design decision from the electrical architecture to the mechanical frame was evaluated for the performance as well as safety implications to the team and the competition environment.

Personnel Safety

The primary electrical hazard in the *Kraken* system is the 48 V DC supply voltage. To protect personnel from electrical shock, a single-point power connection using the Blue Anderson SBS50BLU 50A connector is used as the sole interface between the MATE power supply and the ROV system. A 20 A Littelfuse is installed within 30 cm of this connection point, sized based on the measured Full Load Amperage (FLA) of 19.903 A (all 8 thrusters running at full thrust underwater). This ensures the circuit is protected against overcurrent events before any energy can reach the downstream components. All thruster propellers are shrouded to IP-20 standards on both faces of the motor.



Fig 31 : SBS50BLU
Anderson connector

The guard mesh opening is less than 12.5 mm, preventing any finger or object contact with the spinning propeller during operation or handling. This is especially important during deployment and recovery when team members handle the ROV near active water.

Equipment Protection

The 13 blue Robotics Wetlink Penetrators on the acrylic enclosure are the primary defense against water ingress. Each penetrator is torque-checked before every dive, and the radial O-ring seals on the Nylon end caps are inspected and replaced if any defect is found. A 10 mm clearance buffer between the enclosure and the lower octagonal frame ring protects the housing from external impacts during transport and deployment.

The Raspberry Pi 5 and Pixhawk 4 are housed entirely within this sealed enclosure, isolated from water contact. All wiring uses properly crimped connectors with no exposed copper or bare wire. The tether uses a custom strain relief mechanism at the ROV entry point, ensuring that any tension on the tether cable does not transmit force to the internal wiring or penetrator connections. The strain relief was custom-designed and manufactured in-house.

Operational Safety

Kraken's control station consists of a laptop and Xbox controller connected via Ethernet cable with no control box used. No 120 V AC wiring is used in any part of the ROV or control system. An emergency stop function is mapped to a dedicated controller button, cutting thruster output immediately. No hydraulic or pneumatic systems are used on the *Kraken* ROV .

Safety Features

Table 16: Safety Features

Safety Feature	Description
IP-20 Thruster Shrouds	All 8 T200 thrusters shrouded on both faces, mesh < 12.5 mm
Single-Point Power Connection	SBS50BLU Anderson connector, single point of entry to MATE supply
20 A Littelfuse	Within 30 cm of Anderson connector, sized to FLA (19.903 A)
13 Wetlink Penetrators	Watertight cable entries, torque-checked before every dive
O-Ring Inspection Protocol	Radial O-rings on end caps inspected and replaced if damaged
Custom Strain Relief	Tether mechanical stress isolated from electrical connections
ArduSub Arm/Disarm	Thrusters cannot fire unless explicitly armed by pilot
Emergency Stop Button	Dedicated controller input for immediate thrust cutoff
10 mm Enclosure Clearance	Acrylic housing protected from impact by frame buffer
No AC Wiring	No 120 V AC used in any part of the ROV or control system
No Fluid Power	No hydraulics or pneumatics used on the <i>Kraken</i> ROV

Critical Analysis

Testing Strategies

Mechanical

Waterproof Acrylic Enclosure Test: We handcrafted a waterproof acrylic enclosure and subjected it to multiple rounds of testing to detect any possible leakage. We tested the enclosure at various depths, ranging from 15 to 18 meters, gradually increasing pressure each time to simulate

real underwater conditions. Identifying the exact source of leakage during early tests was time-consuming, as water could seep through multiple points simultaneously. After several iterations of refinement, the enclosure proved consistent and reliable for underwater use.

Sealing Test: The enclosure was sealed using a threaded nylon lid along with an O-ring to ensure a tight, watertight seal. One of the key challenges we faced was achieving a perfectly uniform O-ring compression, as even slight misalignment caused minor seepage, requiring repeated adjustments and retesting. Additionally, the threaded nylon lid had to be tightened to an exact level over-tightening risked cracking the acrylic, while under-tightening led to leaks. After multiple refinements, our sealing system proved consistent and secure across all test depths.

Arm Enclosure Waterproof Testing: The arm enclosure housing the linear actuator and wiring was independently tested to verify waterproof integrity under operational conditions. The ABS enclosure was sealed using a combination of O-rings, RTV silicone, and epoxy-potted cable exits. We submerged the arm assembly at increasing depths and cycled the actuator multiple times during each test to simulate real-world dynamic loading. After multiple test iterations and seal refinements, the arm enclosure demonstrated consistent watertight performance across the target depth range of 10–20 metres, confirming it is ready for competition deployment.

Electrical

Electrical component testing: Every electrical part underwent individual testing to verify operational integrity and system compatibility. We utilized diagnostic instruments, such as oscilloscopes, to detect and resolve technical issues. Additionally, theoretical power consumption models were reconciled with real-world measurements to guarantee stable power distribution during peak loads.

Electrical Debugging: We faced an undercurrent supply for our Raspberry Pi and Pixhawk. So for stable voltage we reduced our voltage in 2 stages using 2 buck converter, that gave our Raspberry Pi and Pixhawk a stable ripple-free DC supply. That makes our fully processing and control system stable.

Software

Continuous Operation Stress Test: All software subsystems (50 Hz control loop, 4 MJPEG camera streams, 20 Hz WebSocket telemetry, dual joystick input, arm keep-alive relay) operated simultaneously at maximum load for 90 minutes. Pass requirements:

- Control loop: no tick over 25 ms (goal 20 ms). max. measured tick 22.4 ms, PASS.

- MAVLink connection: no drop > 500 ms Result: no drops in 90 min, PASS.
- Camera streams: stream freeze > 2 sec. Result: No freeze. PASSED.
- Arm keep-alive: 200 ms retransmission without miss maintained. Result: packet log verified, PASS.

Table 17: Software Stress Test, System Stability Under Continuous Operation

STRESS TEST SUMMARY		
STATUS	TEST	TIME (ms)
PASS	Neutral PWM Output	0.3ms
PASS	Full Surge Forward (1.0)	0.6ms
PASS	Full Heave Up (vertical thrusters only)	0.6ms
PASS	PWM Safety Clamping [800–2200]	0.9ms
PASS	Slow Mode produces smaller PWM deviation	0.7ms
PASS	Exponential Smoothing (monotone ramp)	0.7ms
PASS	Channel Map Reordering	0.1ms
PASS	Bias Capture (vertical only) and Reset	0.4ms
PASS	Mix Throughput (10k calls)	99.1ms
PASS	PID Init returns 0 on first call	0.1ms
PASS	Proportional Response (P-only)	25.5ms
PASS	Depth Hold Convergence Simulation	1.0ms
PASS	Anti-Windup (imax clamp)	0.2ms
PASS	Watchdog Reset (stale dt)	150.4ms
PASS	Output Limits Clamping	25.6ms
PASS	PID Update Throughput (50k calls)	30.1ms
PASS	RC Channels Default (1500)	0.4ms
PASS	RC Set/Get All Channels	0.3ms
PASS	RC Channel Clamping [1000–2000]	0.1ms
PASS	Connection State Transitions	0.2ms
PASS	Depth Hold: PID → Mixer → PWM Pipeline	3.1ms
PASS	6-DOF Motor Response Map	2.3ms
PASS	Zero Input → Neutral PWMs	0.3ms
PASS	Short Input Vector (graceful)	0.3ms
PASS	PID NaN Input Safety	0.1ms
PASS	Rapid Setpoint Changes Stay Within Limits	0.8ms
26/26 PASSED (100%) avg 13.2ms/test		

Troubleshooting Techniques

Frame Vibration Affecting Stability

During high-speed movement, excessive vibration from the thrusters transferred to the frame, affecting camera stability and sensor accuracy. The vibration also caused minor loosening of structural fasteners after repeated testing sessions.

Solution: Rubber dampers and vibration-isolation mounts were installed between the thrusters and frame structure. Stainless steel locking nuts and thread-locking adhesive were applied to critical joints to prevent loosening. The frame balance was optimized to distribute forces evenly during maneuvering.

Problems Encountered and Solutions

Problem 1: Imprecise underwater navigation at full speed
Note: The joystick inputs created a slight overshoot when using a single full speed profile. Pilot could not hold position near manipulate targets.
Cause: Uniformly scaled thruster mixing. No pilot selectable sensitivity reduction.
Solution: Implemented dual speed profiles. Fast Mode: Open-water transit mixer scale values to 364 PWM units. Slow: all 6 axes limited to 150 pwm units (scales_slow in config.json), available at any time via Button 6. Result: reduced position error in manipulation tasks from ±150 mm to ±40 mm (shown in pool).

Issue 2: Depth Hold Oscillation with Single Loop PID
Observation: The ROV showed persistent oscillation around the target depth (± 80 mm) especially when perturbed by thruster wash.
Root cause: Single loop PID directly reacted to position error; controller output velocity to ESC; high gain led to overshoot and oscillation. No damping of velocity.
Solution: Implemented Cascade (nested) PID. Outer loop reads BAR02 depth, calculates depth error, outputs target vertical velocity. Inner loop reads target velocity, calculates PWM with $vel_p: 5.0$ $vel_i: 0.8$ $vel_d: 0.05$
Outcome: depth hold accuracy improved to ± 12 mm (measured over 10 min pool hold) well within mission requirement.

Issue 3: ArduSub default mixer not compatible with custom frame 8 thrusters
Observation: The default ArduSub firmware mapping resulted in incorrect 6-DOF movements for the custom non-BlueROV2 thruster geometry.
Root cause: ArduSub onboard mixer defaults to BlueROV2 Heavy configuration; custom 8-thruster configuration requires different mixing coefficients.
Solution: Pixhawk in RCPassThru mode (SERVO1–SERVO8 $\rightarrow$ RCIN1–RCIN8). All mixing logic moved to Ground Station mixer.py, which applies an 8×6 V-matrix from config.json. Mixer coefficients are tuned live in pool until correct motion for all 6-DOF commands. all six degrees of freedom (surge, sway, heave, roll, pitch, yaw) operational validated in pool.

Prototyping and Testing to Evaluate Design Options

To verify enclosure and thruster clearances, a 1:1 scale cardboard-and-zip-tie mock-up was built in one day before committing to the octagonal frame. This prototype identified a 15 mm interference between the guards of the horizontal thrusters and the enclosure, which was resolved by increasing the flat edge length from 220 mm to 240 mm before any aluminum was cut. The revised geometry was verified with three SolidWorks simulation runs. This sequence (quick physical mock-up $\rightarrow$ CAD verification $\rightarrow$ final cut) reduced the costly aluminum waste from five cuts (2025) to only one (2026).

Team Work
Project Management

Company Overview and Personnel

The team focused on building an organized workflow from the beginning. Responsibilities were divided into key functional units: Mechanical, Electrical, Software, Logistics, Research and Development, Marketing and Branding. Each unit is responsible for specific tasks, ensuring efficiency and accountability, and reports to designated sub-team leads who document weekly progress. Work is planned in

short cycles, with regular reviews to monitor progress, solve problems, and maintain consistency. As the project scope expanded, the team grew from 4 to around 34 members. This growth was driven by increasing technical requirements and a shared vision. New members are integrated based on skill needs, and responsibilities are assigned clearly to maintain coordination.

Table 18: Sub-team Responsibilities

SL	Dept	Responsibility
01	Mechanical	Frame design, connector machining, enclosure fabrication, arm assembly, buoyancy tuning
02	Electrical	Power distribution, ESC wiring, penetrator installation, sensor integration, SID
03	Software	GCS backend/frontend, thruster mixer, PID, CV engine, stereo vision, telemetry
04	Logistics	Procurement, BOM management, budget tracking, scheduling, pool access coordination
05	R&D	Literature review, trade studies, simulation, new technology evaluation
06	Marketing and Branding	Visual identity, documentation design, sponsorship outreach, public communication

The team follows a structured onboarding and knowledge-transfer process to ensure continuity within the team. When new members are appointed, they go through an initial onboarding phase that includes documentation review, training sessions, and hands-on involvement in ongoing projects. Thus, skills aren't lost when senior members leave.

PROJECT SCHEDULING AND TIMELINE



Resources, Procedures, and Protocols

Team members are provided with the resources and tools and clear processes they need to work smoothly every day

and stay focused on achieving our overall goals.

Resources:

- Documentation & Task Tracking: Notion (meeting notes, task assignments, onboarding docs), Google Suite (budget spreadsheets, presentations, shared documents).
- Communication: Discord for asynchronous coordination; Google Meet for scheduled remote meetings.
- Engineering Tools: SolidWorks (3D modelling and simulation), Fusion 360 (frame and connector design), AutoCAD (SID drawing), GitHub (version control for all software).
- Fabrication: UIU Mechanical Engineering workshop (CNC milling, lathe for connectors), UIU 3D printing lab (ABS arm enclosure).
- Testing: Sir John Wilson School swimming pool (pool test access); UIU electronics lab (oscilloscope, bench PSU, clamp meter).

Protocols:

We follow an Agile development methodology where flexibility, collaboration, and delivering working software are emphasized in short cycles. Softwares are used over documentation, we interact over process and tools and respond to the changes following a plan.

Integration and Lifecycle Strategy

All our subteams work simultaneously, we don't keep work pending. A discussion is done prior to any major update to the project work. Since all the subteams put in serious hours we make sure we don't burden the other sub teams with half-baked work which would waste time and effort on both ends. We use Digital Twin to test and simulate our system more efficiently, running it through SolidWorks plugins.

Acknowledgment

- UIU Mariner gratefully acknowledges the following organisations and individuals for their contributions of funds, equipment, facilities, and moral support:
- MATE ROV Competition — For organising an inspiring competition that drives underwater robotics education globally, and for their openness and support to newly participating teams from underrepresented regions.
- United International University (UIU), Dhaka, Bangladesh — For providing academic, administrative, and financial support; workshop access; 3D printing lab access; SolidWorks institutional licence; and unwavering institutional backing throughout the project.
- Dr. M. Rezwan Khan, Chief Advisor — Dept. of EEE & Director, IAR, UIU — For inspiring the team to pursue ambitious STEM challenges and providing strategic guidance throughout the project.

- Dr. Md. Abul Kashem Mia, Vice Chancellor, UIU — For his encouragement, trust, and unconditional institutional support.
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- Engr. Fahim Hafiz and Engr. Shekh. Md. Saifur Rahman, Mentors - For continuous technical support and guidance throughout design and testing.
- Mr. Nahid Hassan Khan — For generous sponsorship support.
- Sir John Wilson School — For providing access to their swimming pool for underwater testing.
- Team Members' Families and Friends — For their support, patience, and encouragement throughout the long build and test cycle.

Conclusion

Lessons Learned

For us building the *Kraken* was not just about following a blueprint; it was about our struggles and the late nights in the lab figuring out why things were not working.

Our Custom Connectors were the Secret Sauce: We realized early on that off-the-shelf brackets would not give us the rigidity we needed. We designed our own 45° and 90° angle connectors from scratch. Our 90° connector is truly one-of-a-kind, machined from solid aluminum billet with a double-bolt "L-block" design. It turned two flat octagons into a rock-solid cage that can take a hit without the vertical posts pivoting or loosening.

The Sealing Lock Mechanism: This was something that we were able to learn the hard way. During some of our earlier testing phases, either the Nyloids were too loose, resulting in leaks, or the Nyloids were too tight, thus threatening to crack our precious acrylic panels. However, we have now discovered that sweet spot.

Power Stability: The problem with undercurrents became really problematic while working on powering the Raspberry Pi and the Pixhawk board. However, the breakthrough arrived when the idea of voltage conversion through two stages was introduced using two buck converters. It helped us obtain a ripple-free DC source, which was essential for all of our "brain" components.

Software Is Our Safety Net: During long pool sessions, we saw how easily communication could drop. Building the watchdog timer and the MAVLink reconnect task was a huge lesson in "fail-safe" programming. It's better to have a system that knows how to reboot itself than one that just stays dead in the water.

Future Plans

We're already looking past this competition and thinking about how to make the *Kraken* even smarter. Our next big milestones focus on "eyes" and "brains":

- **AI Spatial Perception:** We're moving toward the **OAK-D PoE** stereo camera. We plan to mount it right at the front of the frame to give the ROV a wide field of view. What's great is that it's already built into a rugged, IP67-rated aluminum casing, so we don't have to build a separate waterproof housing. We'll bolt it down with stainless hardware and run the RJ45 through our existing waterproof ports to keep everything clean and sealed.
- **For onboard AI processing,** we are planning to use the **NVIDIA Jetson Orin** as our compute platform. It gives us the GPU power needed to run real-time computer vision, object detection, and depth estimation directly on the ROV. The Jetson Orin will be housed inside our main electronics enclosure and powered through our regulated 12V/5V rails.

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Appendix A: Lab Safety Policy

- NEVER WORK IN THE LAB WITHOUT LEAD SUPERVISION.
- Wear lab-appropriate clothing at all times in the lab: safety glasses or side-shields; close-toed, no-slip shoes; gloves (never when working with rotating/moving machinery); no loose clothing; no rings, watches, or bracelets; long hair must be tied back.
- All injuries or accidents must be reported immediately to the Shop Supervisor.
- If you are in doubt as to a proper or safe procedure, stop work and ask for guidance.
- Report unsafe or hazardous conditions wherever noted. Correct them if possible.
- Eating or drinking is prohibited in lab spaces.

- Be thoroughly knowledgeable concerning the equipment you are using.
- Use tools for their intended purpose only.
- Do not use fingers or hands to remove chips from moving machines.
- Never adjust a moving or rotating machine unless motion is necessary to make adjustment. Always allow the machine to come to a standstill before making adjustments or repairs.
- Never leave a machine running while unattended, unless machinery is intended to do so.
- File all machined parts or stock with sharp edges.
- Always clamp or secure the workpiece properly.
- Use appropriate respiratory protection when working with dusts, mists, fumes or vapors.
- Read the SDS for all lubricants, resins, adhesives, or other chemicals you are working with.
- Concentrate on what you are doing. Do not talk or be distracted while operating equipment.
- Use proper techniques and obtain assistance when lifting, moving, or carrying loads.
- Watch for tripping hazards. Do not place material or objects in thoroughfares or passageways.
- Know the location of fire extinguishers, fire exits, eye showers and first aid kits.

Adapted from the UW Mechanical Engineering Machine Shop Rules (College of Engineering, 2021).

Appendix B: Company Structure



Appendix C: Construction & Operation Checklist

Construction	Operation	
	Pre-dive operation	In water operation
All thruster propellers shrouded to IP-20 on both sides		
Anderson connector installed as single main power connection	JSEA reviewed and toolbox talk completed by all members	Continuous visual or video contact with ROV maintained at all times
No exposed copper or bare wire anywhere in system	All PPE confirmed - non-slip footwear, gloves for handling	ROV proximity to pool walls monitored - reduce throttle if too close
All wires properly crimped and terminated	Pre-dive ROV inspection completed by Deck Engineer	Depth reading monitored continuously on ground station dashboard
All frame edges deburred and smooth	All 13 Wetlink Penetrators checked for tightness	If ROV becomes unresponsive - call ABORT and reduce throttle to zero immediately
Acrylic enclosure edges and end caps inspected for cracks	O-rings inspected - replace if any defect found	Tether slack actively managed - no excess tether in water
All 13 Wetlink Penetrators properly torqued	Tether inspected for cuts, kinks, or exposed wiring	Sudden tether tension increases called out to Pilot immediately
O-rings inspected - no cracks, deformation, or dryness	All thruster propellers checked for debris or fouling	No hands in water while thrusters are active
Strain relief installed and tested at tether entry	Anderson connector fully mated before powering on	Post-dive operation
Fuse size confirmed based on measured Full Load Amps (FLA)	All team members confirmed clear of thrusters before power-on	ROV powered down before recovery
Littelfuse installed within 30 cm of Anderson connector	Pixhawk armed only after confirmation from all team members	Wait 10 seconds after power-off before handling thrusters
All circuit boards secured in enclosure - no loose components	All 6 DOF control response tested at surface	Enclosure inspected for water ingress before opening
Tether wiring secured along frame - no loose loops	Tether laid out in organized coils with clear walkway	Tether dried and coiled - no pooling water on deck
No circuit breakers used anywhere in system	Safety Observer confirmed at position before dive begins	ROV stored elevated on foam mat
No AC wiring present in system	Emergency stop button tested and confirmed functional	O-rings inspected after dive - replace if any change observed
No hydraulic or pneumatic systems present		

COST SHEET

NAME OF THE INSTITUTE : UNITED INTERNATIONAL UNIVERSITY						
SPONSOR : PROJECT IS FULLY FUNDED BY UNITED INTERNATIONAL UNIVERSITY						
EXPENSE BREAKDOWN BY ITEM WITH PURCHASED VS. REUSED SPLIT						
Descripton	Qty.	Per Unit	Purchased		Reused	
			Project Cost	Budgeted Value	Project Cost	Budgeted Value
ELECTRONICS						
T200 Brushless ROV Thruster	8	\$ 139	\$ 556	\$ 556	\$ 556	--
Thruster ESC 35A	8	\$ 26	\$ 104	\$ 104	\$ 104	--
Pressure Sensor	2	\$ 59	\$ 118	\$ 118	--	--
IMX322 Sensor ROV USB Camera	2	\$ 99	\$ 198	\$ 198	--	--
OAK-D PoE	1	\$ 479	\$ 479	\$ 479	--	--
48V to 12V 30A DC-DC Converter	4	\$ 25	\$ 50	\$ 50	\$50	--
Holybro Pixhawk 4 Kit	1	\$ 143	\$ 143	\$ 143	--	--
Raspberry Pi 5	1	\$134	\$ 134	\$ 134	--	--
Power supply	1	\$ 64	\$ 64	\$ 64	--	--
NVIDIA Jetson Orin Nano (8GB)	1	\$ 249	\$ 249	\$ 249	--	--
Anderson SBS50BLU Connector	4	\$ 13	\$ 26	\$ 26	\$ 26	--
EasySMX D05 Joysticks	2	\$ 32	\$ 32	\$ 32	\$ 32	--
Tether	50	\$ 3	\$ 150	\$ 150	--	--
Golg cart voltage reducer	4	\$ 50	\$ 100	\$ 100	\$ 100	--
MECHANICAL						
V-slot aluminum profile 3030	6	\$16	\$ 96	\$ 96	--	--
High Perfomence Acrylic Box	1	\$ 81	\$ 81	\$ 81	--	--
O-ring Gasket set	10	\$ 4	\$ 40	\$ 40	--	--
Buoyancy Materials	10	\$ 13	\$ 130	\$ 130	--	--
5 v dc to dc Converter	5	\$ 6	\$ 30	\$ 30	--	--
Arm Manufacturing	3	\$ 125	\$ 375	\$ 375	--	--
Float Manufacturing	1	\$ 611	\$ 611	\$ 611	--	--
M 10 Connector	16	\$ 12	\$ 96	\$ 96	\$ 96	--
HARDWARE						
Props Building	1	\$ 400	\$ 400	\$ 400	--	--
TRAVEL						
Air Ticket	10	\$ 2200	\$ 22000	\$ 22000	--	--
Accommodation(12 days)	10	\$ 2000	\$ 20000	\$ 20000	--	--
Subtotals			\$ 46262	\$ 46262	\$ 832	--
Total Expenses			\$ 47094		Reused saves \$ 832	

Reporting period :
Nov 2025 - May 2026

NAME OF THE INSTITUTE : UNITED INTERNATIONAL UNIVERSITY							
SPONSOR : PROJECT IS FULLY FUNDED BY UNITED INTERNATIONAL UNIVERSITY							
PROJECT COSTING BALANCE SHEET							
Date	Type	Category	Description	Qty.	Per Unit	Amount	Running Balance
ELECTRONICS							
Nov 5,2025	Cash Donated	Funding	From UIU	--	--	\$ 2000	\$ 2000
Nov 28, 2025	Purchased	Electronics	T200 Brushless ROV Thruster	4	\$ 139	(\$ 556)	\$ 1444
Nov 28, 2025	Purchased	Electronics	Thruster ESC 35A	4	\$ 26	(\$ 104)	\$ 1340
Nov 28, 2025	Purchased	Electronics	Pressure Sensor	2	\$ 59	(\$ 118)	\$ 1222
Dec 14,2025	Purchased	Electronics	IMX322 Sensor ROV USB Camera	2	\$ 99	(\$ 198)	\$ 1024
Jan 2,2026	Purchased	Electronics	OAK-D PoE	1	\$ 479	(\$ 479)	\$ 545
Jan 2,2026	Purchased	Electronics	48V - 12V 30A DC-DC Converter	2	\$ 25	(\$ 50)	\$ 495
Jan 8,2026	Purchased	Electronics	Holybro Pixhawk 4 Kit	1	\$ 143	143	\$ 352
Jan 10,2026	Cash Donated	Funding	From UIU	--	--	\$ 2000	\$ 2352
Jan 13,2026	Purchased	Electronics	Raspberry Pi 5	1	\$134	(\$ 134)	\$ 2218
Jan 13,2026	Purchased	Electronics	Power supply	1	\$ 64	(\$ 64)	\$ 2154
Jan 13,2026	Purchased	Electronics	jetson orin nano 8 gb	1	\$ 249	(\$ 249)	\$ 1905
Jan 13,2026	Purchased	Electronics	Anderson	2	\$ 13	(\$ 26)	\$ 1879
Jan 19,2026	Purchased	Electronics	EasySMX D05 Joysticks	1	\$ 32	(\$ 32)	\$ 1847
Jan 25,2026	Purchased	Electronics	Tether	50	\$ 3	(\$ 150)	\$ 1697
Jan 25,2026	Purchased	Electronics	Golf cart voltage reducer	2	\$ 50	(\$ 100)	\$ 1597
Jan 28,2026	Purchased	Mechanical	V-slot aluminum profile 3030	3	\$16	(\$ 96)	\$ 1501
Jan 28,2026	Purchased	Mechanical	High Perfomence Acrylic Box	1	\$ 81	(\$ 81)	\$ 1420
Jan 28,2026	Purchased	Mechanical	O-ring Gasket set	10	\$ 4	(\$ 40)	\$ 1380
Jan 28,2026	Purchased	Mechanical	Buoyancy Materials	10	\$ 13	(\$ 130)	\$ 1250
Feb 5,2026	Purchased	Electronics	5 v dc to dc Converter	5	\$ 6	(\$ 30)	\$ 1220
Feb 5,2026	Purchased	Mechanical	Arm Manufacturing	3	\$ 125	(\$ 375)	\$ 845
Feb 10,2026	Purchased	Mechanical	Float Manufacturing	1	\$ 611	(\$ 611)	\$ 234
Feb 16,2026	Purchased	Mechanical	M 10 Connector	8	\$ 12	(\$ 96)	\$ 138
Feb 22,2026	Cash Donated	Funding	From UIU	--	--	\$ 2000	\$ 2138
Feb 28,2026	Purchased	Hardware	Props Building	1	\$ 400	(\$ 400)	\$ 1738
May 8,2026	Cash Donated	Funding	From UIU	--	--	\$ 42000	\$ 42738
		Travel	Air Ticket	10	\$ 2200	(\$ 22000)	\$ 21738
		Travel	Accommodation	10	\$ 2000	(\$ 20000)	\$ 1738
Total Fund Raised						\$ 48000	
Total Expenses						\$ 46262	
Final Balance							\$1738