

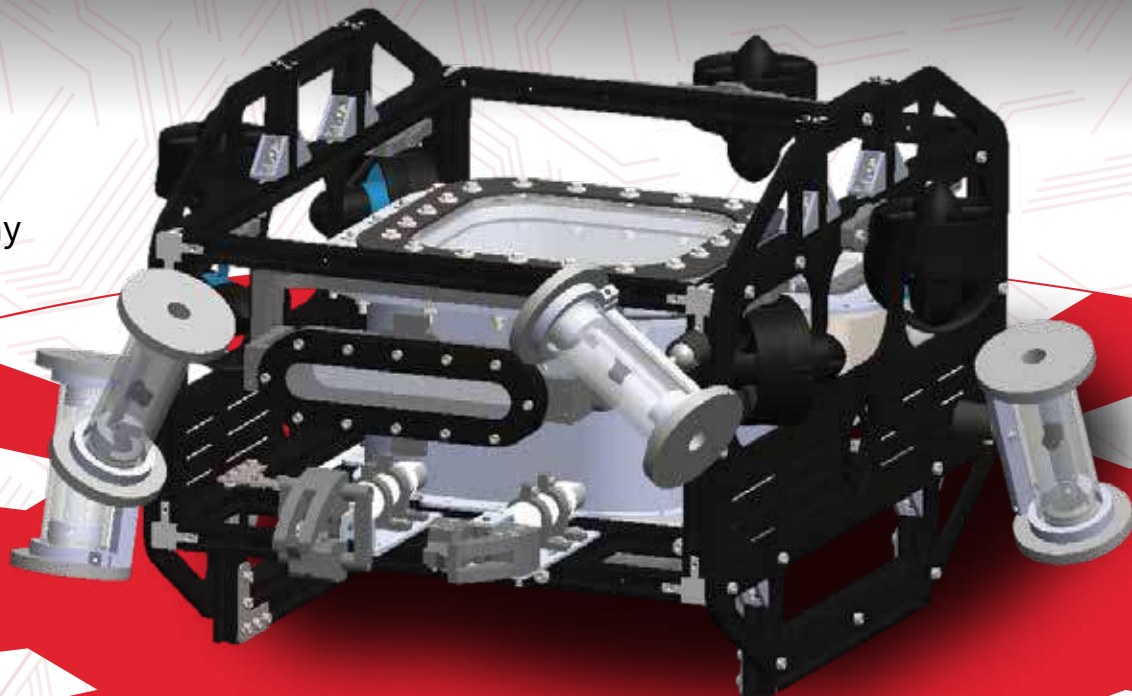


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TECHNICAL REPORT '26

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1 Abstract

Designed to confront the challenges in the Great Lakes and Oceans, Kamikaze is E-JUST Robotic Club's entry for the 2026 MATE ROV Competition. Constructed for the purposes of ocean monitoring, marine renewable energy, and ecosystem restoration, it promotes the UN Decade of Ocean Science and propels sustainable developments in underwater exploration. Kamikaze is a product of 38 employees to deliver a robust and mission-ready solution.

With only four years of experience, Kamikaze was a large step up from its predecessor Shiro Kaijin, where modularity, sustainability, adaptability and ease of pilot were the main design choices while designing. Kamikaze improves on its predecessor by using a modular aluminum extrusion frame allowing the ease of modification and the specialized tools that can accomplish more specific tasks. Kamikaze also implements a new manipulators design made to grip on a wide range of sizes, a sealed 6mm-aluminum canister, a seven-thruster propulsion system with six degrees of freedom. In addition to that, Kamikaze also implements new custom-made PCB with STM32 microcontroller, a custom depth sensor, the usage of aluminum wires and built up from ground software with a new custom station to control it.

Kamikaze is prepared to perform jobs ranging from autonomous 3d modelling , maintaining Wind-Powered Off-shore Oil Platform to determination of green carbs. Accompanied by a custom-built under ice vertical profiling float for autonomous data collecting on ocean health and depth, it becomes a realistic solution for the preservation of great lakes and oceans.

2 Design Rationale

2.1 Design Evolution

The development of **Kamikaze** was the result of a step-by-step design process that began with a critical evaluation of last year's model, Shiro Kaijin (Figure 2). By



Figure 1: E-JUST Robotics Club Team.

identifying its limitations, we carefully assessed alternative solutions, ensuring that each design decision balanced performance, cost, and operational efficiency.

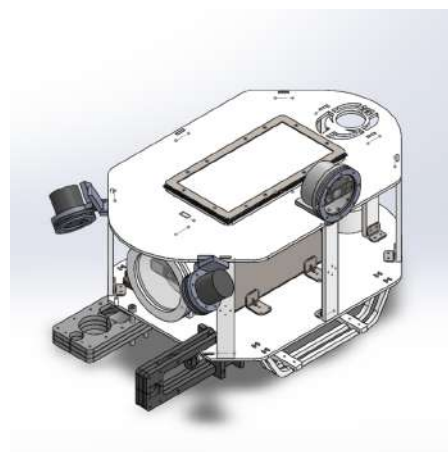


Figure 2: Shiro Kaijin.

Our team conducted structured brainstorming sessions to explore innovations that would enhance functionality while maintaining cost-effectiveness. Through a holistic systems approach, we ensured seamless integration between mechanical, electrical, and software components, optimizing overall performance. As a result, Kamikaze (Figure 3) represents a well-planned evolution that enhances reliability, efficiency, and mission adaptability.



Figure 3: Kamikaze.

2.1.1 Mechanical System Evolution

Frame and Structural Improvements

Shiro Kaijin's frame was constructed entirely from HDPE, which posed challenges in component fixation. Drilling holes for mounting often led to overlap issues, making modifications difficult. To address this, Kamikaze features a modular aluminum extrusion body, enabling flexible component placement, quick adjustments, and easier repairs.

Canister Evolution

After a long R&D process and testing many systems, one of these systems was to have a PETG canister body integrated with aluminum base and flange, however this system gives us the design and manufacturing flexibility but it shows a single point of failure at the point where PETG and aluminum meet. So, the final decision was to have aluminum canister taking into consideration the thickness of aluminum sheet, aluminum alloy used and the welding method.

Propulsion System

Kamikaze improves upon its predecessor's six-thruster configuration by adopting a seven-thruster setup, enhancing maneuverability and control. However, in line with cost-efficiency objectives, all thrusters from last year's model were reused, maintaining a balance between improved functionality and resource optimization.

tion.

Gripper Mechanism Enhancement

Shiro Kaijin's gripper was limited to fixed circular openings, restricting it to predefined object sizes. Kamikaze introduces a versatile gripping mechanism capable of adapting to various object dimensions, significantly increasing efficiency and flexibility in underwater tasks.

Improved Piloting and Camera System

Kamikaze enhances operational efficiency with an upgraded camera system supporting multiple camera types with rotation and tilt functionality. This ensures a comprehensive, adaptable view of the environment, improving pilot control and situational awareness.

2.1.2 Electrical System Evolution

Power Connection and Cable Management Issues

Kamikaze faced instability in power connections due to disorganized cables, causing electrical noise and intermittent connectivity. Each ESC was connected separately, leading to excessive wiring and limited space within the canister. To address this, each ESC is designed on an individual PCB, and all ESC PCBs are consolidated onto the power PCB, significantly reducing cable clutter, minimizing electrical noise, and improving system stability. Additionally, an STM32 microcontroller was added to the power PCB, further optimizing wiring and ensuring a more reliable electrical system.

CAN Bus Integration

To further enhance system communication, a CAN bus was integrated, enabling reliable data exchange between multiple STM32s, reducing wiring complexity, and allowing independent node resets without affecting the overall system. This implementation ensures robust and efficient communication, critical for the seamless operation of Kamikaze's various subsystems.



Limitations of MS5540 Depth Sensor and Custom Depth sensor

The MS5540 depth sensor proved to be inaccurate, slow, and costly, making it an inefficient choice for the system. To overcome these limitations, Kamikaze replaced it with a custom- designed PCB dedicated to the depth sensor, enabling real-time, highly accurate measurements along with improved connectivity options (Figure 4). The new design was further optimized by reducing the board size to nearly half its original footprint, achieved through enhanced PCB design techniques and tighter manufacturing tolerances. Despite utilizing fewer components and a more compact layout, extensive testing confirmed that the new sensor outperformed the previous implementation in both accuracy and reliability.

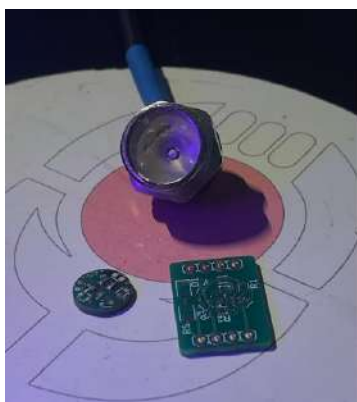


Figure 4: Custom depth sensor and compact PCB re-design.

Active Pressure Compensation System Designed as a safety fail-safe rather than a sealing method, the team developed a pressure regulation system that keeps the canister's internal pressure higher than the surrounding water (Figure 5). Although real world factors like pump flow rates limit its perfection, the system acts as a reliable fail-safe for electronics. It is controlled via an overwater PCB that allows for both manual and automatic pressure adjustments, and the pressure behavior is monitored through a LabVIEW interface (Figure 6).

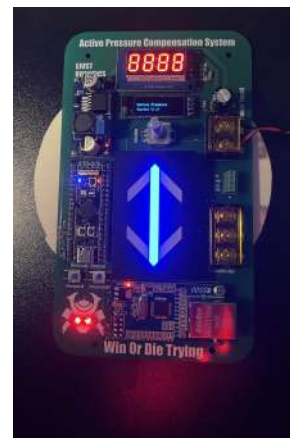


Figure 5: Active pressure compensation system.

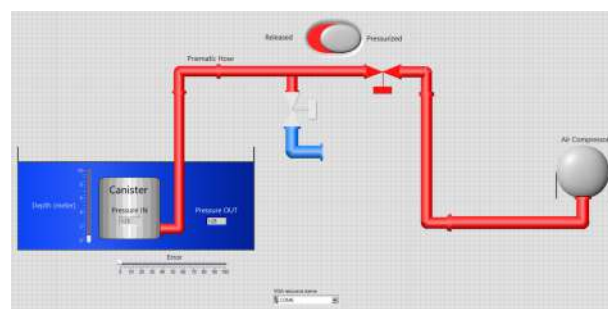


Figure 6: Monitoring system using LabVIEW

Implementing Voltage and Current Sensors Voltage and current sensors were integrated to enhance the system's monitoring capabilities. This implementation enabled precise tracking of power consumption and facilitated the early detection of potential faults, improving overall system safety, reliability, and performance.

Board Design Constraints

Due to the previous inadequacies of the previous PCB printing quality, we opted to manufacture our PCBs at JLCPCB. This drastically improved the stability of our system allowing us to use double sided boards and tighter tolerances, enabling us the capacity to use smaller SMD packages including 0805 and 0603. Also, as the quality of the PCB was improved we also could troubleshoot more efficiently and easily. With these advantages we significantly reduced the time needed to fully test the boards and had the boards ready in no time.

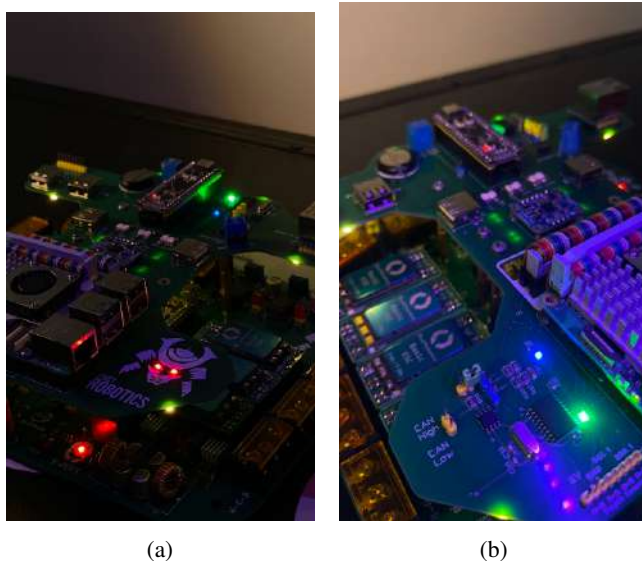


Figure 7: High Quality JLC PCBs

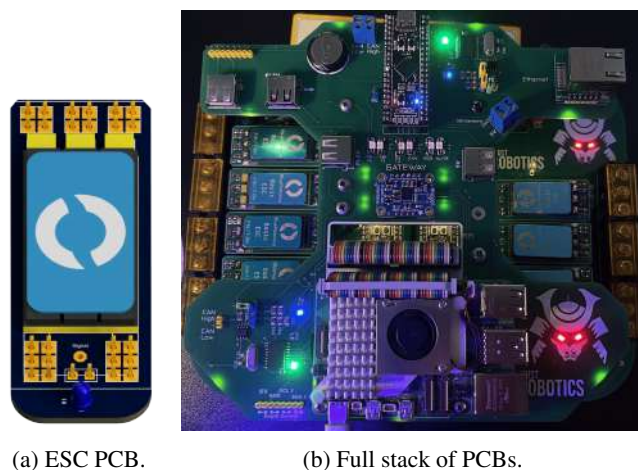


Figure 8: Kamikaze PCBs.

2.1.3 Software System Evolution

This season, the software architecture underwent major evolutionary upgrades to enhance reliability, precision, and autonomy, building upon the robust foundation established last year:

- **Custom Inverse Kinematics (IK):** Developed a tailored IK node to support our novel 7-thruster configuration, moving away from manual torque calculations to achieve direct, 6-Degree-of-Freedom (DOF) precision.
- **Advanced v-SLAM:** Upgraded our perception stack using RTAB-Map and the ZED2i stereo camera to generate real-time 3D point clouds and provide precise localization for autonomous mission tasks.
- **Over-The-Air (OTA) Programming:** Integrated OTA capabilities for the very first time. This unprecedented addition provides the software team with a massive operational advantage, allowing us to remotely flash firmware, execute debugging cycles, and tweak algorithms without ever breaching the ROV's physical watertight seals (Figure 9).

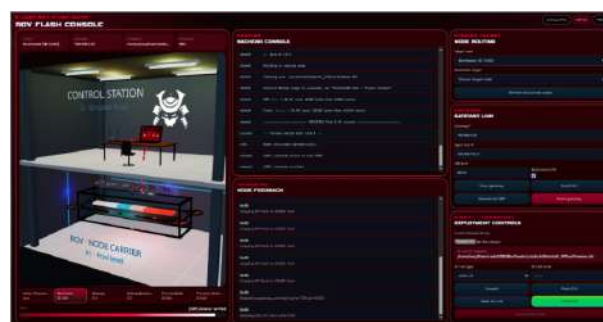


Figure 9: level OTA programming diagnostics

ZED Camera

This year, we added a stereo camera to our ROV to enhance our navigation capabilities. The ZED2i camera is capable of providing depth perception and 3D mapping. We believe that this addition is crucial to the de-



velopment of our ROV, and it's a decent investment for the future.

μ ROS

We improved our communication model even more by the integration of micro-ROS, a ROS 2 implementation for microcontrollers, on one of the STM32 we have. We used micro-ROS Ethernet to connect the STM32 to the top-side computer, which is running ROS 2, allowing for seamless integration between the microcontrollers and the main computer. Micro-ROS ensures real-time communication and efficient data exchange, enhancing the overall performance of our ROV.

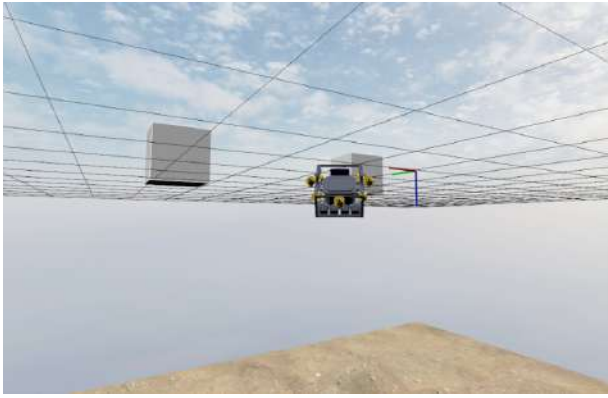


Figure 10: Kamikaze ROV Simulated in the DAVE underwater environment

2.2 Design and Manufacturing Process

2.2.1 Conceptual Design

The design process began with a comprehensive evaluation of last year's ROV to identify areas for improvement. The team focused on two primary aspects: performance optimization and the integration of new features required for this year's tasks.

To ensure a structured approach, brainstorming meetings were conducted to analyze feasibility, cost, and impact on overall performance. One of the major innovations was the adoption of a modular aluminum extrusion body, a strategic decision aimed at enhancing adaptability and extending the ROV's lifespan.

Another key challenge was selecting suitable material for the electronic canister. After evaluating material strength and pressure resistance, the team decided to proceed with Aluminum, ensuring a cost-effective and flexible solution that could withstand underwater conditions.

2.2.2 Preliminary Design

Once the core design concepts were defined, SolidWorks simulations were conducted to evaluate structural integrity, hydrodynamics, and thruster configurations. These data-driven insights played a critical role in optimizing component placement and material selection.

To ensure an optimal balance between performance and affordability, a trade-off matrix (Table 1) was developed, comparing materials based on weight, cost, and manufacturability. The table presents the weighted selection criteria per component according to a weighted sum presented in Equation 1, where materials are chosen by maximizing the sum of weighted property scores. Additionally, build vs. buy decisions were assessed, ensuring that in-house manufacturing was pursued where it provided a functional and economic advantage, while outsourcing was considered for components requiring specialized fabrication.

$$\text{Total Score} = \sum_{\text{Criteria}=1}^n (\text{component weight})_{\text{criteria}} \times (\text{material score})_{\text{criteria}} \quad (1)$$

Criteria	Weight				Materials					Selected Material
	Frame	Body	Canister	Gripper	HDPE	Acrylic	Aluminum	Stainless steel	3D printing	
1 Transparency	0	0	0	0	0	10	0	0	0	-
2 Strength	0.1	0.4	0.5	0.2	6	4	9	10	3	-
3 Cost & Availability	0.2	0.2	0.1	0.4	8	6	7	5	8	-
4 Fabrication (ease)	0.5	0.3	0.1	0.2	9	7	7	6	8	-
5 Ductility	0.1	0.1	0.3	0.1	7	3	8	6	4	-
6 Specific Gravity	0.1	0	0	0	9	8	7	2	8	-
Total Score	Frame				8.3	6.5	7.3	4.6	7.4	HDPE
	Body				7.7	5.6	8.1	6.8	7	Aluminum
	Canister				7.1	5.3	8.3	4.7	4.3	Aluminum
	Gripper				7.6	5.2	6.8	5.6	7.4	HDPE

Table 1: Criteria and Material Selection Matrix.

2.2.3 Detailed Design and Manufacturing

With validated designs, the final ROV model (Figure 11) was fully developed in SolidWorks, incorporating

stress, buoyancy, and flow simulations to ensure structural stability and hydrodynamic efficiency.

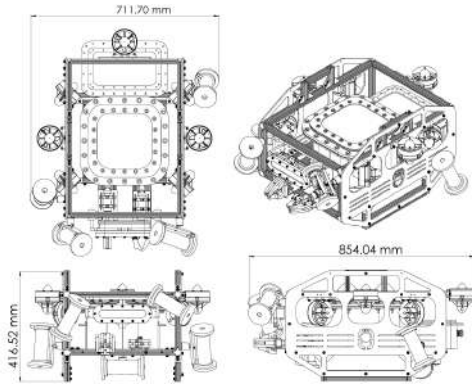


Figure 11: Kamikaze Drawings

For manufacturing, a systems-based approach was taken:

- The aluminum plates body was Laser CNC-machined and assembled using precise modular connectors.
- The canister was made using 6mm-aluminum, with design improvements tested through simulation and prototype experiments.
- The grippers and other HDPE parts were cut using router cutters, leveraging precise CAD models to minimize material waste. 2D CAD models (Figure 12) were generated to optimize material usage.

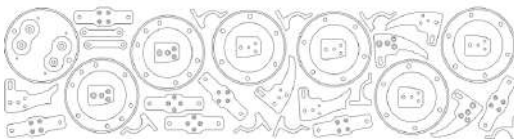


Figure 12: DXF file for cutting the grippers.

Finally, the complete ROV assembly was tested to ensure seamless integration of mechanical, electrical, and software components.

2.3 Vehicle Core Systems

2.3.1 Mechanical System

2.3.1.1 Frame

Kamikaze's frame (Figure 13b) is designed using a cuboid aluminum V-extrusion structure, providing a stable and modular foundation for mounting various components. The 20×20 and 20×40 aluminum extrusions offer a strong yet lightweight framework that maintains structural integrity in underwater conditions.

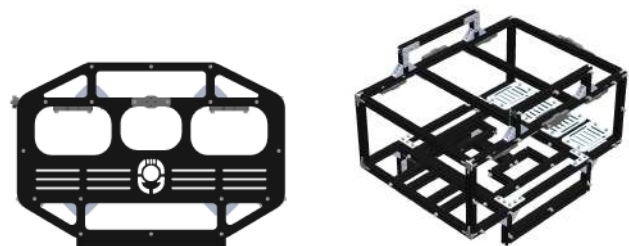
To enhance stability and buoyancy, HDPE side frame sheets (Figure 13a) are integrated into the design. These sheets not only contribute to the aesthetic appeal of the ROV but also help in maintaining balance during operations. Their strategic placement ensures that the ROV remains hydrodynamically stable while supporting the overall structural framework.

The frame is designed with precise mounting slots, allowing secure positioning of thrusters, cameras, and operational tools while maintaining easy access for maintenance. The bolted assembly ensures that components can be reconfigured or replaced without permanent modifications.

Additionally, the frame is tailored for the E-JUST Robotics team, ensuring compatibility with the mission requirements of the MATE ROV competition while balancing durability, weight efficiency, and adaptability.

2.3.1.2 Propulsion

Kamikaze is equipped with seven T200 Blue Robotics



(a) HDPE Side Frame.

(b) Aluminum Extrusion Frame.

Figure 13: Kamikaze's Frame Illustration.



thrusters, strategically placed to achieve six degrees of freedom for precise maneuverability (Figure 14). This setup balances performance, power consumption, and cost-efficiency, ensuring mission success without excessive energy use.

Using seven thrusters instead of a larger number reduces power draw while maintaining stability and control. Each thruster's power consumption is affected by drag force, given by:

$$F_d = \frac{1}{2} C_d \rho A v^2 \quad (2)$$

Where:

- F_d = Drag force (N)
- C_d = Drag coefficient (ROV shape-dependent)
- ρ = Water density (kg/m³)
- A = Cross-sectional area (m²)
- v = ROV velocity (m/s)

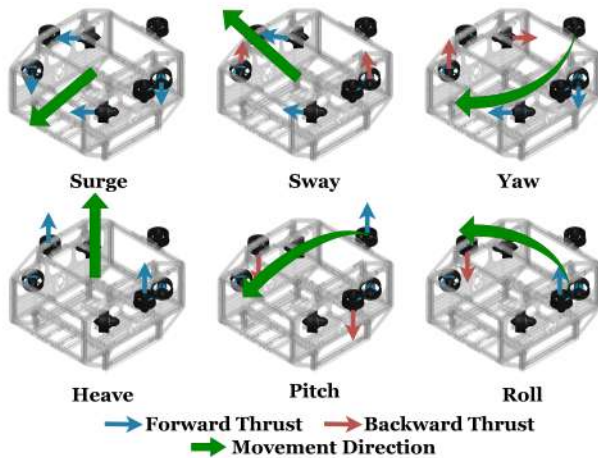


Figure 14: Kamikaze's Degrees of Freedom.

A CFD flow simulation was conducted to analyze water flow around Kamikaze (Figure 15), minimizing drag and enhancing hydrodynamic efficiency.

Trade-offs in Thruster Selection

- **Power vs. Performance:** More thrusters improve stability but increase power consumption. Seven

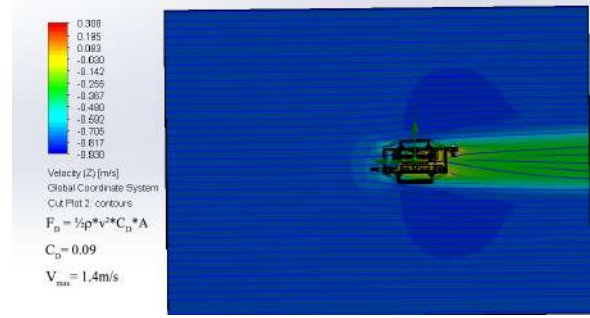


Figure 15: Flow Simulation.

thrusters provide a balance between efficiency and control.

- **Cost vs. Mission Needs:** Reusing last year's T200 thrusters reduces costs while still meeting competition requirements.

2.3.1.3 Buoyancy and Stability

The ROV is designed to have positive buoyancy by carefully selecting lightweight materials and ensuring the buoyant force is slightly greater than its weight. Using Archimedes' principle (Equation 3) and SolidWorks simulations, we confirmed that the ROV naturally surfaces while maintaining stability.

$$F_B = \rho_{\text{water}} \times \text{Volume Displaced} \times \text{Gravity} \quad (3)$$

This was achieved by positioning the center of buoyancy (Table 2) above the center of gravity (Table 3), ensuring smooth and controlled movement in the water.

Parameter	Value	Parameter	Value
Mass	18390.88 grams	Mass	17389.17 grams
Volume	18390882.63 mm ³	Volume	8925547.20 mm ³
Center of Buoyancy	X=-0.05, Y=-20.00, Z=-0.10 mm	Center of Gravity	X=0.03, Y=-21.53, Z=-7.36 mm

Table 2: Mass properties of wa- Table 3: Mass properties of ter displaced (buoyancy force) the product and internal components (weight force)

Wet weight is calculated as follows:

$$\begin{aligned} \text{Wet Weight} &= \text{Buoyancy Force} - \text{Weight Force} \\ &= 18,390.88 \text{ grams} - 17,389.17 \text{ grams} \\ &= 1,001.71 \text{ grams} \end{aligned}$$

The buoyancy analysis determined that the ROV, with a mass of 18,390.88 grams, displaces 17,389.17 grams



of water, resulting in a net wet weight of 1,001.71 grams. Since it is positively buoyant, the ROV will float. Therefore, after installing the electrical and other components, the buoyancy was checked again to ensure positive buoyancy was maintained. Based on these values, a flotation system was implemented to provide the ROV with a buoyant force of approximately 45 Newtons.

2.3.1.4 Main Canister

The canister serves as the primary enclosure for the ROV, protecting essential components such as micro-controllers, power systems, and sensors while ensuring pressure resistance, corrosion protection, and ease of maintenance. The design consists of a 6mm-aluminum body that consists of two main parts welded together and then welded with 3-mm base where cable glands are placed with embedded acrylic windows, providing structural stability and waterproof integrity under operational conditions.

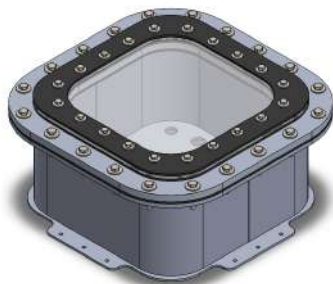


Figure 16: Kamikaze's Main canister.

PETG was chosen previously as a part of our Canister R&D process as a cost-effective alternative to aluminum, offering a balance between mechanical strength and manufacturability but it had a single point of failure as the integration between PETG and the aluminum base and flange was not that good. So, we decided to go back to make it from aluminum taking into consideration the sheet thickness, the alloy used and the welding method to be sure that the canister is well sealed

260×260×125 mm, optimized for component housing and pressure resistance.

2.3.1.5 Sealing Strategy

Waterproofing is critical for the ROV's performance and durability. The sealing approach protects electronic components while maintaining structural integrity under varying pressures. **Main Canister Sealing (Electronics Housing)**

- IP68-rated metallic cable glands ensure watertight cable entry.
- Bolted fastening ensures long-term stability.

ZED Camera Enclosure (Figure 17a)

- O-ring in a groove forms a primary seal.
- RTV Gasket Maker provides additional waterproofing.
- Compression sealing & Allen bolts apply uniform pressure.

Acrylic Camera Enclosures (Figure 17b)

For other cameras, an acrylic cylinder with an arylon end cap and an O-ring groove is used to ensure water resistance. The camera PCB is fixed inside the enclosure with a 3D-printed mount for stability.



(a) ZED Camera.



(b) Other Cameras.

Figure 17: Cameras Enclosures.

Bolt Spacing Calculation for Optimal Sealing

To ensure optimal sealing pressure and prevent gasket deformation under load, the bolt spacing (C) is calculated based on flange stiffness, gasket pressure, and deflection using equation 4.



$$C = \left[\frac{480 \left(\frac{a}{b} \right) E t^3 \Delta H}{13 P_{\min} + 2 P_{\max}} \right]^{1/4} \quad (4)$$

where:

- C = Bolt spacing (mm)
- a = Width of the flange plate (mm)
- b = Width of the gasket (mm)
- E = Modulus of elasticity of the flange material (Pa or N/m²)
- t = Thickness of the flange (mm)
- ΔH = Max. gasket deflection - Min. gasket deflection (mm)
- $P_{\min}$ = Minimum gasket pressure (Pa or N/m²)
- $P_{\max}$ = Maximum gasket pressure (Pa or N/m²)

2.3.1.6 Cameras

To ensure comprehensive underwater vision and precise control of the ROV during operation, a total of six cameras have been integrated into the system. Among these, a ZED camera is strategically placed at the front of the ROV to provide stereoscopic 3D depth perception. The remaining five cameras are a mix of Webcams, Rapoo, and Life Cams, each selected for their reliability, compactness, and clarity in underwater environments. These are distributed across different key positions of the ROV as illustrated in Figure 18, ensuring full visual coverage around the vehicle. Their placement allows the pilot to monitor the surroundings of the ROV, including the side and rear views, the grippers, and other mission-specific components.

2.3.1.7 Grippers

Two claw grippers (Figure 19) are designed to handle various item shapes and diameters. They are constructed from 10mm HDPE for durability and aluminum for fixation, ensuring a lightweight yet sturdy design. The grippers are pneumatically actuated using

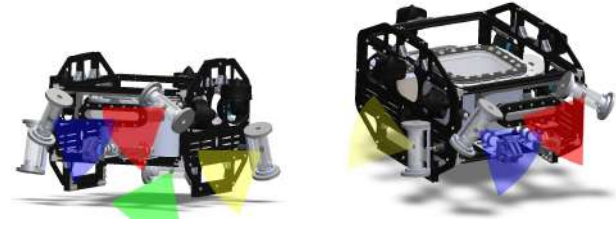
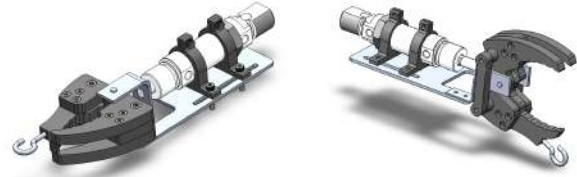


Figure 18: Cameras Positions.

a 25mm stroke piston that applies 113–135N of force in both forward and backward directions. With a maximum opening width of 70mm, they can securely grip all required competition objects. The fluid SID can be found in Appendix 7.



(a) Horizontal Gripper.

(b) Vertical Gripper.

Figure 19: Kamikaze Grippers.

To enhance functionality, two screw hooks were integrated, enabling the ROV to lift hooks and manipulate ropes, expanding its operational capabilities. To optimize the gripper's design and prevent potential bending stress-induced failures, a comprehensive stress analysis was performed. This theoretical evaluation ensured the gripper's ability to withstand the designated weight. The results (Figure 20) confirmed that:

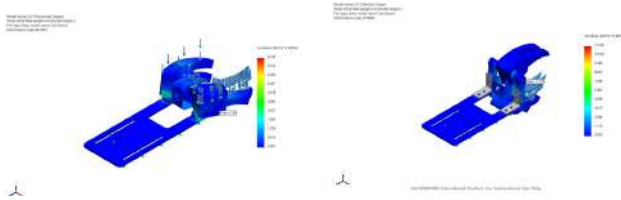
- The horizontal gripper can hold up to 14.6 kg.
- The vertical gripper can hold up to 11.8 kg.
- Both with a safety factor of 2.

2.3.2 Electrical System

2.3.2.1 Control Units

(i) Topside Control Unit

The Topside unit is where the pilot and the main program function. Several components are used to make up the topside control unit, which are shown in table 4.



(a) Horizontal Gripper Analysis. (b) Vertical Gripper Analysis.

Figure 20: Kamikaze Grippers Analysis.

Station Component	Function
Logitech G Extreme 3D Pro Joystick	Used for controlling the ROV's motion.
Laptop	Used for displaying all information received from the underwater unit.
Power Source	Provides 48V operating voltage and a current maximum rating of 30A.
Compressor	Used for supplying compressed air to the ROV's manipulator.
Monitor	Used for displaying video feeds from the ROV
Router	Used for establishing a wired connection between the ROV and the topside control unit.
Anderson connector	A type of electrical connector used for connection power to the ROV

Table 4: ROV Station Components and Functions

For efficient control and communication between the topside control unit and the ROV, the components found in Table 5 are used in the vehicle.

Vehicle Component	Function
T200 Thrusters with ESC	Thrusters used for controlling the ROV's motion, including the Electronic Speed Controller (ESC)
48V to 12V DC-DC Converters	Converts the operating 48V to 12V
Raspberry pi 5	A powerful microcontroller used for processing and controlling the ROV
STM32	A microcontroller board used for controlling various functions of the ROV
1080p USB wide-angle Cameras	Providing high quality footage for tasks like navigation and 3D modelling.
720p USB camera	Providing footage from sides of the vehicle.

Continue on the next column

Table 5: Vehicle Components and Functions

Zed 2i stereo camera	Depth camera that captures 3D images, generates depth maps
W5500 Ethernet module	For real-time system monitoring and debugging
CAN bus module	Ensures efficient and reliable communication between nodes

Table 5: Vehicle Components and Functions

(ii) Sensors

To provide the necessary data to control the ROV, different sensors are used, each for the different parameters. The sensors used can be found in the following table 6.

Sensor	Function
Custom depth sensor (MS5837)	Measuring underwater pressure and depth level of the vehicle
BNO055 sensor	Measuring the angular velocity and linear acceleration of the vehicle
Voltage & Current Sensors (ACS712)	Track power consumption

Table 6: ROV Sensors and Functions

Implementation of a Custom-Designed Depth Sensor

A custom-designed depth sensor was introduced to replace the previously existing board. The new sensor delivered greater accuracy, real-time measurements, and supported a wider range of connectivity options. This upgrade significantly improved system performance and reliability, ensuring precise and efficient depth measurement.

(iii) Underwater Control Unit

The vehicle components are all mounted on 2 thoroughly designed PCBs for maximum efficiency and low space consumption, connecting all the microcontrollers and the sensors inside the ROV.

(iv) System Integration

The ROV's electrical system operates through a structured communication framework that links a topside control station to the vehicle via an Ethernet tether.



Control signals from a joystick and laptop are routed through an onboard Ethernet switch to a Raspberry Pi 5, which serves as the primary controller, and a W5500 Ethernet module. This setup facilitates a bidirectional flow of data, allowing the Raspberry Pi to process high-level commands while simultaneously handling the video feed and telemetry data to be sent back to the surface for real-time monitoring on a graphical user interface (GUI).

The architecture is divided into three modular subsystems—Power, Sensor, and Debugging—all integrated via the CAN bus protocol. An STM32 microcontroller in the Power subsystem manages seven T200 thrusters through ESCs and monitors power metrics, while the Sensor subsystem utilizes a BNO055 sensor and another STM32 to aggregate IMU and depth data. A specialized Debugging subsystem connects to the network switch to allow for remote troubleshooting and fault management across all modules. All collected data is ultimately funneled through the Raspberry Pi and transmitted via ROS (Robot Operating System) to ensure reliable system-wide coordination and pilot feedback.

2.3.2.2 Electric Power

The provided power is 48 V and with a maximum of 30 A. This power needs to be converted and well distributed to suit our needs in the ROV, as powering the thrusters, ESCs, vision system, development boards, and other peripherals.

(i) Power Conversion System

The 48-Volt supply voltage is converted into 12 V using five different DC-DC Step down converters. Four of the converters provide a current of 30 Amps, and the fifth one provides 10 Amps. The total current is then distributed to the thrusters and the power unit PCB to supply power to the other boards inside the canister. In addition, there are Four 12V-to-5V step-down (buck) converters inside the power unit PCB, two of them provide 5 Amps for the Raspberry Pi board. The other two

provide 3 amps, one of them supplying STM32 microcontrollers and the CAN bus modules in the power PCB while the other supply the sensors and other indicators. Details of power distribution can be seen in Table 7.

Component	Quantity	Voltage (V)	Current (A)	Power Per Unit (W)	Total Power (W)
T200 Thruster	7	12	12	144	1008
Basic ESC	7	12	0.15	1.8	12.6
Raspberry Pi 5	1	5	5	25	25
STM32	4	3.3	0.125	0.4125	1.65
MCP2515 CAN Bus Module	5	5	0.1	0.5	2.5
W5500 Ethernet Module	1	5	0.13	0.65	0.65
BNO055	1	5	0.0123	0.0615	0.0615
720p USB Camera	3	5	0.2	1	3
1080p USB camera	2	5	0.275	1.375	2.75
MS5837 Depth Sensor	1	5	0.002	0.01	0.01
ZED 2i stereo camera	1	5	0.5	2.5	2.5
Total					1060.91

Table 7: Power Calculation for the ROV.

Total Current Drawn at 48V: $1060.9/48 = 21.10$ A,
Applying Safety Factor: $1.3 \times 21.10 = 28.73$ A

Required Fuse = 30A

(ii) Power Unit

As mentioned above, two PCB containing three subsystems were designed specifically for the power conversion system inside the ROV.

2.3.2.3 Tether Management Protocol

The tether is made of Polyethylene Terephthalate (PET) light weight 15mm expandable cable sleeve which provides protection for the cables inside (Figure 21). Tether length is 25 meters long and consists of two 16mm² cables made from Aluminum and PVC jacket material. CAT6e for ethernet communication. The 2 pneumatic hose supply is also included in the tether, one as an inlet and the other as an outlet.

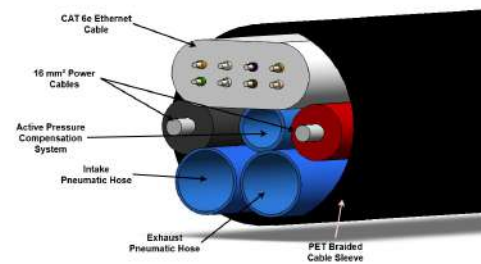


Figure 21: Tether Cross Section.



2.3.3 Software System

2.3.3.1 Communication System

The ROV's communication architecture which is illustrated in Figure 22 can be divided into two parts: the top side control unit and the ROV unit.

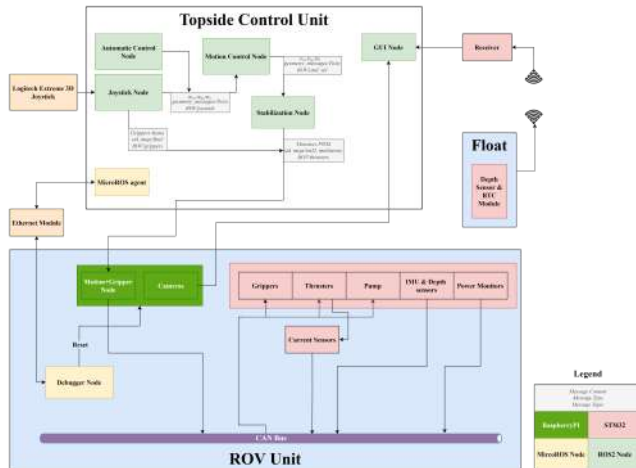


Figure 22: Communication architecture

System Evolution and Communication Backbone

In last year's architecture, we utilized ROS 1 as the main framework for communication between the control unit and the ROV's micro-controllers.

Communication with MCUs was handled through `rosserial`, which introduced a critical limitation: the presence of a single point of failure—the ROS Master. Any instability or failure in the master would cause the entire system to halt, making it unreliable in underwater environments where robustness is essential.

This year, we have transitioned fully to ROS 2, eliminating the centralized master dependency. Communication between the topside control unit and the ROV unit is now handled using ROS2 & CAN communication, which is more reliable, scalable, and real-time capable.

In parallel, we've integrated `micro-ROS` to run a debugger node on the ROV side. This node communicates with the topside unit via an Ethernet module, acting as a backup communication path. In the event of failure of our SBC—the Raspberry Pi, this channel en-

sures continued monitoring of the entire system's vitals which greatly facilitates debugging in case of a problem with our system.

This upgraded architecture enhances reduces the risk of total system failure, making it far more suitable for mission-critical underwater operations and industrial applications.

Topside Control Unit

The topside control unit hosts the nodes and agents that work above water which includes:

- Joystick Node
- Automatic Control Node
- Stabilization Node
- Motion Control Node
- GUI Node
- Micro-ROS agent

Data is received from the following streams:

- Camera feed from the ZED camera as well as the side-assisting cameras
- Readings from sensors which includes an IMU sensor and a depth sensor
- Readings from the joystick
- Receiver from the Float unit

The joystick node is interfaced with the Logitech Extreme 3D Pro Joystick, capturing signals and converting them into ROS messages, which then are sent over to the motion control node in order to convert these signals to motion vectors and gripper operations.

For autonomous tasks, the automatic control node is pivotal. It receives commands from the joystick and autonomously sends out commands to the motion control node.

The motion control node converts the received messages into motion vectors that are then sent to the stabilization node.



The stabilization node is used to maintain the operational stability of the ROV by applying various PID controllers to counter any disturbances.

The GUI node acts as the pilot's interface, displaying camera feeds for navigation as well as displaying the ROV's vitals.

Vitals include:

- IMU readings
- Depth readings from both the ROV unit and the Float unit
- Thrusters PWM values

ROV Unit

The ROV unit is where a lot of the heavy lifting happens, it executes commands received from the topside control unit, streams cameras and hosts the debugger node.

The ROV unit has a Raspberry Pi 5 that is responsible for streaming cameras to the GUI node as well as it hosts a ROS 2 node that is responsible for receiving the commands from the stabilization node.

Connected to the Raspberry Pi 5 is the CAN bus where it receives data from sensors such as current sensors, a depth sensor, an IMU and the power monitor. That are then published to both the topside control unit as well as the debugger node.

Float Unit

The float unit hosts a depth sensor that transmits its readings using an NRF transceiver module and an RTC (Real-time Clock) to the receiver which are then displayed on the GUI in the topside control unit.

2.3.3.2 Graphical User Interface

Our GUI prioritizes stability, usability, and responsiveness, balancing personalization with default configurations. Built with Python and PyQt5, it ensures a stable and efficient desktop experience.

System Architecture

The GUI follows a modular design, dividing functionality across four interfaces: Pilot, Copilot, Engineer, and Float. This enhances maintainability while tailoring tools to each role.

Pilot Interface

Designed for minimal clutter, the Pilot interface displays five camera feeds essential for navigation. To ensure smooth streaming, we use Python's `Multiprocessing` library, preventing latency and glitches. The Pilot can switch views and resize feeds as needed. Our redundant streaming system prevents a single point of failure—if one camera disconnects, others remain functional.

Copilot Interface

The Copilot interface extends camera controls, allowing real-time brightness, contrast, and backlight adjustments for varying underwater conditions. It also displays telemetry data, including six degrees of freedom (Vx, Vy, Vz, Roll, Pitch, Yaw), depth, and thruster speeds, aiding in system monitoring and troubleshooting. A screenshot of the interface is shown in Figure 23.



Figure 23: Screenshot of the Copilot interface.

Engineer Interface

The Engineer interface provides quick access to automation scripts for tasks like invasive carp detection and depth estimation. It also facilitates seamless media capture for Photosphere documentation. All functions are integrated within the GUI, streamlining workflow

without external tools. A screenshot of the interface is shown in Figure 24.

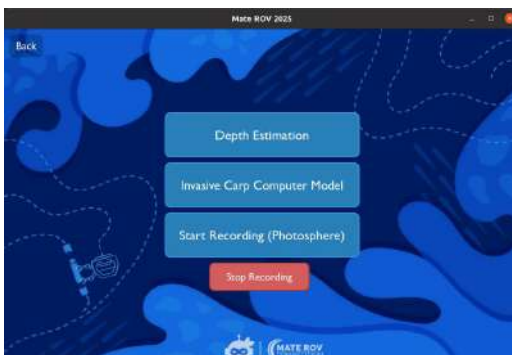


Figure 24: Screenshot of the Engineer interface.

Float Interface

The Float interface enables communication with the float before vertical profiling begins and displays depth data along with additional metrics post-profile.

2.3.3.3 Kinematics

The Kamikaze's movement underwater may be one of the most important aspects of the design. We had to ensure stability, maneuverability, and speed. We achieved this by focusing on two main aspects:

- **Thrusters Configuration:** We employed a seventh thruster this year to improve the robot's maneuverability as shown in figure 25. With the current vectored thrusters configuration and this new thruster, we can achieve motion in 6 degrees of freedom. This novel configuration may be the first of its kind to allow for such a wide range of motion while only using 7 thrusters.
- **PID Control:** We have implemented PID controllers for all critical movement axes, allowing for precise control over the robot's movement and ensures that it remains stable in the water. We implemented an FFT (Fast Fourier Transform) based auto-tuning algorithm to tune the PID parameters, as this is our first year using the new Vehicle. We also supplemented the algorithm with a live plotting feature, shown in figure 26, to allow

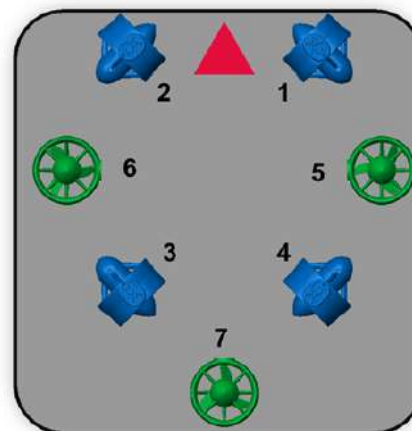


Figure 25: Thruster Configuration

for manual adjustments to the PID parameters.

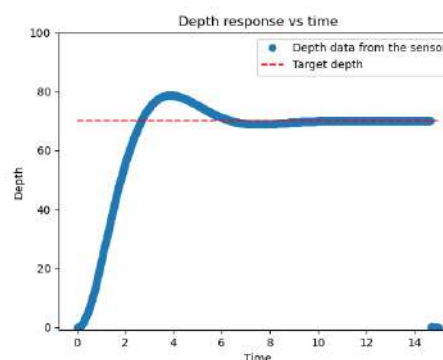


Figure 26: Live Plotting of PID Parameters

2.3.3.4 Open Sourcing the Kamikaze

We have all of our working code available on our [GitHub repository](#). A lot of effort was made this year to maintain, document, and clean up the code, making it easier for future teams to understand and build upon. We believe that this is a crucial step in the development of the Kamikaze, as it allows for a more collaborative environment and ensures that the knowledge gained from each year is not lost.



2.4 Mission Specific Auxiliary Tools

2.4.1 Vertical Profiling Float

EJUST Robotics Clun supports the National Science Foundation (NSF)-funded GO-BGC project's mission to build a global network of chemical and biological sensors for ocean health monitoring. As part of this initiative, our team has developed Fat Man, a vertical profiling float designed for ocean observation and data collection. This float enhances the ability to monitor key environmental parameters, providing valuable insights into ocean dynamics and contributing to global research efforts on climate change.



Figure 27: E-JUST Vertical Profiling Float, Fat Man.

Fat Man is constructed from transparent acrylic, allowing visual inspection and error detection, and is divided into two main sections by a PTEG disk with O-ring seal to separate the electrical components from the water chamber and buoyancy engine that is based on power screw mechanism. A buoyancy engine with power screw and NEMA-17 enables precise buoyancy control by regulating water intake and release. The electrical system, powered by an STM32 microcontroller, integrates a depth sensor, motor driver, and NRF24L01 radio module for real-time data collection and transmission. Supported by NiMH batteries, the system ensures stable operation, reinforcing EJUST Robotics Club's commitment to advancing ocean re-

search and technology.

2.4.2 Green Crab Detection

Developing our vision system to solve one of this year's missions, counting green crab underwater.



Figure 28: Counting green crabs

3 Safety

3.1 Safety Philosophy

At E-JUST Robotics Club, safety is the foundation of every aspect of Kamikaze ROV's design, construction, and operation. We are committed to preventing injuries, protecting equipment, and ensuring a secure working environment for all members.



Figure 29: Cutting the PVC pipes for the training track assembly.

3.2 Workshop Safety

The E-JUST Robotics Club recognizes the potential dangers and hazards inherent in assembling robotics,



whether mechanical or electrical. Consequently, the club has put in place strict safety procedures to ensure the security of every member. In addition, a variety of safety gear is provided in the workshop, such as soldering fume extractors, protective gloves, and face guards. All operations are supervised by a professional safety director who makes sure that the extensive safety checklist found in Appendix A is strictly followed.

3.3 Safety Training

In addition to receiving technical instruction, new members receive extensive safety training from experienced peers. All members acquire expertise in the procedures required to always guarantee safety through comprehensive safety training and hands-on experience obtained in a supervised environment.

3.4 Kamikaze Safety Features

Safety remains a priority for the E-JUST Robotics Club, which is reflected in the design and production of Kamikaze. In compliance with MATE Organization requirements, a properly sized fuse is installed at the Anderson connectors. Strain relief is applied at end of the tether to prevent stress on connectors and ensure uninterrupted communication.

All bolts are securely covered, and the frame is carefully sanded to eliminate sharp edges. Kamikaze's thrusters are equipped with protective shrouds (Figure 30) to enhance operator. Additionally, its manipulators and auxiliary equipment feature extra safety measures, with Neoprene coverings ensuring a firm grip while preventing damage to nearby objects during transportation. Each thruster operating in the aquatic environment is protected by a fuse to minimize electrical shock risks and prevent damage. For efficient heat dissipation, converters are positioned outside the canister and fully insulated, while heat-conducting components inside the canister are attached to its walls to create a heat sink effect. This design effectively manages temperatures and ensures optimal system performance.



Figure 30: Shrouded Thrusters.

3.5 Safety Checklist

All members participating in Kamikaze's deployment must follow a strict safety procedure enforced by the E-JUST Robotics Club. Routine inspections are conducted, and Appendix B outlines a comprehensive operating safety standard. While all members are responsible for adhering to the safety checklist, its strict implementation is supervised by a trained safety director.

4 Testing and Troubleshooting

4.1 Full System Testing

A comprehensive full-system test is crucial to ensuring the optimal performance and reliability of our ROV before competition. This testing process evaluates all functionalities of the ROV, identifying any potential issues and guaranteeing its readiness for the challenges it will face. The flowchart below (Figure 31) outlines the systematic steps involved in our ROV's full-system test, ensuring all critical aspects are examined.

4.2 Mechanical Testing

The mechanical testing phase for Kamikaze focused on reliability, safety, and performance through a rigorous, iterative prototyping process. The evaluation centered on two primary systems:

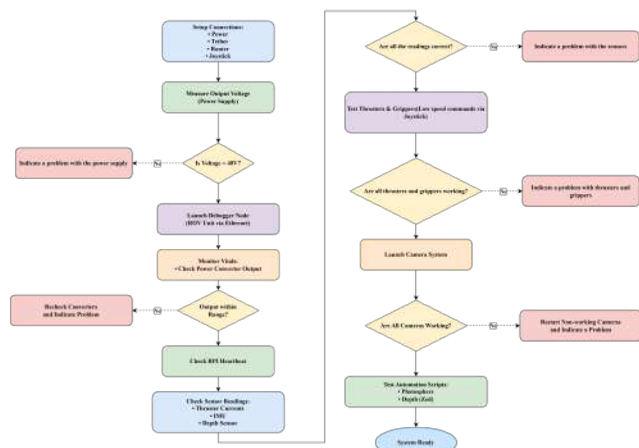


Figure 31: Full System Testing Flowchart.

Core Testing Areas

- **Pneumatic System:** Verified through visual inspections of hoses and fittings. Leak detection was performed via audible pressure tests to ensure efficient actuation and tight seals.
- **Sealing Mechanism:** To ensure waterproofing, the electronics enclosure was submerged and weighed to detect water ingress. If leaks occurred, internal air pressure was used to identify the source via bubble trails for targeted repairs.

Troubleshooting & Methodology

To mitigate risks and refine the design, the team utilized a structured diagnostic approach:

- **Component Isolation:** Breaking down the system to pinpoint specific faulty subsystems.
- **Real-time Monitoring:** Using visual inspections during active testing to catch failures as they happened.
- **Failure Mode Analysis:** Analyzing potential risks to prevent future mechanical issues.

4.3 Electrical Testing

The electrical testing for Kamikaze focused on a “bottom-up” approach, ensuring individual component

stability before full-system integration to prevent cascading failures.

Testing Methodology

The team employed a rigorous isolation strategy to verify the following:

- **Power Stability:** Voltage converters were tested under full load, and PCBs were scanned for short circuits. Thruster current consumption was monitored to ensure they stayed within safe operating limits.
- **Microcontrollers & Communication:** STM32 units, CAN bus, and Ethernet modules were checked for connection integrity and accurate data flow.
- **Sensors:** The depth sensor and the BNO055 were validated independently for accuracy before being integrated into the Power PCB.

Troubleshooting & Monitoring Systems

To maintain the ROV during operation, several real-time diagnostic layers were implemented:

- **Integrated Debugging:** A dedicated system (STM32 + Ethernet + CAN bus) allows the team to monitor subsystems individually from the surface station without restarting the entire ROV.
- **Active Power Tracking:** Current sensors on each ESC detect motor overloads, while voltage sensors on each converter monitor for power fluctuations.
- **Physical & Signal Audits:**
 - **Short Circuit Detection:** Manual inspections of PCBs for unintended connections or damaged hardware.
 - **Signal Integrity:** Examination of signal traces to eliminate noise or interference that could cause communication errors between subsystems.

5 Logistics

5.1 Company History

Founded in 2021 at Egypt-Japan University of Science and Technology (E-JUST), the club began with courses and workshops to support robotics learners. Over time, members engaged in large-scale projects, forming specialized teams for competitions.

A major milestone was the **formation of the first ROV team in 2023**, which competed in MATE ROV 2023 and won the "No Pain, No Gain" award. The team improved further in MATE ROV 2024, excelling in underwater tasks.



Figure 32: EJUST Robotics Club ROVs over years.

The club unites students from various fields, following a structured training process to ensure knowledge transfer and skill development:

1. **General Training:** New members learn robotics fundamentals, including design, electronics, programming, and control.
2. **Evaluation:** Members are assessed to identify strengths and roles.
3. **Team Selection:** Based on performance, members join the ROV or other teams.

The E-JUST ROV team has **38 members** divided into:

- **Technical Sector:** Focuses on ROV design and development.
- **Non-Technical Sector:** Manages operations and outreach.

This year, the team developed **Kamikaze**, our custom ROV, using Agile methodology and cloud-based collaboration.

5.2 Company Structure

Company structure is shown in Figure 33.

Team Board

5.3 Project Management

5.3.1 Project Scheduling

The vehicle development schedule has four phases (Further illustrated in Appendix C):

1. Training Phase (12 weeks, Aug 1 - Oct 16, 2025)

- Foundational and specialized training in software, mechanical, and electrical systems.
- ROV-specific training, task automation, and mock challenges.

2. Planning Phase (2 weeks, Oct 17 - Oct 31, 2025)

- Finalize designs, select components, and define software and electrical frameworks.

3. Prototype Build & Testing (19 weeks, Nov 1, 2025 - Mar 14, 2026)

- Mechanical assembly, electrical integration, and software implementation.
- Underwater testing, and system integration.

4. Final Preparation & Mock Competitions (Mar 14 - Apr 20, 2026)

- Simulate competition tasks and finalize adjustments. Prepare for transport and setup.

The schedule ensures a structured development process for a fully tested ROV.

5.3.2 Resource Management

- **Custom vs. Commercial Solutions:** We developed custom ESCs, a USB Hub, and manipulators for integration, performance, and cost efficiency.
- **Cloud-Based Collaboration:**

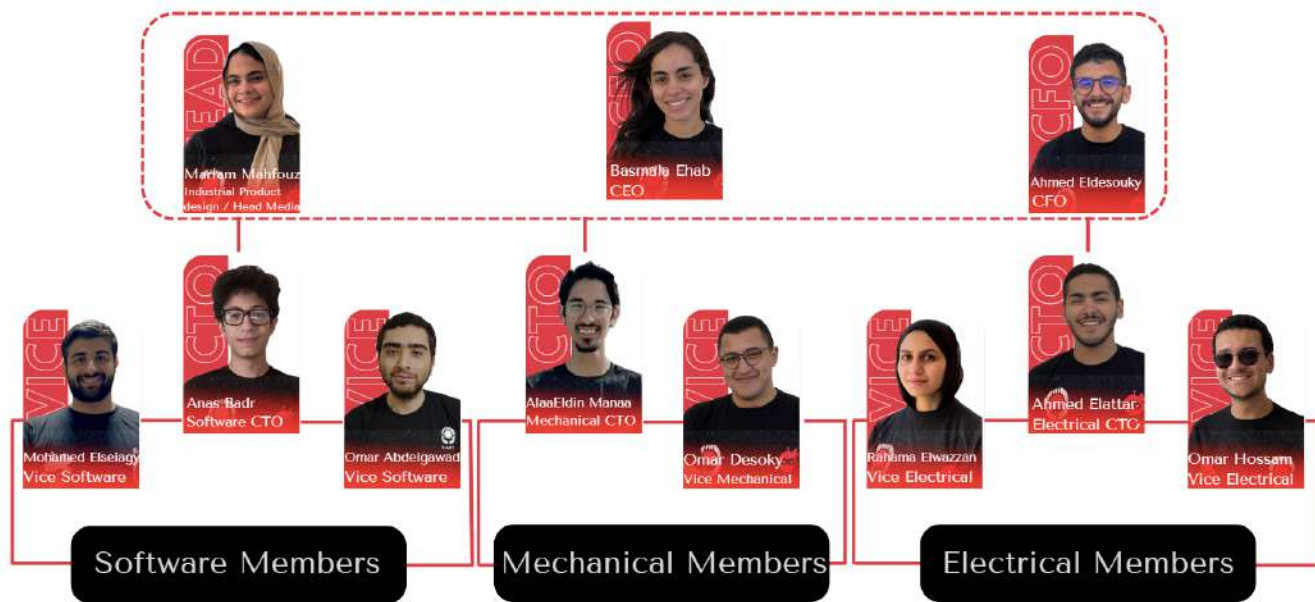


Figure 33: Company Structure.

- Cloud storage enabled sharing of design files and task submissions for remote collaboration.
- Altium shared models ensured access to the latest PCB designs.

- **Collaborative Documentation:** *Overleaf* was employed for high-fidelity LaTeX documentation and technical reporting.
- **GitHub** for development: Managed (CI/CD), version control, and issue tracking.

5.3.3 Procedures & Workflow

• Agile Development Approach:

- **Agile methodology** promoted collaboration and modularity.
- **ClickUp Ecosystem** As our primary project management hub, ClickUp (Premium Workspace) was central to our workflow. It was used to manage sprint planning, automate task tracking, and maintain comprehensive internal documentation via ClickUp Docs.

• Communication & Coordination:

- Centralized Visualization: We utilized *ClickUp's integrated Whiteboards* and Mind Maps for brainstorming and system flowcharts, ensuring all design logic remained linked to specific tasks.

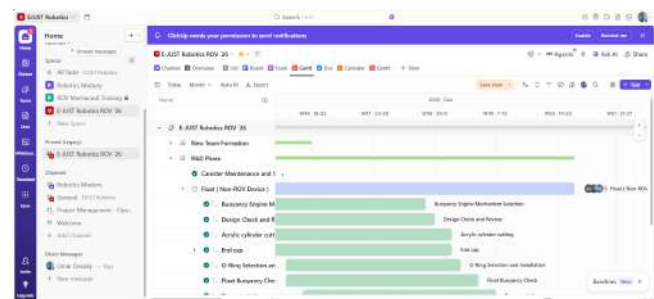


Figure 34: Evidence of our ClickUp workspace used for sprint planning, task tracking, and team coordination.

5.3.4 Protocols & Problem-Solving

- **Safety & Reliability:** Strict testing ensured safe underwater operation.
- **Code & Hardware Optimization:**
 - **GitHub** enabled parallel software development and version tracking.
 - Custom hardware optimized power efficiency.



- **Issue Tracking & Contingency Planning:**

- *Notion* documented technical challenges and solutions.
- *Miro's* visualization tools assisted in analyzing issues.

By integrating Agile workflows, cloud-based collaboration, real-time communication, and custom-built hardware, we ensured Kamikaze met its objectives.

5.4 Budget and Accounting

Operating within a limited budget driven by E-JUST University and ISF funds, the Ejust Robotics prioritizes judicious resource management to counter Egypt's high inflation rate and diminishing purchasing power (calculated at 52.64 EGP per 1 USD). To maximize efficiency and avoid unnecessary expenses, our (CFO) oversees all financial operations using a custom, cloud-based tracking system that monitors real-time cash flow, projects costs, and guarantees strict accountability for every dollar spent.

To further optimize funds, we adopted a strategic component-reuse approach. By retaining the core structure and major components of our previous ROV and Float, Kamikaze, we kept baseline costs low. This allowed the budget to be redirected toward critical upgrades : such as a newly manufactured canister, and fully revamped PCBs : significantly enhancing our capabilities without the massive expense of a full rebuild.

More detailed budget breakdowns can be found in Appendix.

6 Conclusion

6.1 Future Improvements

E-JUST Robotics Club is committed to staying at the forefront of modern technology and achieving success through continuous improvement and innovation. The team places strong emphasis on developing cutting-edge solutions and is actively exploring new methods

to upgrade its ROV systems.

To support this vision, we are focusing on expanding the capabilities of our current ROV, Kamikaze, through the integration of advanced technologies and system enhancements. These improvements aim to increase efficiency, reliability, and adaptability in a variety of underwater scenarios. By investing in more powerful technologies, we aim to precisely locate the ROV, laying the groundwork for fully autonomous operations in the near future.

As part of our future vision, we also aim to utilize Kamikaze in the fields of marine research and environmental sustainability. The ROV will be adapted to perform various underwater tasks that support scientific exploration, and environmental protection efforts.

6.2 References

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7 SIDs

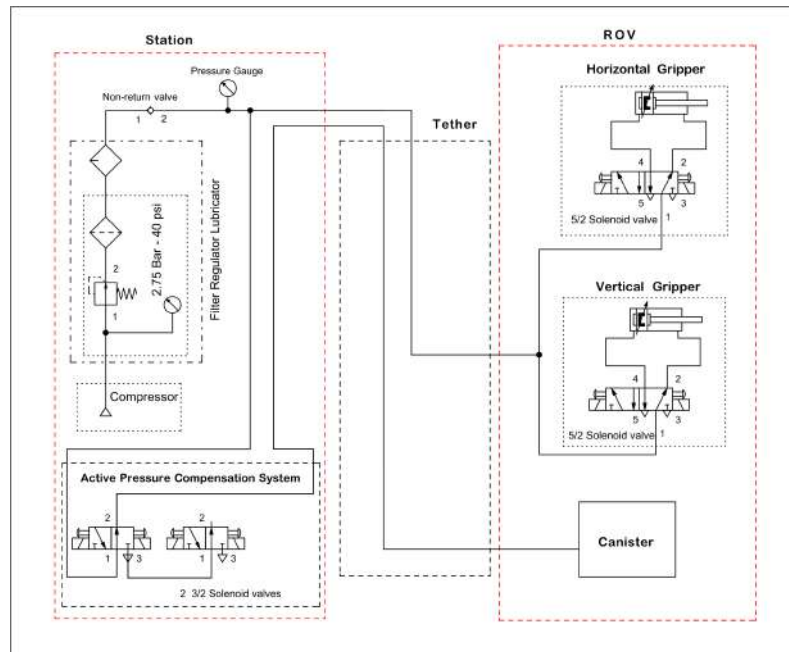


Figure 35: Pneumatic SID.

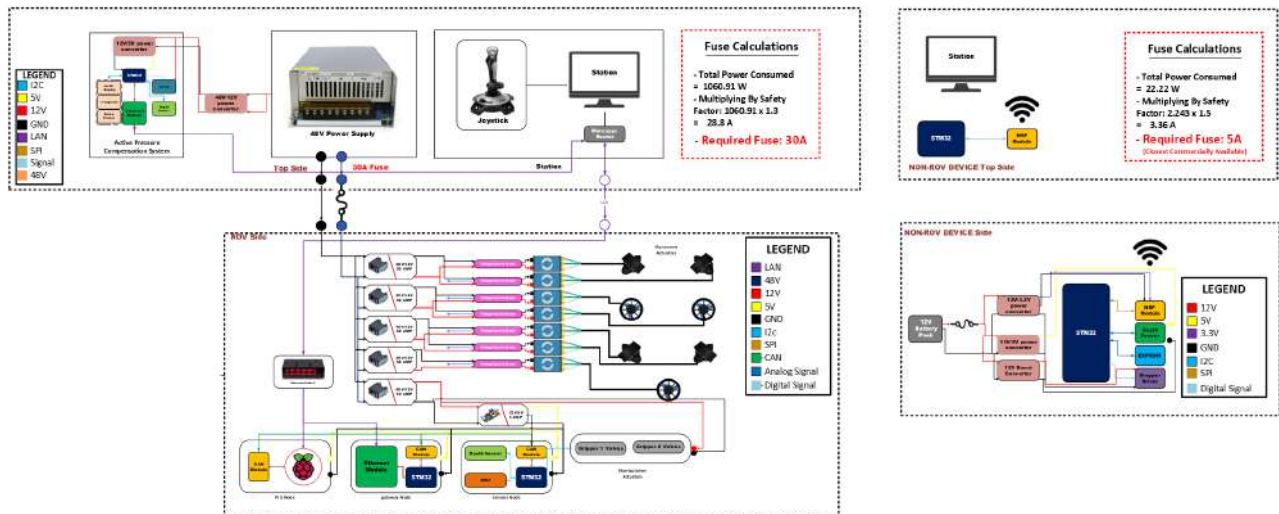


Figure 36: Electrical SID.



8 Appendix

A Construction Checklist

Construction	Operation	
	Pre-Deployment	Launch and Water Entry
☐ Ensure that appropriate personal protective equipment (PPE) is worn during all tasks.	☐ On deck in proper safety attire.	☐ Two members handle ROV.
☐ Ensure that protective gloves are used when handling sharp tools or hazardous materials.	☐ Ensure power is OFF.	☐ Tether handler holds tether.
☐ Ensure that safety goggles are worn to protect the eyes during cutting, or similar operations.	☐ Clear poolside of obstructions.	☐ Visually inspect leaks and air bubbles.
☐ Ensure that earmuffs or hearing protection are used when operating loud equipment.	☐ Confirm untangled tether connected securely with strain relief.	☐ Test thrusters, manipulators, and payloads.
☐ Store sharp tools and equipment properly when not in use to prevent accidental injuries.	☐ Check tether connection to Control Unit.	Communication Loss
☐ Cover blades and sharp edges with caps or protective covers when tools are stored.	☐ Verify no exposed wires or loose connections.	☐ Reboot ROV.
☐ Keep emergency kits regularly checked and maintained to ensure they are ready for use.	☐ Confirm electronics housing sealing.	☐ Resend test package.
☐ Ensure that fire extinguishers are accessible and in good working condition.	☐ Ensure control computer is operational.	If no communication: ☐ Power down ROV. ☐ Retrieve ROV via tether. ☐ Check for damage or leaks. ☐ Dry Test
☐ Ensure that first-aid kits are available and fully stocked in the workspace.	Power up	Retrieval
☐ Clearly label hazardous materials to ensure safe identification.	☐ Confirm ROV receives 48V.	☐ Surface ROV and turn off thrusters.
☐ Store hazardous materials separately according to safety guidelines.	☐ Perform dry tests on thrusters, manipulators, and payloads.	☐ Assigned crew grab ROV by handles.
☐ Maintain well-ventilated work areas or use fume extractors when working with materials such as epoxy or solder.	☐ Check all video feeds.	☐ Secure ROV on deck.
☐ Handle electrical components and wiring carefully, ensuring proper insulation and grounding to prevent electrical hazards.		☐ Power down ROV and Control Unit.

Figure 37: Construction and operational checklist diagram.

B Operational Safety Checklist

The operational safety checklist is included in Figure 37.

C Project Plan

This appendix contains a Gantt chart which serves as a visual representation of the project plan, illustrating the chronological order of tasks (Figure 38).



Figure 38: Gantt Chart for the Project Plan.

Ejust Robotics MATE ROV Funding Sources

Category	Source	Cost (\$)
Sponsorship	E-just University fund	1900
Sponsorship	ISF fund	1000
Self-fund	By Team members	200
Total Income		3100

Table 1: Comprehensive Kamikaze ROV Budget and Cost Analysis

Category	Component Description	Status	Budget (\$)	Actual (\$)
Mechanical				
	Frame (Aluminum extrusion, HDPE)	Reused	—	190.00
	Canister Manufacturing	New	150.00	130.00
	Canister Prototype and Testing	New	135.00	121.00
	Cameras' Enclosure Manufacturing	New	100.00	86.00
	Aluminum Sheet	New	160.00	148.00
	Acrylic Cylinder	New	40.00	31.00
	Artelon	New	20.00	16.00
Electrical				
	Components and Electronics	New	240.00	240.00
	New PCB Manufacturing	New	182.00	182.00
	Rapoo Camera	New	104.00	104.00
	New Sensors Manufacturing	New	86.00	86.00
	T200 Thrusters (x6)	Reused	—	2,964.00
	ZED 2 Stereo Camera	Reused	—	840.00
	ESC (Electronic Speed Controller) (x6)	Reused	—	419.00
	Raspberry Pi 5 - 8GB RAM	Reused	—	193.00
	12V to 5V DC-DC Converter (x3)	Reused	—	148.00
	High Torque Servo Motor	Reused	—	40.00
	ROV Controller	Reused	—	20.00
	15mm Expandable Braided Cable Sleeve	Reused	—	19.30
	Water Depth/Pressure Sensor MS5540	Reused	—	17.00
	TP-Link TL-WR840N Router	Reused	—	17.00
	10 DOF IMU (MPU9250+BMP280)	Reused	—	16.00
	STM32F401RCT6	Reused	—	10.00
Float				
	Float Manufacturing	New	25.00	18.00
	Linear Rod M8 Guide	New	15.00	8.00
	Square Flange Linear Ball Bearing LMK8	New	10.00	5.00
	SHF8 Linear Axis Guide Holder	New	5.00	3.00
Sealing				
	Glands	New	50.00	39.00
	Rubber Gasket	New	40.00	30.00
	O-rings	New	15.00	8.00
	Blue Foam (5cm thickness)	Reused	—	6.70
Pneumatics				
	Pressure Regulator	Reused	—	65.00
	Pneumatic Cylinder MI25-25-S (x2)	Reused	—	20.00
	Air Solenoid Valve 12VDC (5/2)	Reused	—	12.00
	Air Solenoid Valve 12VDC Bi-Directional	Reused	—	11.00
	Non-return Valve	Reused	—	10.00
Tools & Safety				
	Digital Multimeter (x2)	Reused	—	33.00
	Soldering Iron 220V 100W (x2)	Reused	—	17.00
	Safety Glasses, Vests, PPE	Reused	—	70.00
Total Cost of New Components			1,377.00	1,254.00
Total Cost of Reused Components			—	5,138.00
GRAND TOTAL COST			\$ 1,377.00	\$ 6,392.00

International Logistics & Travel Breakdown

Category	Scope	Expense Breakdown (USD)				Total (\$)
Logistics	Base Team Travel	ROV Shipping: 650	—	Local Transport: 400		1050
	Per Member Exp.	Flight Tickets: 1600	—	Residency: 350	— Visa: 185	2205