KAMIKAZE

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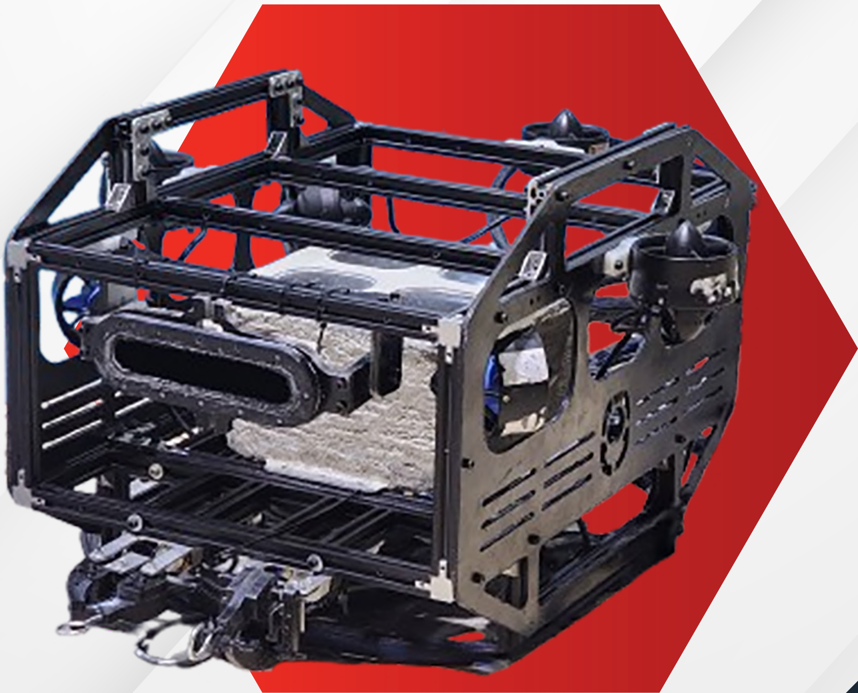
Technical Report ‘25



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Contents

1 Abstract

Designed to confront the challenges of climate change in the Great Lakes and Oceans, Kamikaze is E-JUST Robotic Club's entry for the 2025 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 47 employees to deliver a robust and mission-ready solution.

With only three 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 lightweight 3D-printed PETG 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 documenting Great Lakes shipwrecks to collecting water samples, deploying hydrophones, and maintaining offshore wind farm bases. Accompanied by a custom-built 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.

Figure 1: E-JUST Robotics Club Team.

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

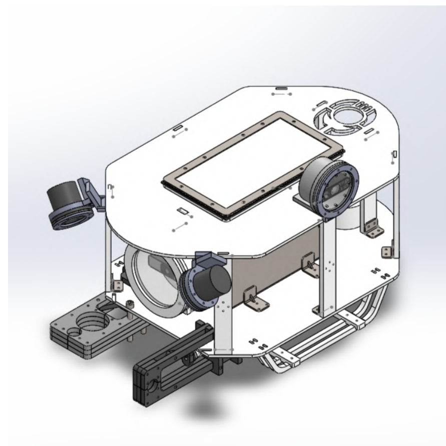


Figure 2: Last year's ROV - Shiro Kaijin.

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.

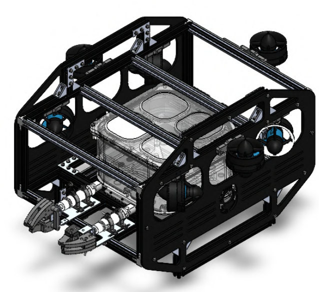


Figure 3: Kamikaze.

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
One of the major design advancements in Kamikaze is the transition from an aluminum canister to a 3D-printed PETG canister. While aluminum provided durability, it was costly, difficult to modify, and unnecessarily heavy. The new 3D-printed PETG canister offers greater design flexibility, allowing for customized internal layouts, easy adjustments, and rapid prototyping without the constraints of metal fabrication.

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.

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
Shiro Kaijin 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 resolve this, Kamikaze integrates all ESCs into a single 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.

Inadequacy of Arduino UNO
The Arduino UNO, used as the main controller, struggled to handle multiple sensors, leading to irregular data handling and performance issues. Kamikaze replaces it with an STM32 microcontroller, offering better stability, higher processing power, and improved efficiency for industrial applications.

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
The MS5540 depth sensor was inaccurate, slow, and costly, making it an inefficient choice. Kamikaze replaces it with a custom-designed depth sensor, providing real-time, accurate measurements and better connectivity options. To improve monitoring capabilities, voltage and current sensors were also implemented, allowing precise tracking of power consumption and early detection of system faults.

Reliability of Main Control PCB
Shiro Kaijin used relays in the main control PCB, which affected system stability. Kamikaze replaces them with MOSFETs, enhancing reliability and improving per-

formance. Additionally, a debugging node using the W5500 Ethernet module was introduced, enabling real-time system monitoring and remote reset of multiple nodes, ensuring stability and efficient troubleshooting.

Switching from Copper to Aluminum Wires

Copper wires in high-power transmission corroded quickly, posing safety risks. Kamikaze replaces them with aluminum wires, which are lighter, more durable, and resistant to redox reactions, ensuring safer and more efficient power transmission.

2.1.3 Software System Evolution

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, which can be utilized in Task 1: Shipwreck length estimation. We exploited epipolar geometry algorithms to be able to estimate the length of the ship from the depth data provided. We believe that this addition is crucial to the development of our ROV, and it's a decent investment for the future.

μROS

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.

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. An aluminum design was initially considered but was found to be twice as expensive as a 3D-printed alternative. After evaluating material strength and pressure resistance, the team decided to proceed with 3D printing, ensuring a cost-effective and flexible solution that could withstand underwater conditions while being easy to assemble and modify.

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.

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

To validate these theoretical analyses, small-scale prototypes were developed for key components. The 3D-printed canister was tested for sealing effectiveness, and successful trials confirmed its reliability before

#	Criteria	Weight: Frame	Body	Canister	Gripper	Materials: HDPE	Acrylic	Aluminum	Stainless steel	3D printing	Selected Material
1	Transparency	0	0	0.1	0	0	10	0	0	0	-
2	Strength	0.1	0.4	0.3	0.2	6	4	9	10	6	-
3	Cost & Availability	0.2	0.2	0.3	0.4	8	6	7	5	8	-
4	Fabrication (ease)	0.5	0.3	0.2	0.2	9	7	7	6	8	-
5	Ductility	0.1	0.1	0.1	0.1	7	3	8	6	4	-
6	Specific Gravity	0.1	0	0	0.1	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	6.8	4.7	**7.5**	3D Printing
		Gripper				**7.6**	5.2	6.8	5.6	7.4	HDPE

Table 1: Criteria and Material Selection Matrix.

moving to full-scale manufacturing. Camera housings were also prototyped to optimize field-of-view placement. This iterative process allowed for practical verification of design choices before finalizing the ROV.

2.2.3 Detailed Design and Manufacturing

With validated designs, the final ROV model (Figure 4) was fully developed in SolidWorks, incorporating stress, buoyancy, and flow simulations to ensure structural stability and hydrodynamic efficiency.

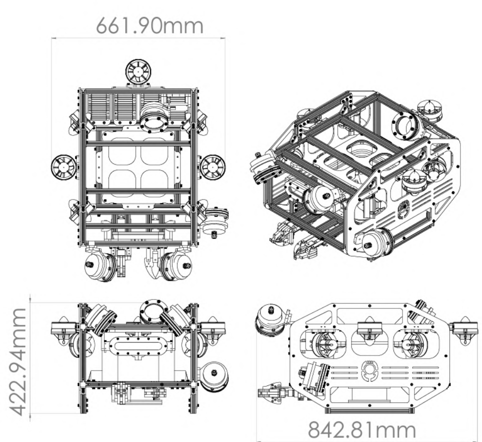


Figure 4: Kamikaze Drawings

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 3D printing, 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 5) were generated to optimize material usage.

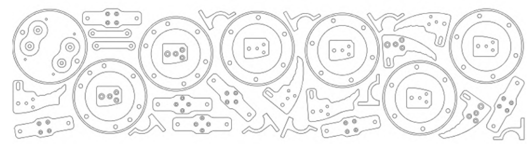
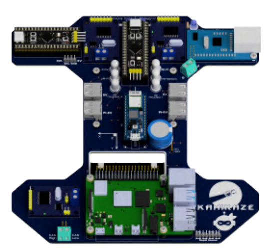


Figure 5: DXF file for cutting the float and grippers.

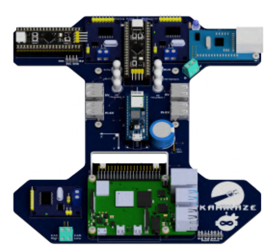
For the electrical system, significant innovations were implemented:

- The ESCs were integrated into a single PCB, reducing wiring complexity, electrical noise, and space consumption within the canister. This improvement streamlined system integration and enhanced overall performance. (Figure 6)
- A custom-designed depth sensor replaced the previous board, offering higher accuracy, real-time measurements, and expanded connectivity options. This upgrade ensured more precise and reliable depth control.

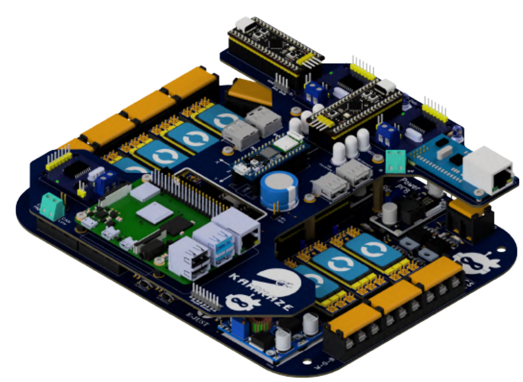


(a) Control PCB.

(b) ESC PCB.



(c) Control PCB.



(d) Full stack of PCBs.

Figure 6: Kamikaze PCBs.

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 7b) 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.

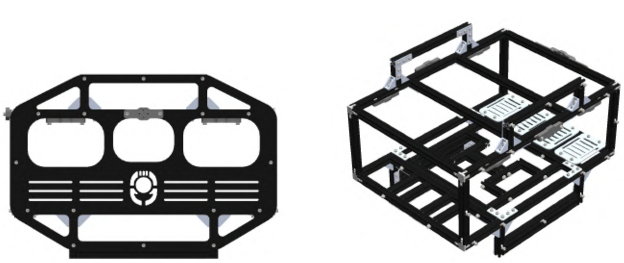
To enhance stability and buoyancy, HDPE side frame sheets (Figure 7a) are integrated into the design. These sheets not only contribute to the aesthetic appeal of the ROV but also help in maintaining balance during operations. Their strategic placement ensures that the ROV remains hydrodynamically stable 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 thrusters, strategically placed to achieve six degrees of freedom for precise maneuverability (Figure 8). This setup balances performance, power consumption, and cost-efficiency, ensuring mission success without excessive energy use.



(a) HDPE Side Frame. (b) Aluminum Extrusion Frame.

Figure 7: Kamikaze's Frame Illustration.

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/m^3)
- A = Cross-sectional area (m^2)
- v = ROV velocity (m/s)

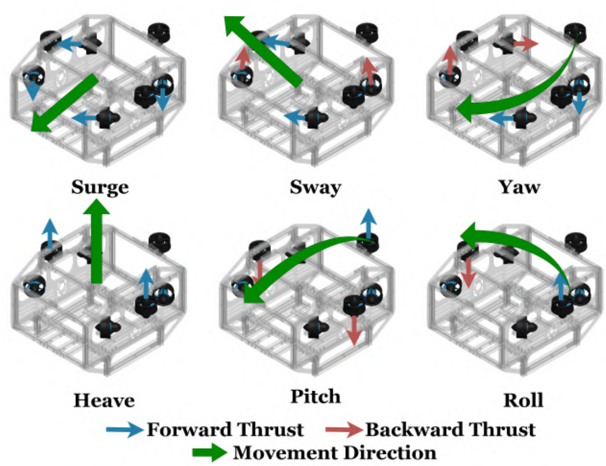


Figure 8: Kamikaze's Degrees of Freedom.

A CFD flow simulation was conducted to analyze water flow around Kamikaze (Figure 9), minimizing drag and enhancing hydrodynamic efficiency.

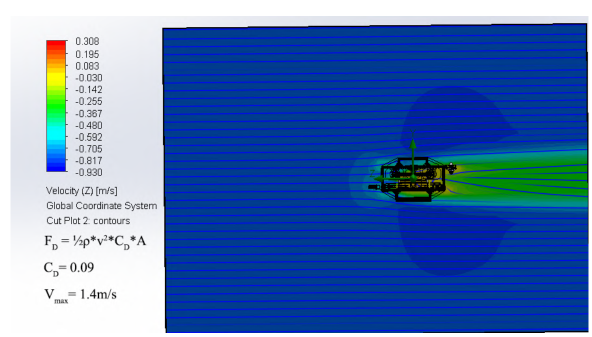


Figure 9: Flow Simulation.

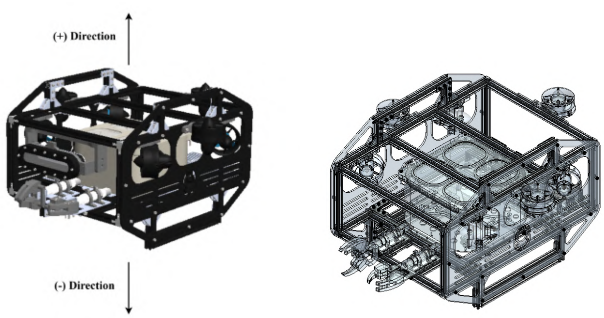
Trade-offs in Thruster Selection

- **Power vs. Performance:** More thrusters improve stability but increase power consumption. Seven 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 (Figure 10), we confirmed that the ROV naturally surfaces while maintaining stability.

$$F_B = \rho_{\text{water}} \times \text{Volume Displaced} \times \text{Gravity} \tag{3}$$



(a) If an ROV displaces more water than its weight, it floats; otherwise, it sinks.

(b) Buoyancy model in SolidWorks.

Figure 10: SolidWorks analysis for Kamikaze's Buoyancy.

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
Mass	18390.88 grams
Volume	18390882.63 mm^3
Center of Buoyancy	X=-0.05, Y=-20.00, Z=-0.10 mm

Table 2: Mass properties of water displaced (buoyancy force)

Parameter	Value
Mass	17389.17 grams
Volume	8925547.20 mm^3
Center of Gravity	X=0.03, Y=-21.53, Z=-7.36 mm

Table 3: Mass properties of the product and internal components (weight force)

Wet weight is calculated as follows:

$$\begin{aligned} WetWeight &= BuoyancyForce - WeightForce \\ &= 18,390.88\, grams - 17,389.17\, grams \\ &= 1,001.71\, grams \end{aligned}$$

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 microcontrollers, power systems, and sensors while ensuring pressure resistance, corrosion protection, and ease of maintenance. The design consists of a 3D-printed PETG body, an aluminum base, and a PETG lid with embedded acrylic windows, providing structural stability and waterproof integrity under operational conditions.

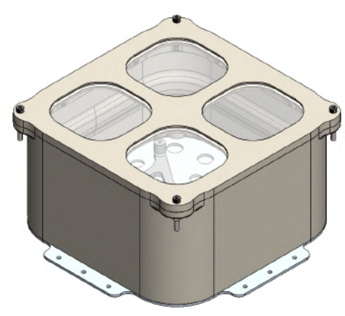
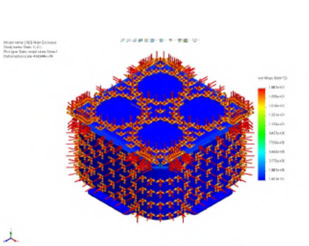


Figure 11: Kamikaze's Main canister.

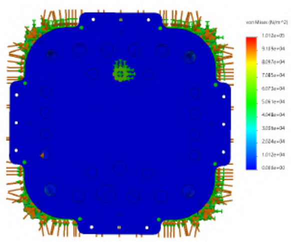
PETG was chosen as a cost-effective alternative to aluminum, offering a balance between mechanical strength and manufacturability. Although PETG is inherently waterproof, Sikadur®-31 CF sealant was applied to enhance structural integrity and reliability. The 3mm-thick aluminum base provides structural support for bulkhead glands, preventing layer separation and ensuring durability. The canister dimensions are 276×276×142.59 mm, optimized for component housing and pressure resistance. A three-stage sealing process was implemented, consisting of mechanical fastening, epoxy bonding, and polyurethane sealant, to maintain a watertight enclosure. The removable PETG lid, secured with M5 screws and dual O-rings, allows for easy inspection and maintenance, while four embedded acrylic windows provide visual access without disassembly.

To evaluate structural performance, a Finite Element Analysis (FEA) was conducted:

- **Top View (Figure 12a):** Stress is concentrated around circular openings and edges, which experience higher mechanical loads from water pressure.
- **Bottom View (Figure 12b):** Bolted connections and interface zones between the base and side walls accumulate stress, making them susceptible to deformation.



(a) Top View Analysis.



(b) Bottom View Analysis.

Figure 12: Main Canister Finite Element Analysis.

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. This design integrates 3D-printed PETG, aluminum, high-performance adhesives, and mechanical fasteners for optimal sealing efficiency.

Main Canister Sealing (Electronics Housing)

- Sikadur-31 CF adhesive prevents micro-gaps.
- IP68-rated metallic cable glands ensure watertight cable entry.
- Epoxy resin & super glue reinforce adhesion.
- Bolted fastening ensures long-term stability.

ZED Camera Enclosure (Figure 13a)

- O-ring in a groove forms a primary seal.
- RTV Gasket Maker provides additional waterproofing.
- Compression sealing & Allen bolts apply uniform pressure.
- Sikadur-31 CF protects against water exposure.

Artelon Camera Enclosures (Figure 13b)

For other cameras, Artelon enclosures replace aluminum.

- Acrylic cover sandwiched with an O-ring seal ensures water resistance.
- Allen bolts provide tight compression for long-term sealing.

(a) ZED Camera.

(b) Other Cameras.

Figure 13: 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.

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

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/m^2)
- t = Thickness of the flange (mm)

- ΔH = Max. gasket deflection - Min. gasket deflection (mm)
- P_{min} = Minimum gasket pressure (Pa or N/m^2)
- P_{max} = Maximum gasket pressure (Pa or N/m^2)

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 14, 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.

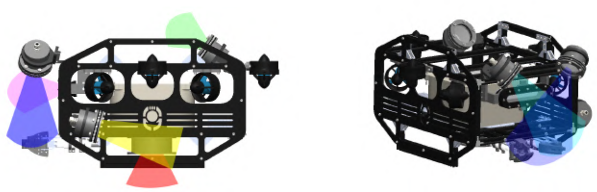
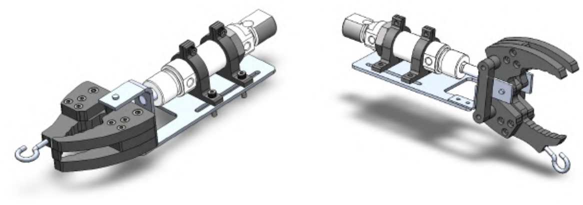


Figure 14: Cameras Positions.

2.3.1.7 Grippers

Two claw grippers (Figure 15) 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 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 A.1.

To enhance functionality, two screw hooks were integrated, enabling the ROV to lift hooks and manipulate

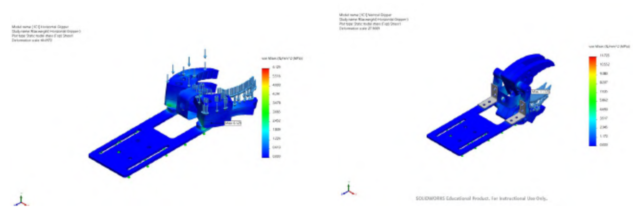


(a) Horizontal Gripper. (b) Vertical Gripper.

Figure 15: Kamikaze Grippers.

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 16) 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.



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

Figure 16: Kamikaze Grippers Analysis.

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.

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.

Continue on the next column

Table 4: ROV Station Components and Functions

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.
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
Arduino Nano RP2040 IMU	Measuring the angular velocity and linear acceleration of the vehicle
Voltage & Current Sensors (ACS712)	Track power consumption

Continue on the next column

Table 6: ROV Sensors and Functions

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 is interconnected through a structured communication framework. At the top side, the joystick sends control signals to the laptop, which transmits them to the router and then down the tether via an Ethernet cable. On the ROV side, an Ethernet switch distributes the signals, directing one output to the Raspberry Pi 5 (the primary controller) and another to the W5500 Ethernet module.

The system is designed as an integrated network of three modular subsystems. The Power Subsystem houses Electronic Speed Controllers (ESCs) and an STM32 microcontroller. The Raspberry Pi 5 sends control signals to the STM32 board, which then controls the seven ESCs connected to their respective T200 thrusters. Additionally, the STM32 microcontroller continuously collects real-time power consumption data of the thrusters and power converters, including current and voltage readings from the ACS712 current sensor, and transmits it to Raspberry Pi 5 via the CAN bus module for monitoring and analysis.

The second subsystem is the Sensor System which includes the depth sensor and an Arduino Nano RP2040 for the IMU readings, both of which are connected to an STM32 microcontroller that handles data acquisition. STM32 processes the sensor data and sends it to Raspberry Pi 5 via the CAN bus protocol, ensuring timely and reliable data transmission. Finally, the Debugging subsystem which consists of an Ethernet module connected to an STM32 microcontroller, interfaced with the network switch via an Ethernet cable. Through CAN bus integration, the Ethernet module communicates with the other subsystems, enables real-time system debugging, allowing for troubleshooting of the entire system remotely. It also provides fault control, monitoring and managing any failures that may occur within the Power PCB or Sensor subsystem.

Finally, the camera's video feed is processed by the Raspberry Pi 5, transmitted back to the topside through the tether, and displayed on the GUI on the laptop. Additionally, all other sensor data, including depth measurements, current and voltage values from the Power PCB, and IMU from the Arduino Nano RP2040, are collected by the STM32 microcontrollers and sent to the Raspberry Pi 5 via CAN bus. The Raspberry Pi then transmits this information via ROS to the topside control station, where it is displayed on the GUI for real-time monitoring.

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 twp 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
Arduino Nano RP2040	1	5	0.45	2.25	2.25
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: $1060.9/48 = 21.10\,\text{A}$,
Applying Safety Factor: $1.3 \times 21.10 = 28.73\,\text{A}$
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

The tether is made of Polyethylene Terephthalate (PET) light weight 15mm expandable cable sleeve which provides protection for the cables inside (Figure 17). 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.

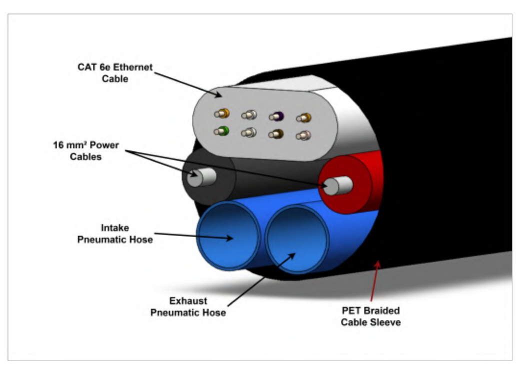


Figure 17: Tether Cross Section.

2.3.3 Software System

2.3.3.1 Communication System

The ROV's communication architecture which is illustrated in Figure 18 can be divided into two parts: the top side control unit and the ROV unit.

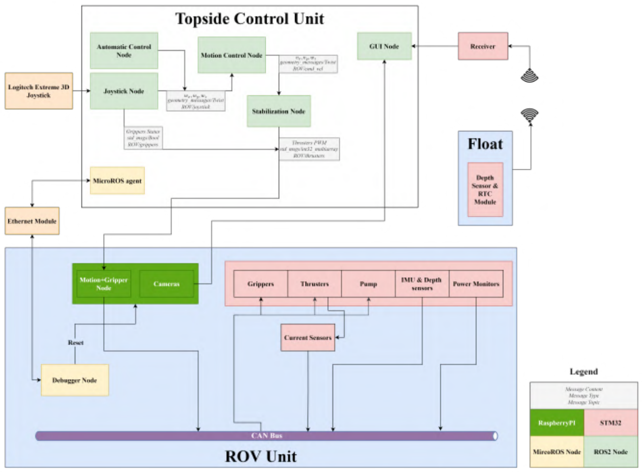


Figure 18: Communication architecture

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 ensures 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 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 senor that transmits it's 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 19.

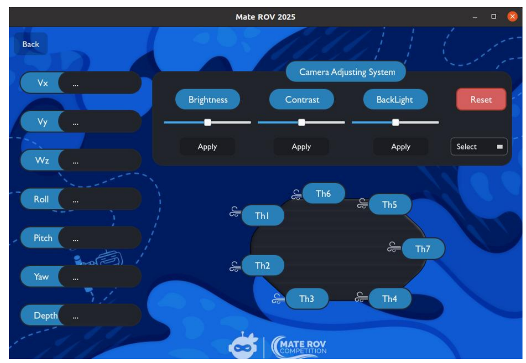


Figure 19: Screenshot of the Copilot interface.

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 20.

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:

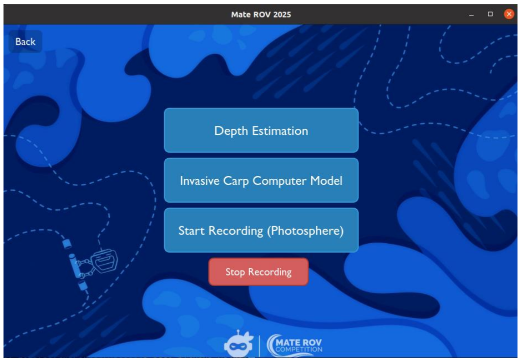


Figure 20: Screenshot of the Engineer interface.

- **Thrusters Configuration:** We employed a seventh thruster this year to improve the robot's maneuverability as shown in figure 21. 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.

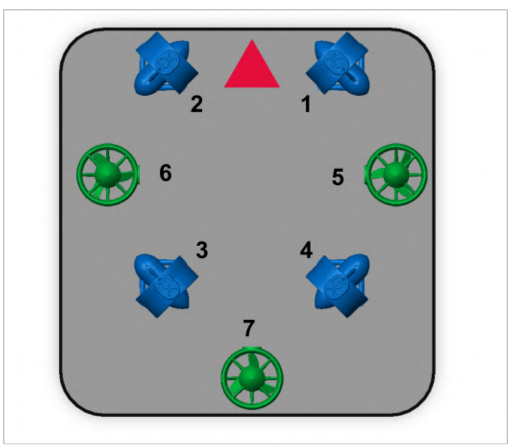


Figure 21: Thruster Configuration

- **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 22, to allow for manual adjustments to the 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 Stabilizing Cap Positioning Extension

One of the specialized systems developed for Kamikaze is the Stabilizing Cap Positioning Extension (SCPE). While Kamikaze installs a new thermistor, the SCPE (Figure 23a) secures the thermistor cap in place, ensuring perfect alignment.

The mechanism's smooth and controlled extension is provided by a telescopic ball-bearing slide, which is like those found in drawer runners. A 2.5-inch diameter cup at the top provides a little amount of alignment tolerance, guaranteeing a firm but flexible hold on the cap.

The extension lengthens as the SCPE holds onto the cap and Kamikaze lowers, keeping the cap in place. The extension shrinks as Kamikaze rises with the thermistor, holding the cap firmly in place and facilitating a smooth hookup.

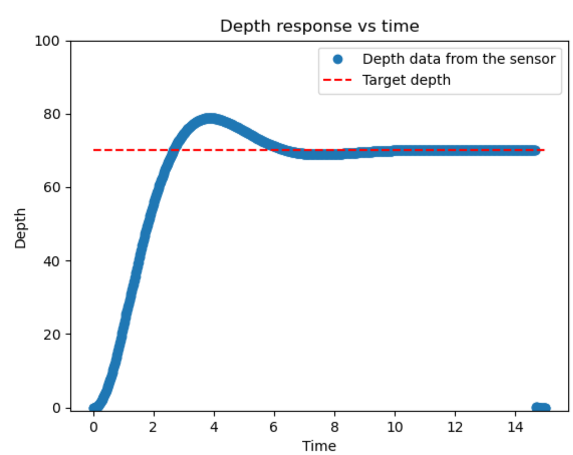


Figure 22: Live Plotting of PID Parameters

2.4.2 Liquid Sample Acquiring System

To enable efficient and flexible liquid sample collection, a modular design approach (Figure 23b) was implemented. This design allows for straightforward assembly, disassembly, and maintenance of individual components, thereby improving both convenience and system reliability during the sampling process. To further ensure optimal functionality under high-pressure conditions, the system incorporates a mini pump with a flow rate of 80 L/h, which was tested underwater to validate its performance. Additionally, a collection bottle featuring a user-friendly disassembly mechanism was integrated, easing the sample retrieval process and confirming its compatibility within the overall system.

2.4.3 Jelly Collecting Shutter Mechanism

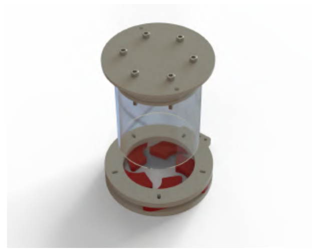
A specialized mechanism has been developed to collect and transport a jelly-like object filled with water to the surface. The system consists of a sealed acrylic tube, closed at the top, with a pneumatically controlled shutter at the bottom. When the pilot successfully guides the jelly inside the tube, the shutter activates, preventing it from drifting away while allowing water to flow freely. This design (Figure 23c) ensures that the jelly remains contained within the tube as it ascends due to buoyancy, enabling controlled and efficient transport to the surface.

2.4.4 Customized Hook

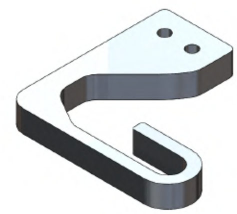
A customized hook mechanism has been developed to efficiently collect chenille strips (pipe cleaners) from the water surface. Since the strips float on the surface, they cannot be gripped using the ROV's main gripper. Positioned at the top of the ROV, the hook (Figure 23d) is strategically designed to maximize the number of strips gathered in a single attempt. To further enhance the mechanism's effectiveness, Velcro can be added to ensure the strips stick within the hook securely. This design improves the ROV's efficiency in completing the task, ensuring a higher collection rate.

(a) Stabilizing Cap Positioning Extension.

(b) Liquid Sample Acquiring System.



(c) Jelly Collecting Shutter Mechanism.



(d) Customized Hook.

Figure 23: Kamikaze's Mission-Specific Tools.

2.4.5 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.

Fat Man is constructed from transparent acrylic, allowing visual inspection and error detection, and is divided into two sections by an HDPE disk to separate the electrical components from the water chamber. A suction system with peristaltic pumps 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 Robo[illegible]mitment to advancing ocean re-

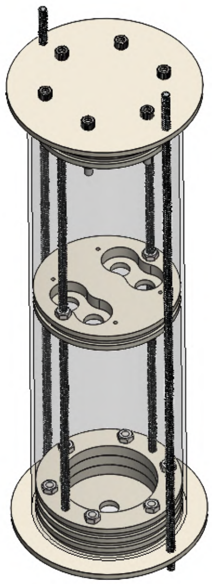


Figure 24: E-JUST Vertical Profiling Float, Fat Man.

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 team members.

Figure 25: 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 B 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 com prehensive safety training and hands-on experience obtained in a supervised environment.

3.4 Kamikaze Safety Features

Safety remains a top 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 both ends 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 26) to enhance operator and handler safety. 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 ef-

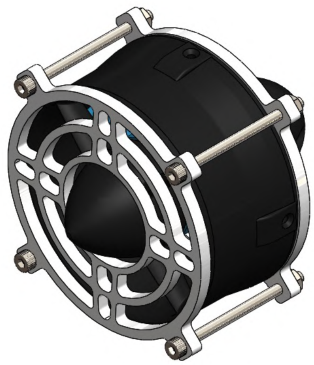


Figure 26: Shrouded Thrusters.

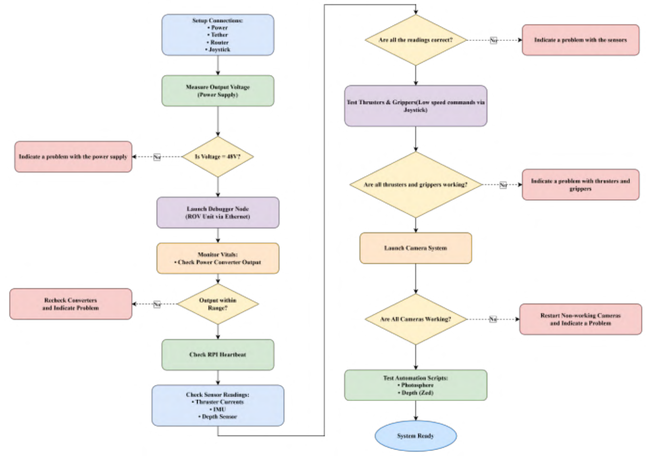


Figure 27: Full System Testing Flowchart.

fect. This design effectively manages temperatures and ensures optimal system performance.

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 C 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 27) outlines the systematic steps involved in our ROV's full-system test, ensuring all critical aspects are examined.

4.2 Mechanical Testing

To ensure maximum reliability, safety, and performance, Kamikaze's mechanical system underwent a comprehensive and rigorous testing process. This approach ensured seamless operation under challenging underwater conditions, minimized the risk of failure, and upheld high safety standards.

From the initial design phase, all components were carefully developed with a strong focus on safety, integration, and effectiveness. Before moving on to the final design and manufacturing stage, every prototype was thoroughly tested and refined to ensure flawless incorporation into Kamikaze's final structure.

- **Pneumatic System Testing:** To ensure the reliability and performance of the pneumatic manipulators, a series of targeted tests were conducted. All pneumatic hoses, joints, and fittings were visually inspected to ensure proper assembly and tight sealing. The system was then pressurized, and any air leakage was detected by listening to hissing sounds particularly at fittings and connectors. Any issues were promptly resolved to ensure leak-free, efficient pneumatic actuation.

- **Sealing Mechanism Testing:** The electronic enclosure's sealing was tested under pressure conditions similar to those expected during operation. The enclosure was submerged and weighed underwater to check for any water ingress. If a leak was observed, compressed air was introduced into the enclosure, and the source of the leakage was identified by monitoring escaping bubbles. This allowed for targeted repairs and ensured complete waterproofing.

These mechanical and functional tests were complemented by a structured troubleshooting methodology, including:

- Component isolation to identify faulty subsystems.
- Visual inspections and real-time monitoring during tests.
- Failure mode analysis to understand and mitigate risks.

4.3 Electrical Testing

Testing Methodology

The aim of the electrical test was to maintain the stability of the system and ensure that no time was wasted in identifying faulty components. Initially, all components were tested individually in an isolated environment to prevent potential damage or accidents. The voltage converters were assessed to verify their ability to provide stable power under full load conditions. Before deployment, PCBs were thoroughly inspected for any short circuits to prevent escalation of damage to sensitive components. The thrusters' current consumption was carefully monitored to ensure they operated within safe power limits and received sufficient supply for proper function. The STM32 microcontrollers were tested for connection integrity and accurate readings to confirm full functionality. Similarly, each module including the CAN bus and Ethernet modules was tested independently to verify proper operation and communication. Additionally, all sensors, including the depth sensor and the Arduino Nano RP2040 handling the IMU, were tested separately to ensure accurate readings and reliable connectivity before integrating them into the Power PCB. This structured testing approach ensured that every electrical component functioned optimally before system-wide integration.

Troubleshooting Strategies & Techniques

To improve troubleshooting efficiency, a debugging system is integrated into the Power PCB. This system includes an Ethernet module connected to an STM32 microcontroller, which communicates with all ROV subsystems via CAN bus and connects to the station through Ethernet. This setup enables real-time monitoring of each subsystem individually, allowing for quick identification of faults without requiring a full system restart.

Another key strategy is continuous power monitoring. Current sensors are connected to each ESC to track power consumption in real time, making it easier to detect potential issues such as motor overload or failure. Additionally, voltage sensors are integrated into each power converter to monitor power stability, ensuring consistent and reliable performance. This proactive approach helps prevent unexpected failures and maintains optimal functionality throughout the mission.

If a problem arises that is not related to power monitoring or debugging, the next step is to check for short circuits. The affected PCB is inspected for any unintended connections or damaged components, which are then resolved before further testing. In cases where the issue is related to signal transmission, all signal traces are examined to verify continuity and ensure that no interference or noise is affecting data communication. Ensuring signal integrity is essential for the proper operation of the system and helps prevent miscommunication 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.

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

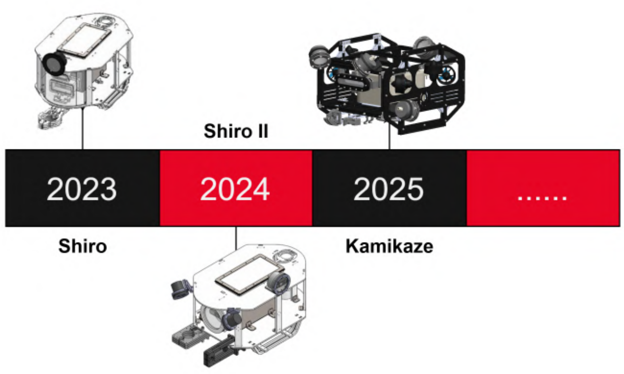


Figure 28: EJUST Robotics Club ROVs over years.

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 **47 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 29.

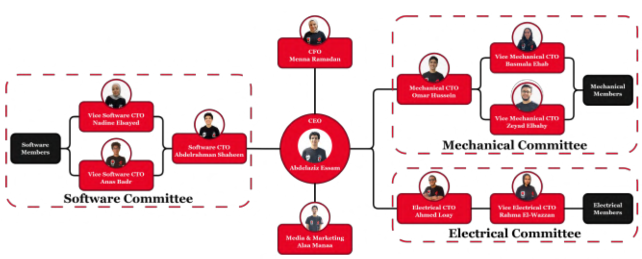


Figure 29: Company Structure.

Team Board

- **CEO (Chief Executive Officer):** Oversees all activities and high-level decision-making.

- **CFO (Chief Financial Officer):** Manages budget, funding, and financial operations.

Technical Sector

The technical sector has three divisions, each led by a CTO (Chief Technical Officer) and Vice CTOs:

1. **Mechanical Committee:** Responsible for designing and manufacturing the physical structure of Kamikaze.

2. **Electrical Committee:** Develops and integrates power distribution and control systems.

3. **Software Committee:** Focuses on control algorithms, vision processing, and system automation.

Non-Technical Sector

Beyond technical development, the Non-Technical Team plays a key role in logistics, outreach, and team operations:

- **Logistics:** Plans events and coordinates resources.

- **PR:** Manages communications and partnerships.

- **Media & Marketing:** Creates content and manages social media.

- **Sponsorship & Fundraising:** Secures funding and sponsors.

- **Event Management:** Organizes workshops and outreach.

5.3 Project Management

5.3.1 Project Scheduling

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

1. **Training Phase (12 weeks, Aug 1 - Oct 16, 2024)**

- 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, 2024)**

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

3. **Prototype Build & Testing (19 weeks, Nov 1, 2024 - Mar 14, 2025)**

• Mechanical assembly, electrical integration, and software implementation.

• Underwater testing, and system integration.

4. **Final Preparation & Mock Competitions (Mar 14 - Apr 24, 2025)**

• 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, a Square Canister, and manipulators for integration, performance, and cost efficiency.

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

5.3.3 Procedures & Workflow

- **Agile Development Approach:**
  - ***Agile methodology*** promoted collaboration and modularity.
  - ***Notion*** managed sprint planning, tracked tasks, and documented our work.
- **Communication & Coordination:**
  - Weekly Online Meetings: Weekly virtual meetings via ***Discord*** allowed real-time updates.
  - ***Miro*** for Visualization: Used for mind maps and flowcharts.
  - ***Overleaf*** for Documentation: Enabled efficient collaboration.
  - ***GitHub*** for development: Managed (CI/CD), version control, and issue tracking.

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

E-just Robotics operates within a limited self-funded budget and relies primarily on university funds. Therefore, it is crucial to use these resources judiciously to avoid unnecessary expenses. To oversee this, a Chief Financial Officer (CFO) manages all financial aspects, including budget setting and ensuring efficient utilization of the company's financial resources.

Additionally, Egypt currently experiences a high inflation rate, which diminishes the purchasing power of the same amount of funds.

More detailed budget breakdowns can be found in Appendices E and F.

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 semi-autonomous and 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, ecosystem monitoring, and environmental protection efforts.

6.2 Acknowledgements

E-JUST Robotics Club would like to extend our gratitude to E-JUST for its unwavering technical and financial support since our inception. Special appreciation goes to Prof. Amr Adly, the university president, and Prof. Amr B. Eltawil, the dean of the School of Innovative Design Engineering, for their continuous support. We also acknowledge the invaluable contribution of the mechatronics department and our technical supervisors:

- Dr. Victor Parque, Visiting Professor from Waseda University.
- Dr. Haitham El-Hussieny, Associate Professor.

We would also like to thank:

- MATE for organizing such an amazing competition.
- AAST for coordinating the regional competition.
- SolidWorks and Altium for sponsoring us with student licenses.

Figure 30: E-JUST Logo

6.3 References

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(a) MATE Logo

(b) AAST Logo

(c) SolidWorks Logo

(d) Altium Logo

Figure 31: Logos of acknowledged entities.

7 Appendix

A SIDs

A.1 Fluid SID

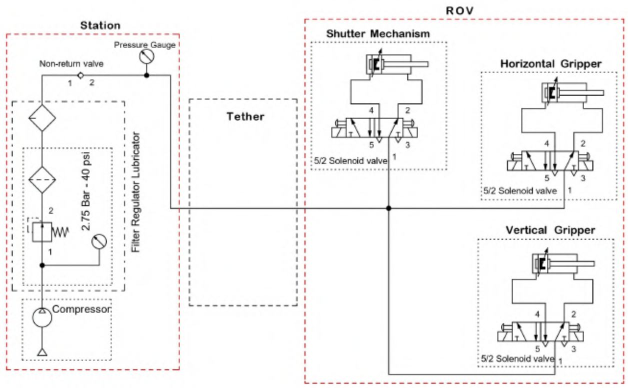

Figure 32: Pneumatic SID.

A.2 Electrical SID

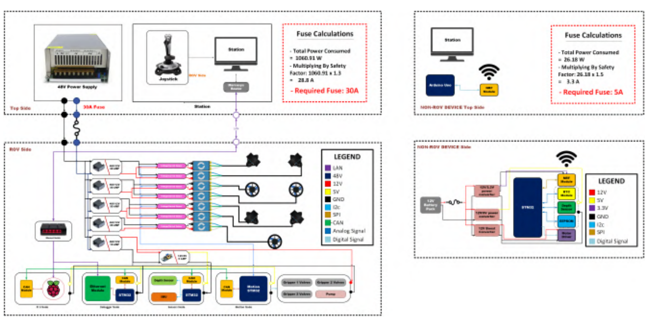

Figure 33: Electrical SID.

B Construction Checklist

❏ Ensure that appropriate personal protective equipment (PPE) such as gloves, goggles, and earmuffs are worn during all tasks.

❏ Sharp tools and equipment are stored properly when not in use, with blades covered or secured in racks or containers to prevent accidental cuts or injuries.

❏ Regularly check and maintain emergency kits, including fire extinguishers and first-aid supplies.

❏ Clearly label and store hazardous materials separately to ensure safe handling.

❏ Handle sharp tools with care, store them securely when not in use, and cover sharp edges with caps if available.

❏ Emergency response procedures are clearly outlined and accessible, including the location and condition of fire extinguishers, first aid kits, and emergency contact information.

❏ Maintain well-ventilated work areas and use additional fume extractors to prevent inhalation of harmful fumes while working with materials such as epoxy and soldering.

❏ Electrical components and wiring are handled with care, following proper insulation and grounding procedures to prevent electrical shocks or short circuits.

C Operational Safety Checklist

C.1 Pre-Deployment

❏ On deck in proper safety attire.

❏ Ensure power is OFF.

❏ Clear poolside of obstructions.

❏ Confirm untangled tether connected securely with strain relief.

❏ Check tether connection to Control Unit.

❏ Verify no exposed wires or loose connections.

❏ Confirm electronics housing sealing.

❏ Ensure control computer is operational.

C.2 Power Up

❏ Confirm ROV receives 48V.

❏ Perform dry tests on thrusters, manipulators, and payloads.

❏ Check all video feeds.

C.3 Launch and Water Entry

❏ Two members handle ROV.

❏ Tether handler holds tether.

❏ Visually inspect for leaks and air bubbles.

❏ Test thrusters, manipulators, and payloads.

C.4 Communication Loss

❏ Reboot ROV.

❏ Resend test package.

If no communication:

❏ Power down ROV.

❏ Retrieve ROV via tether.

❏ Check for damage or leaks.

❏ Dry Test

C.5 Retrieval

❏ Surface ROV and turn off thrusters.

❏ Assigned crew grab ROV by handles.

❏ Secure ROV on deck.

❏ Power down ROV and Control Unit.

D 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 34).

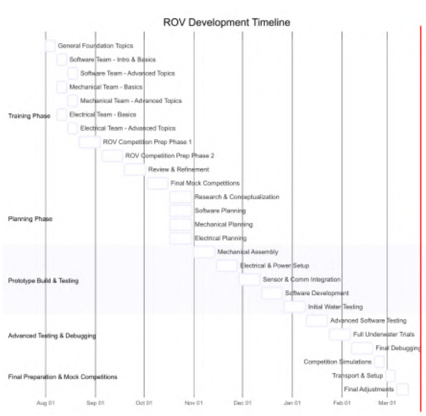

Figure 34: Gantt Chart for the Project Plan.

E Budget

E.1 Travel Estimate

	Category	Expenses (USD)
Expenses per Team	Team transportations in Alpena, Michigan	400
	ROV Shipping	650
Total		**1050**
Expenses per Member	Residency in Alpena, Michigan per member	350
	Tickets expenses per member	1600
	Visa Fees per member	185
Total per member		**2205**

Table 8: Traveling expense breakdown.

The number of individuals traveling to the USA will be determined based on available sponsorship opportunities, which may cover some or all of the costs. We expect to have a clear understanding of these details by June 1, 2025.

E.2 Fundraising

Category	Source	Cost (USD)
Sponsorship	E-just University fund	2000
Sponsorship	ISF fund	1000
Self-fund	By Team members	156
Total Income		**3156**

Table 9: Income breakdown.

E.3 Budget Allocation

Category	Description	Cost (USD)
ROV Materials & Machining	ROV tether, Cameras encapsulation, Canister	1080
ROV Electronics	power converters, cameras, etc	1050
Float	Its Structure, Electronics, and Sensors	400
Lab Safety	Safety glasses, labels, ventilation, gloves, etc.	70
Team Operations	Team branding (shirts, Logo stickers, etc)	275
Competition Fees	Registration fees for MATE ROV Competition	650
Total Expenses		**3,525**

Table 10: Budget Allocation.

F Cost Breakdown

F.1 Reused Items

Category	Component	Quantity/Weight	Total Price (USD)
Electronics	T200 Thrusters	6	2964
	ESC (Electronic Speed Controller)	6	419
	Logitech C270 Widescreen HD Webcam	3	109
	Water Depth/Pressure Sensor MS5540	1	17
	TP-Link TL-WR840N 300 Mbps Wireless N Router	1	17
	10 DOF IMU (MPU9250+BMP280)	1	16
	ROV Controller	1	20
	12V to 5V DC-DC Converter	3	148
Tools/Supplies	Digital Multimeter	2	33
	Soldering Iron 220V 100W	2	17
Pneumatics	Pressure regulator	1	65
	Air Solenoid Valve 12VDC Bi-Directional	1	11
	Pneumatic Cylinder MI25-25-S	2	20
	Non-return Valve	1	10
	Air Solenoid Valve 12VDC (5/2)	2	12
Safety Equipment/PPE	Safety Glasses, Vests, etc	–	10
Total			4150

Table 11: Reused components and their costs.

The exchange rate between the U.S. dollar (USD) and Egyptian pound (EGP) is 50.57 EGP per dollar in Sun, 28 March 2025.

F.2 Purchased Items

Category	Component	Total Price USD
Mechanical Material	Artelon Sheet (10mm*1m*1m)	76.95
	Toggle Clamp Latch	102.94
	Transparent Acrylic Sheet (6mm*2m*1.3m)	120.44
	2020 extrusion	54.56
	2040 extrusion	16.73
	Aluminium T-bracket	15.44
	Aluminium L-slot bracket	10.29
	90 degree Aluminium plate	16.73
	T-slot Nut	15.44
	Allen bolt	11.58
	Aluminium sheet	54.56
Electronics	ESC (Electronic Speed Controller)	95.74
	ZED 2 Stereo Camera	839.75
	CCTV Camera	77.46
	Raspberry Pi 5 - 8GB RAM With Active Cooler	193.01
	Cat 6e 50 meter	15.93
	STM32F401RCT6	8.36
	Stranded Aluminum Wire - 16 mm²	59.29
	WS2812 RGB Diffused Addressable LED 5mm 5V	6.18
	UGREEN Braided USB to USB C	46.32
	General purpose Mosfets	7.72
	High Torque Servo Motor (15 kg.cm - Metal Gear)	39.12
	STM32F411 Black Pill	23.68
	15mm Expandable Braided Cable Sleeve	19.30
	Barrier Terminal Block	12.87
	PCB Manufacturing	102.94
	Resistors	6.43
Pneumatics	Pneumatic Straight fitting 6 mm	2.51
	Air Solenoid Valve 12VDC Bi-Directional	13.38
	Pneumatic Cylinder M125-25-S	11.71
	Non-return Valve	11.71
	Air Solenoid Valve 12VDC (5/2)	7.03
Sealing	Pneumatic Clear Hose 8*6mm	11.37
	Sealing Blue Foam (5cm thickness)	6.69
	Glands	1.67
	Rubber Gaskets (1m*1m)	11.71
Float	Acrylic Cylinder (20 cm)	257.35
	Stainless Lead Screw with Nut (8x1000mm) Pitch 2mm	7.46
	Pneumatic Hose	10.29
	Allen bolt	3.86
	Lead Screw Nut	0.26
	Artelon Sheet (5mm*50cm*50cm)	15.44
	PCB Manufacturing	77.20
	STM32F411 Black Pill	11.84
	NI-MH Rechargeable Battery AA 1800mAh 1.2V (2PCS)	20.07
Total		2,531.31

Table 12: Purchased Materials.