Contents

1 Abstract

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

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

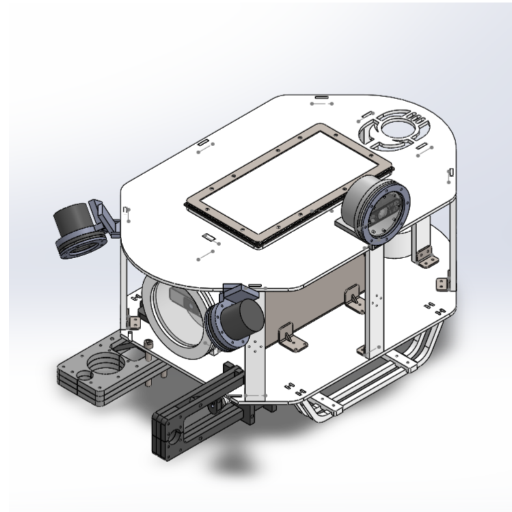


Figure 1: Last year's ROV - Shiro Kaijin.

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 represents a well-planned evolution that enhances reliability, efficiency, and mission adaptability.

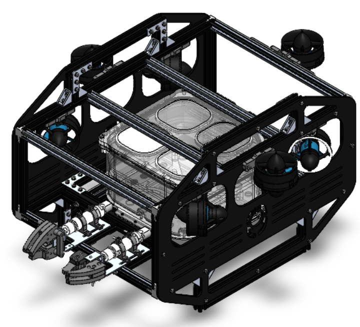


Figure 2: Kamikaze.

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. 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.

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 overall performance. Additionally, a debugging node using the W5500 Ethernet module was introduced, enabling real-time system monitoring and remote reset of multiple nodes, ensuring continuous 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

Something about the software system evolution. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Figure 3: Software System Evolution.

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 (Figure 4) was developed, comparing materials based on weight, cost, and manufacturability. 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.

Figure 4: Material Selection

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 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 5) was fully developed in SolidWorks, incorporating stress, buoyancy, and flow simulations to ensure structural stability and hydrodynamic efficiency.

Figure 5: 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 6) were generated to optimize material usage.

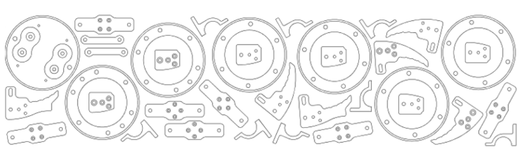


Figure 6: DXF file for cutting the float and grippers.

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 7)
- 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.

Figure 7: PCB

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

2.2.4 Mechanical System

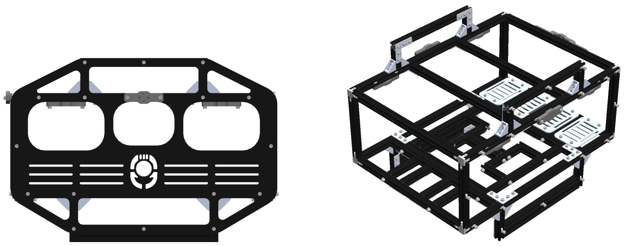
2.2.4.1 Frame

Kamikaze's frame (Figure 8b) 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 8a) 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



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

Figure 8: Kamikaze's Frame Illustration.

requirements of the MATE ROV competition while balancing durability, weight efficiency, and adaptability.

2.2.4.2 Propulsion

Kamikaze is equipped with seven T200 Blue Robotics thrusters, strategically placed to achieve six degrees of freedom for precise maneuverability (Figure 9). 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:

$$F_d = \frac{1}{2} C_d \rho A v^2 \tag{1}$$

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)

A CFD flow simulation was conducted to analyze water flow around Kamikaze (Figure 10), minimizing drag and enhancing hydrodynamic efficiency.

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.

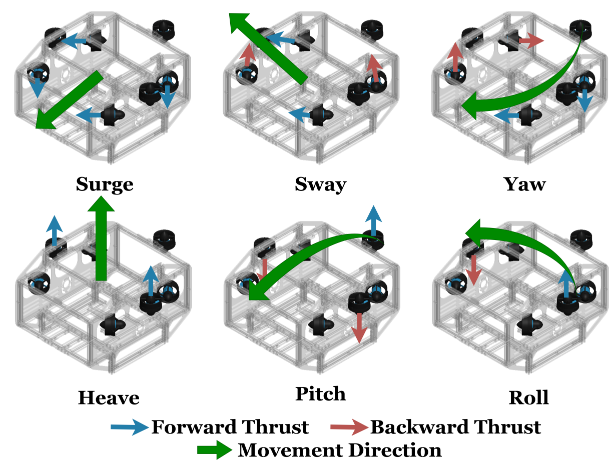


Figure 9: Kamikaze's Degrees of Freedom.

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

2.2.4.3 Buoyancy and Stability

Something about buoyancy and stability. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla.

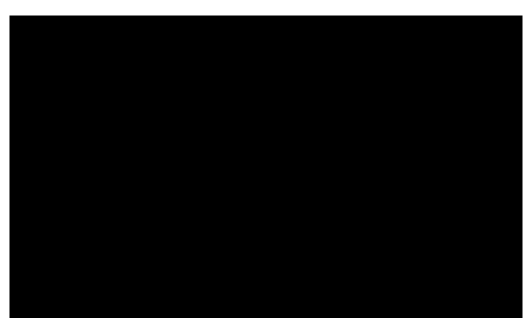


Figure 10: Flow Simulation.

Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Figure 11: Buoyancy.

2.2.4.4 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.

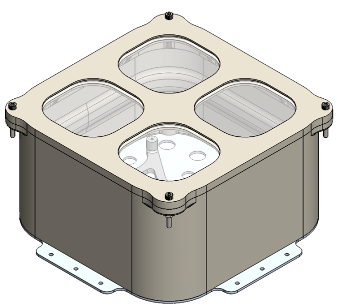


Figure 12: Kamikaze's Main canister.

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 13a):** Stress is concentrated around circular openings and edges, which experience higher mechanical loads from water pressure.
- **Bottom View (Figure 13b):** 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 13: Main Canister Finite Element Analysis.

2.2.4.5 Sealing Strategy

Something about sealing strategy. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc.

Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Figure 14: Sealing.

2.2.4.6 Cameras

Something about cameras. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

2.2.4.7 Grippers

Something about grippers. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique

Figure 15: Cameras.

senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Figure 16: Grippers.

2.2.5 Electrical System

2.2.5.1 Control Units

(i) **Topside Control Unit**

(ii) **Sensors**

(iii) **Underwater Control Unit**

(iv) **System Integration**

2.2.5.2 Electric Power

(i) **Power Conversion System**

(ii) **Power Unit**

2.2.5.3 Tether

2.2.6 Software System

2.2.6.1 Communication System

Some communication system talk.

2.2.6.2 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 17.

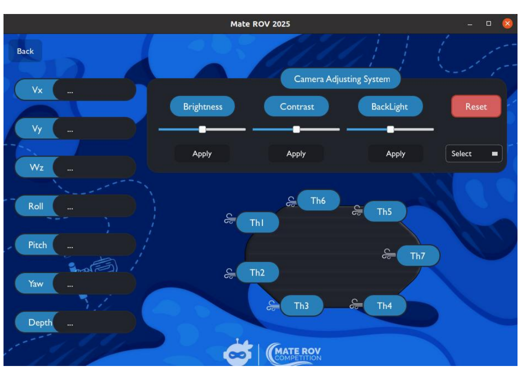


Figure 17: Screenshot of the Copilot interface.

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 18.

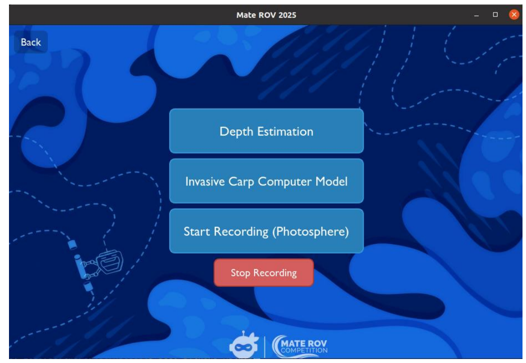


Figure 18: Screenshot of the Engineer interface.

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

2.2.6.3 Some third point

some software system talk.

3 Safety

4 Testing and Troubleshooting

5 Logistics

6 Conclusion

7 Appendix