



Benha National University, Faculty of Engineering



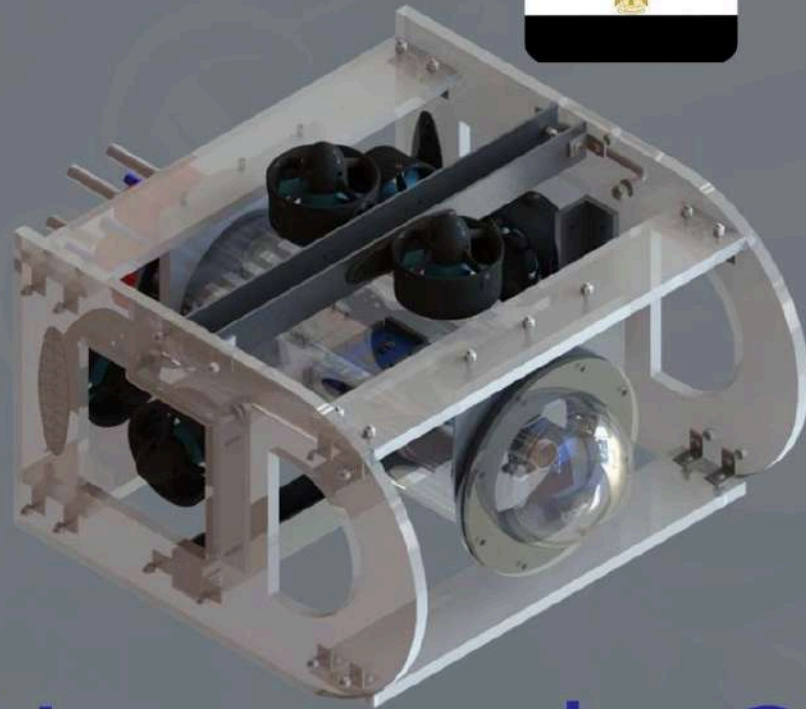
President | Seif Aboulella '26
CEO | Mahmoud Elsayed '27
VCEO | Marina George '27
CTO | Nahed Tamer '27
VCTO | Hossam Tarek '27

Head Mechanical | Youssef Sameh '27
Mechanical Member | Seif Hisham '26
Mechanical Member | Omar Othman '27
Mechanical Member | Omar Roshdy '27
Mechanical Member | Ahmed Samir '27
Mechanical Member | Mohamed Anwar '27
Mechanical Member | Ahmed Tohamy

Head Hardware | Mohamed Hisham '26
Hardware Member | Mariam Hany '27
Hardware Member | Menna Ayman '27
Hardware Member | Salah Tamer '27
Hardware Member | Shrouk Ayman '27

Head Software | Yara Eyad '27
Software Member | Maya Ahmed '28
Software Member | Shrouk Ayman '27
Software Member | Andrew '26

Head R&D | Esraa Ashraf '27
VHead R&D | Rita Tahan '27
Head HR | Omar Abdelatty '27
VHead HR | Omar Hany '27
Media & Marketing | Mohamed Assem '29
Media & Marketing | Esraa Yousry '26



Noramndy_2

Mentors

Dr.Dina Hosny Soliman Elnaggar

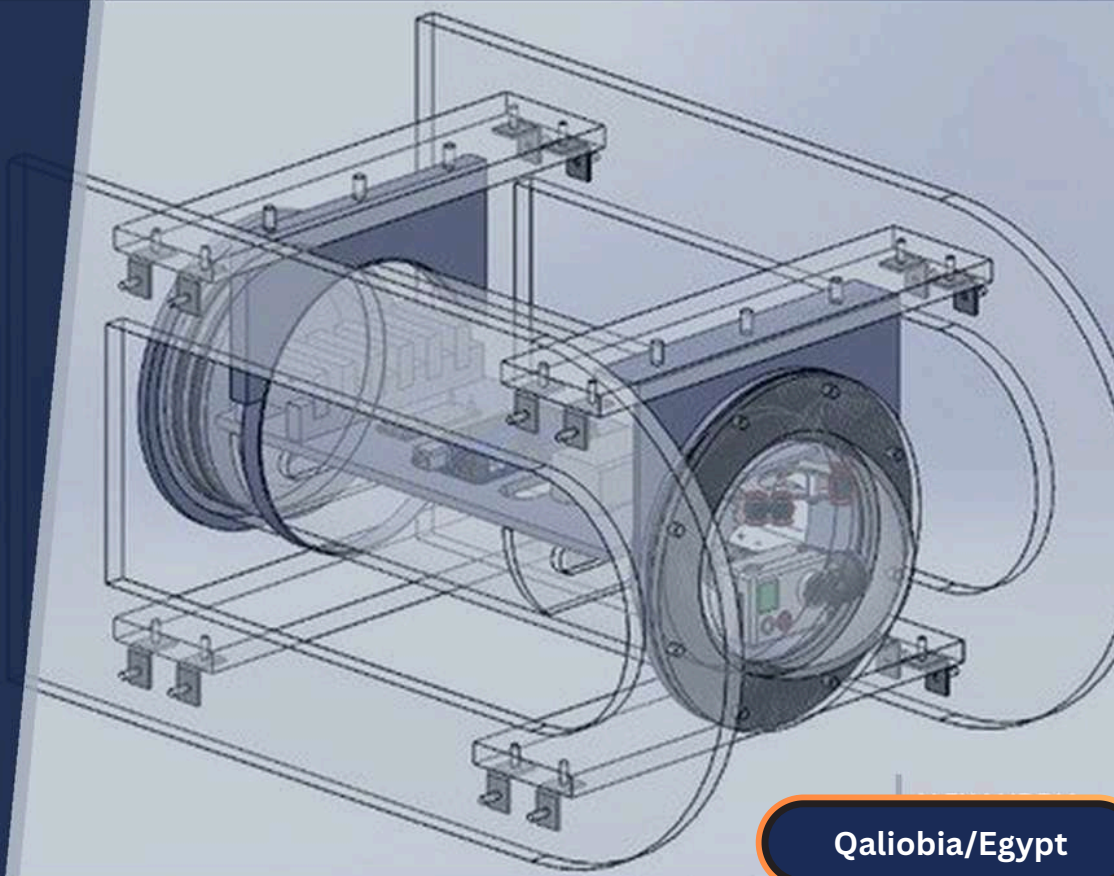
Dr.Mohamed Saed Abdelghafar

AQUAVENTURES TEAM

Dive Bolder, Dive Deeper



AQUAVENTURE
HOOLIGANS



Qaliobia/Egypt

Technical Report2026

**20
26** | TECHNICAL
REPORT



1. Company Abstract

AquaVentures is a student-led engineering company based in Benha National University (BNU), Al Obour City, Egypt, one of the region's most prominent industrial hubs. Inspired by our surroundings, we recognize the critical need for automated underwater solutions in industrial maintenance and environmental protection.

In an era of rapid environmental shifts, underwater robotics is vital for sustainable development.

This project introduces a multi-functional Remotely Operated Vehicle (ROV) designed to address global challenges: invasive aquatic species, hazardous industrial maintenance, and climate change monitoring.

The primary objective is the mechanical management of Water Hyacinth (*Eichhornia crassipes*), an invasive plant disrupting local biodiversity. Equipped with a custom harvesting module, the ROV operates effectively in high-density vegetation zones.

Simultaneously, the vehicle provides a robotic alternative for Industrial Tank Cleaning and Inspection, eliminating the need for human divers in confined, hazardous environments.

A distinguishing feature is its role as a Mobile Submersible Data Laboratory; integrated with an advanced sensory array, the platform logs longitudinal data on pH, temperature, and dissolved oxygen to track climate change impacts.

Engineering-wise, the ROV features a 5-DOF propulsion system for precise maneuverability and a modular chassis optimized via hydrodynamic simulation. This prototype harmonizes mechanical power with scientific intelligence, paving the way for a new generation of underwater vehicles dedicated to preserving water resources and advancing subsea industrial automation.

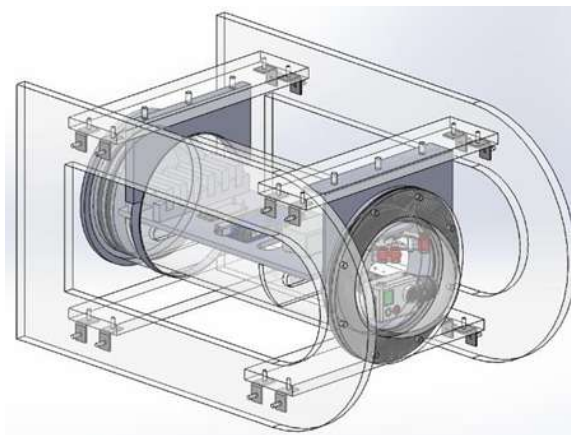




TABLE OF CONTENTS

1. Abstract	2
2. Team work and project management	3
3. Design Rationale	3
3.1 Design Evolution	4
A. Innovation	5
3.2 Vehicle Structure and Systems	5
A. Vehicle Structure and Frame	6-7
B. Propulsion	6
3.3 Core System	6
A. Mechanical	7
B. Electrical	7-8
C. Software	7
3.4 Payload and Tools	8
A. Digital Camera System	9
B. Retrieval Claw	10-11
4. System Integrated Diagram(SID)	12
5. Safety	13
A. Safety Philosophy	14
B. Vehicle Safety Features	14
6. Conclusion	15
A. Acknowledgements	16
7. VEHICLE STRUCTURE AND SYSTEMS	17
	19
	22

1. Team work and project management

A. Company Profile

AquaVentures is an emerging underwater robotics and subsea technology firm based in the industrial hub of Al Obour City, Egypt, operating within the advanced academic ecosystem of Benha National University (BNU). Our mission is to engineer high-performance, cost-effective Remotely Operated Vehicles (ROVs) designed to tackle complex aquatic challenges, from industrial tank maintenance to the preservation of Nile River ecosystems and maritime infrastructure.

Our multidisciplinary team brings together a diverse group of engineers specializing in Mechatronics and Communications Engineering. This strategic combination of expertise allows us to bridge the gap between robust mechanical hardware and high-speed data transmission. Under a professional management structure, the team has implemented Agile methodologies, ensuring that every technical milestone—from the initial 48V power architecture to the ESP32-based communication protocols—was achieved with precision and speed.

Despite a condensed development timeline starting in late 2025, the AquaVentures team worked tirelessly to design, prototype, and assemble the Normandy SR-2 from the ground up. Our workflow is divided into specialized departments to ensure maximum efficiency:

Mechatronics Division: Responsible for structural integrity (hybrid sheet-metal frames), propulsion (6 bilge-pump configuration), and the 4-DOF mechanical dynamics.

Communications & Control Division: Focused on the Cat6 data backbone, high-speed signal processing, and the IP-based vision system to ensure zero-latency feedback.

Planning & Strategy Team: Managed the exhaustive documentation, safety protocols, and "Lean" business modeling required to meet international standards.

Operating out of the Benha National University labs, we have cultivated a high-performance environment rooted in mentorship and peer-to-peer learning. By leveraging our collective backgrounds in social entrepreneurship and industrial automation, AquaVentures has established a scalable foundation for future subsea innovation, aiming to lead the way in underwater technology within the Afro-Arab market.

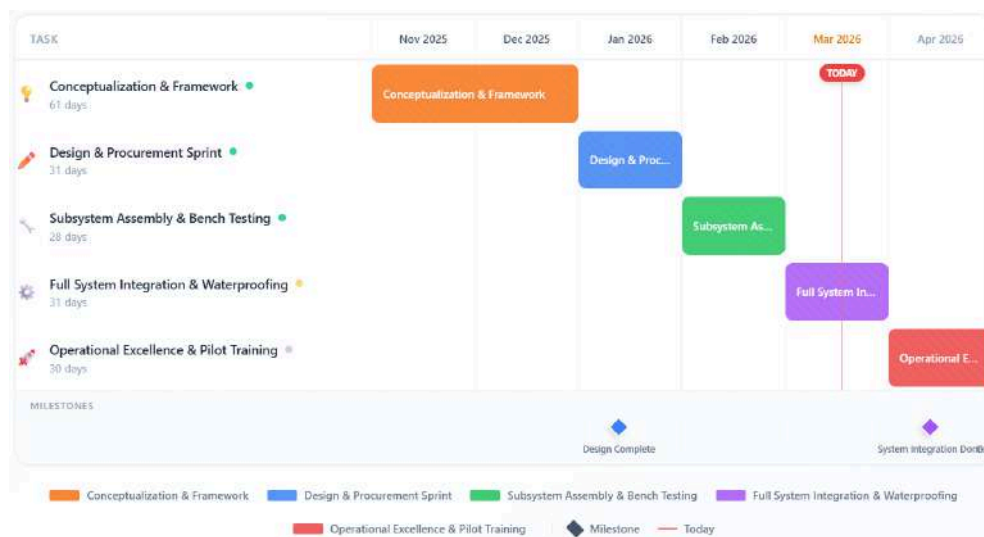


B. Project Management

The AquaVentures team operates under a structured yet flexible project management framework, designed to balance rigorous academic schedules with the demanding technical requirements of the Normandy_2. To ensure maximum efficiency and accountability, our team implemented a Dual-Session Weekly Sprint, meeting two evenings per week for intensive technical synchronization, supplemented by full-day "Integration Saturdays" during critical assembly phases.

Project Timeline (2025 - 2026)

- November - December 2025: Conceptualization & Framework Following the formation of the team at Benha National University (BNU), we initiated the "Discovery Phase." This involved a deep dive into MATE safety regulations, structural feasibility studies for the hybrid frame, and the official allocation of roles across the Mechatronics and Communications divisions.
- January 2026: Design & Procurement Sprint The team transitioned into the CAD Design phase, utilizing SolidWorks to model the Normandy SR-2's chassis and internal electronics tray. Simultaneously, we initiated the procurement of the ESP32 controllers, IP Cameras, and 48V power components, ensuring all hardware met our specific design constraints.
- February 2026: Subsystem Assembly & Bench Testing This phase focused on "Dry Testing." The 48V-to-12V power rail was assembled and stress-tested, while the Cat6 tether was integrated with the surface control station. The ESP32 was successfully programmed to interface with the 6-thruster array and the dual-axis grippers, confirming the logic and control protocols.
- March 2026: Full System Integration & Waterproofing All mechanical and electronic subsystems were integrated into the main PVC and sheet-metal frame.
- April 2026: Operational Excellence & Pilot Training The final month was dedicated to Field Trials and Pilot Proficiency:





3.1 Design Evolution

A. Innovations

Developing our first ROV, Normandy_2, presented a unique engineering challenge: creating a high-performance vehicle that balances industrial-grade durability with cost-efficiency. Throughout the design and fabrication phases, our guiding principles were Affordability, Simplicity, and Sustainability. We focused on reducing system complexity to minimize potential failure points while maximizing stability in underwater operations. The following key innovations define the Normandy_2

Unlike traditional plastic or expensive carbon-fiber frames, we opted for a galvanized sheet metal chassis. This choice provides superior structural mass and a low center of gravity, ensuring natural stability and reducing the need for complex ballast systems. The "Open-Frame" design allows for rapid component mounting and modular adjustments during mission-specific reconfigurations.

To maintain a low-cost profile without sacrificing thrust, the team repurposed six high-flow bilge pumps as the primary propulsion units. By integrating custom-fitted nozzles and optimized propellers, we achieved a powerful thrust-to-weight ratio. This 6-thruster configuration enables agile movement across four degrees of freedom (4 DOF), allowing the pilot to navigate complex underwater structures with ease.

For electronic protection, we utilized custom-machined PVC enclosures secured with industrial-grade cable glands. This hybrid approach combines the chemical resistance of PVC with the mechanical reliability of high-pressure seals, providing a robust, leak-proof environment for the core electronics at a fraction of the cost of commercial underwater housings.

At the heart of our system is the ESP32 microcontroller, selected for its high processing speed and versatile I/O capabilities. This allows for low-latency command processing and real-time telemetry. Our communication protocol is streamlined to handle dual-camera HD feeds and sensor data simultaneously, ensuring the pilot has full situational awareness through a simplified, reliable tether architecture.



B. Design Process

The design of the Normandy_2 followed a systematic engineering workflow aimed at producing a robust, mission-capable underwater vehicle. Our primary challenge was balancing the high structural integrity of industrial materials with the precise buoyancy requirements of the 2026 MATE mission.

Structural Architecture:

- For the main frame, we deviated from traditional plastic-only designs by engineering a Galvanized Sheet Metal (2mm) chassis. This decision was driven by the need for a stable, low-center-of-gravity platform that resists underwater currents. To maintain modularity, the upper superstructure utilizes PVC piping, which provides an ideal balance of durability, corrosion resistance, and cost-effectiveness. This hybrid construction ensures that the Normandy SR-2 remains rigid under pressure while allowing for easy attachment of mission-specific tools.

Electronic Integration & Waterproofing

- The electronics suite, centered around the ESP32 microcontroller, faced significant spatial constraints within the PVC control enclosures. To ensure watertight integrity, we incorporated high-pressure industrial cable glands, creating a reliable seal for all power and data tethers. A critical part of our design process involved optimizing the internal component layout to prevent overheating and electromagnetic interference within the confined PVC housing.

Manipulator Strategy (Dual-Gripper System)

- The manipulator system was designed for versatility. By integrating two independent grippers—one oriented horizontally and the other vertically—we eliminated the need for complex vehicle repositioning during recovery tasks. These manipulators were fabricated to handle varied geometries, from delicate environmental sensors to bulky industrial debris, ensuring efficiency and reliability during the 2026 mission tasks.

Hardware Optimization

- As hardware designers, a significant portion of our brainstorming focused on the Control Box layout. Given the limited dimensions of the PVC Control Box, we had to optimize the PCB and wiring architecture to maximize space utilization. After thorough analysis, we implemented a compact, stacked-component layout, which offered the highest space efficiency for our ESP32-based circuitry, ensuring a clean and manageable interface for the pilot.

3.2 Vehicle Structure and Systems

A. Vehicle Structure and Frame

The frame of the Normandy_2 was engineered for maximum structural integrity and operational stability. The vehicle measures 50cm x 40cm x 35cm. Utilizing a Galvanized Sheet Metal base provides the ROV with a low center of gravity, enabling a stable and controlled descent while minimizing the impact of underwater currents during mission runs. This rugged, flat-base design ensures the vehicle remains steady on the seafloor or during delicate industrial tank cleaning tasks. The frame is a hybrid construction, where the metal chassis provides the core strength, and a PVC superstructure allows for the precise positioning of the six bilge-pump thrusters, dual-camera system, and modular tools. A key feature of our design is the integrated dual-handle system, which ensures the ROV is transported and deployed safely by the crew. Following assembly, the Normandy SR-2 underwent rigorous testing by our pilots in Al Obour City, demonstrating exceptional communication, agile maneuverability across 4 DOF, and a high level of safety for both the operator and the aquatic ecosystems.

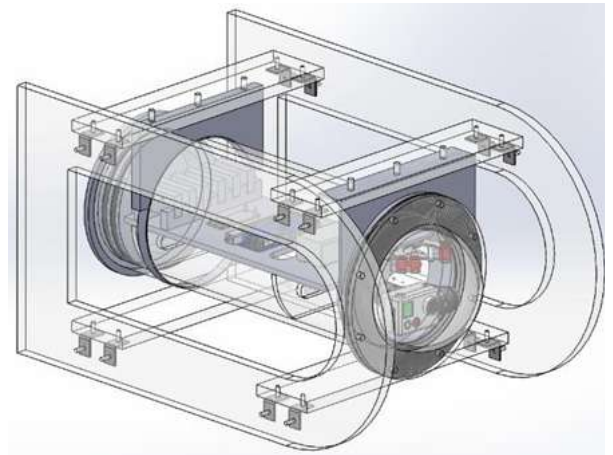


Figure 1- Current Normandy_2 Design

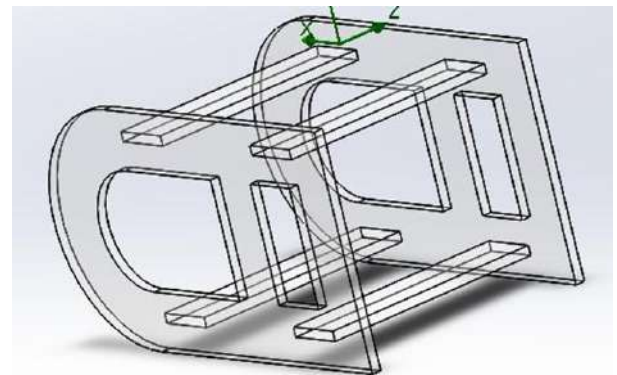


Figure 2- SolidWorks representation of the simplified model

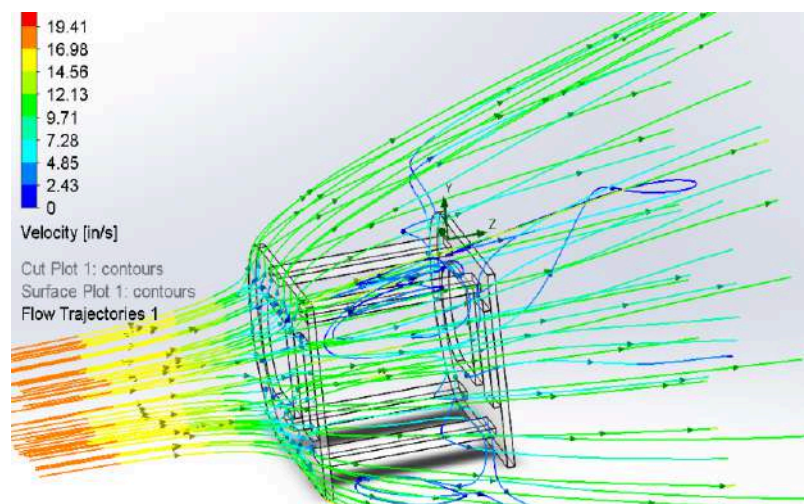


Figure 3- Flow simulation trajectories for a velocity of 22.0 in/s.

- Chassis Design and Functional Protection The side panels of the Normandy_2 are the foundational structural components of the ROV, serving as the primary vertical supports that house and protect the central electronics enclosure. Beyond structural stabilization, these panels are engineered as integrated "skids," allowing the vehicle to rest securely on flat surfaces during maintenance while maintaining a safe clearance for the pressure hull. This design prevents hazardous underwater debris from scratching or compromising the integrity of the ESP32 control suite. Furthermore, the side panels function as a rigid mounting matrix for the six-thruster propulsion system, specifically managing the complex axial and torsional loads generated during 4-DOF maneuvers in the X, Y, and Z Cartesian axes.

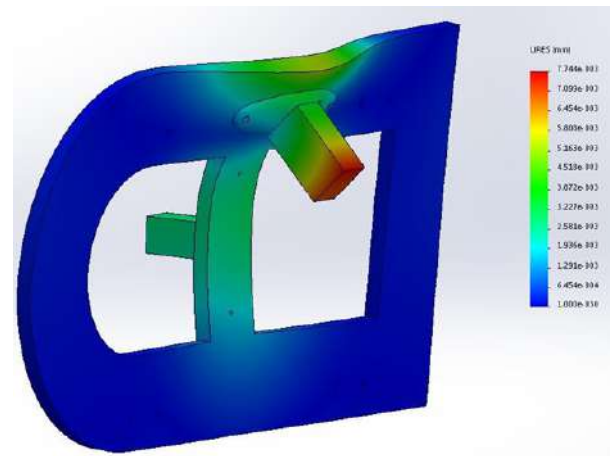


Figure 4- Strain in millimeters

- The theoretical calculations were validated through Finite Element Analysis (FEA) within SolidWorks. Due to the complexity of the thruster geometries, mass-equivalent models were utilized to simulate Von Mises stress concentrations across the hybrid frame. The simulations confirmed that the maximum stress remained well within the elastic region of the material, supporting the decision to maintain a robust 0.8-inch profile for maximum stability. From a hydrodynamic perspective, the frame is optimized to navigate at a maximum velocity of mph (17.6 in/s). This flow analysis justifies the selection of our six-motor configuration, ensuring the Normandy_2 maintains a superior thrust-to-weight ratio to overcome drag while preserving its hydrostatic equilibrium during sensitive missions

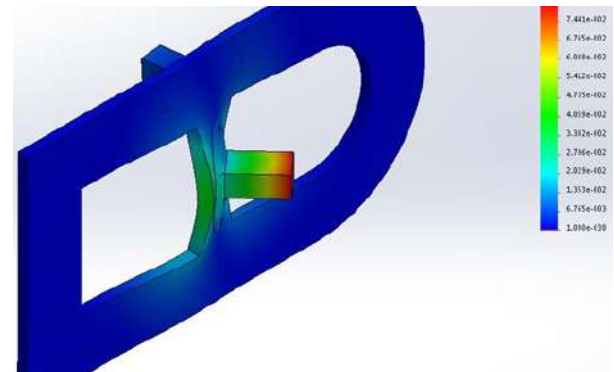


Figure 4- Displacement in millimeters

B. Propulsion

The propulsion system of the Normandy_2 is strategically engineered to deliver high thrust and precise maneuverability using a configuration of six high-flow bilge-pump thrusters. To achieve optimal agility, the thrusters are distributed across the frame to enable four degrees of freedom (4 DOF): surging (forward/backward), and heaving (up/down).

Four thrusters are mounted horizontally in a vectored configuration, allowing for smooth lateral and longitudinal movement, while the remaining two thrusters are positioned vertically to manage depth control and maintain hydrostatic stability. This symmetrical layout ensures that the ROV remains upright and stable at all times, even when operating in turbulent industrial environments. Each thruster is retrofitted with custom-fitted nozzles and high-efficiency propellers to maximize water flow and thrust-to-weight ratio. By opting for this unconventional yet robust propulsion design, AquaVentures has developed a mission-ready system that delivers exceptional underwater performance at a fraction of the cost of commercial alternatives, aligning with our core values of affordability and engineering simplicity.



Figure 5- Bilge Pump

3.3 Core System

The Normandy_2 utilizes a high-speed control architecture centered around the ESP32 microcontroller, leveraging its dual-core processing for low-latency command execution and real-time telemetry. At the surface, the operator interface processes multi-axis joystick inputs, translating them into digital signals that travel via the tether to the onboard logic unit. The ESP32 then generates precise PWM (Pulse Width Modulation) signals to govern the six bilge-pump thrusters, enabling agile movement across 4 DOF. This electrical suite is integrated with a dual-camera HD system for real-time visual feedback and dedicated controls for the dual-axis gripper system, ensuring seamless synchronization between the pilot's commands and the ROV's physical response in demanding underwater missions.

A. ROV Electronics

The electronic heart of the Normandy_2 is a high-performance, integrated system designed to bridge the gap between complex operator commands and precise underwater execution. At the core of our onboard intelligence is the ESP32 microcontroller, a dual-core powerhouse selected for its high clock speed and versatile I/O capabilities. This unit acts as the primary communications hub within the PVC electronics enclosure, converting digital signals received from the surface—via a multi-axis precision joystick—into discrete, high-frequency Pulse Width Modulation (PWM) commands. These signals are then distributed to the power distribution board to regulate the voltage levels sent to the six bilge-pump thrusters, allowing for a high degree of responsiveness and agility across four degrees of freedom (4 DOF).

Beyond propulsion, the electronics suite is engineered for total situational awareness. The Normandy_2 incorporates a specialized telemetry and sensor-fusion layer that continuously monitors the vehicle's operational status. This real-time data is streamed back to the surface via a high-speed tether, providing the pilot with a constant feedback loop regarding the ROV's health and environmental conditions. For visual navigation, the system features dual HD video processing circuits mounted at the front of the internal electronics tray. These circuits handle the encoding of signals from two high-definition cameras, ensuring a low-latency, crystal-clear visual feed that is critical for the delicate operation of the horizontal and vertical dual-gripper system.

To ensure reliability in the high-pressure underwater environment, all components are meticulously organized on a custom-fabricated internal tray. This layout was strategically designed to maximize space efficiency within the cylindrical PVC housing while optimizing passive heat dissipation from the voltage regulators and the ESP32. We utilized a translucent inspection segment in the enclosure design, allowing our maintenance crew to perform rapid visual health checks of the internal circuitry before and during deployments.

B. Tether

To maximize electrical efficiency, the Normandy+2 utilizes a high-voltage power architecture. The tether delivers 48V DC via heavy-duty 10 AWG copper conductors. This high-voltage approach significantly minimizes Voltage Drop over the 15-meter length compared to standard 12V systems. Upon reaching the ROV, the voltage is efficiently regulated down to 12V DC using onboard high-current Buck Converters to power the six bilge-pump thrusters and the ESP32 control suite. This design ensures consistent thrust and stable logic operation even during peak power demands.

The communication backbone of the tether is a shielded Cat6 Ethernet cable. This dedicated high-bandwidth link facilitates a rock-solid connection between the surface station and the onboard ESP32 microcontroller. It is capable of handling dual High-Definition (HD) video streams and real-time telemetry data simultaneously, providing the pilot with a low-latency "telepresence" experience essential for precise underwater operations.

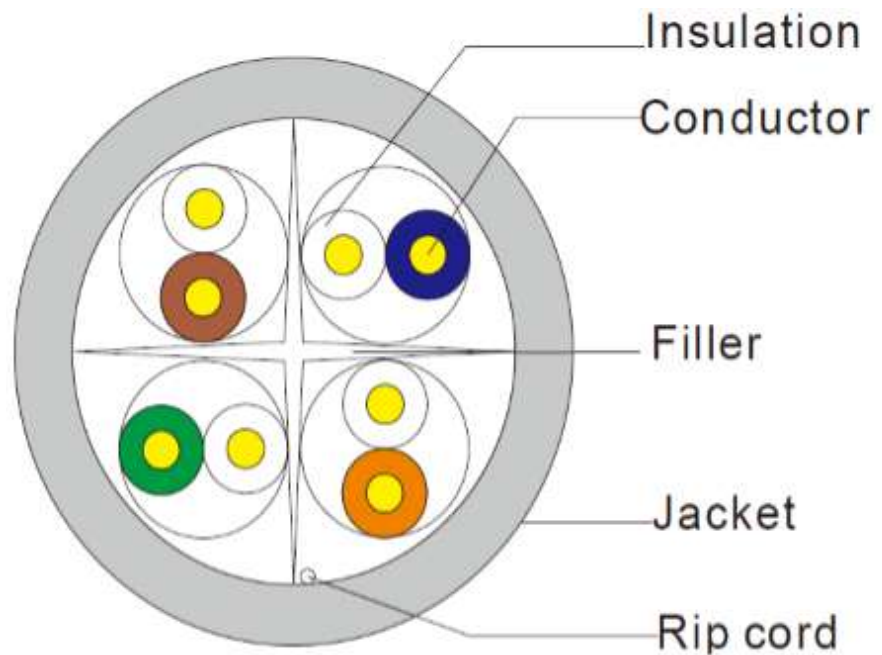


Figure 6-Cat6 SID



C. Control System & Configuration

1.1 System Overview

1. Control System & Architecture

The Pioneer ROV 2026 software is built on a distributed architecture that strictly separates ROV control from mission task execution, ensuring that any software failure in the task layer does not compromise vehicle maneuverability.

At its core, an ESP32 microcontroller onboard the ROV manages all motor control and sensor fusion, while a surface laptop running handles AI inference, task software, and the mission GUI.

These two systems communicate over a CAT6 Ethernet tether carrying both data and Power over Ethernet (PoE), with a TP-Link 4-port switch at the surface distributing connectivity to the IP cameras and the ESP32.

The pilot interfaces with the system using a PS4 DualShock 4 controller connected via USB to the laptop, which translates stick inputs into thruster commands transmitted to the ESP32 over WebSocket.



1.2 Software Stack

Layer	Technology	Purpose
ROV Firmware	Arduino C++ on ESP32	Motor control, sensor reading, WebSocket server
AI / Vision	Python 3.11 + YOLOv8n + OpenCV	Crab detection, frame extraction, ArUco
Task Software	Python scripts (per task)	eDNA calculator, iceberg tracker, transect logger
3D Reconstruction	3DF Zephyr (free)	Photogrammetry 3D model of coral garden
Mission GUI	HTML + CSS + JS (Flask backend)	Unified display of all task data and ROV telemetry

1.3 Network Configuration

All communication between the ROV and the surface laptop uses wired Ethernet over the CAT6 tether. WiFi is not used as it cannot penetrate the water column reliably.

Device	IP Address	Protocol
Surface Laptop	192.168.1.100	Host
ESP32 (ROV)	192.168.1.50	WebSocket Server
Camera 1 (Forward)	192.168.1.101	RTSP Stream
Camera 2 (Downward)	192.168.1.102	RTSP Stream
PoE Switch	192.168.1.1	Network Hub

2. PID Control & Stability

2.1 Role of PID :

PID (Proportional-Integral-Derivative) control is critical for two tasks:

- Task 1.2 – Coral Garden Ridge Modelling: The ROV must float manually around the coral garden in a stable, controlled pattern to capture overlapping photos for photogrammetry. Stability in all axes is essential for sharp, usable images.
- Task 1.3 – Transect Video: The ROV must hold a fixed position against current above the coral garden while recording video.

2.2 PID Architecture:

Three independent PID controllers run on the ESP32, one for each rotational axis:

Axis	Sensor Input	Actuator Output	Competition Use
Pitch (nose up/down)	IMU (MPU6050)	Front/rear thruster differential	Keep camera level for photogrammetry
Roll (side tilt)	IMU (MPU6050)	Port/starboard thruster differential	Prevent tilted images
Yaw (rotation)	IMU (MPU6050)	Left/right thruster differential	Hold heading during transect
Depth	Bar30 Pressure Sensor	Vertical thruster	Maintain altitude above coral garden

2.3 PID Procedures Task 1.2 – Coral Garden Survey

For photogrammetry survey, the PID system maintains stability while the pilot flies the ROV around the coral garden:

- Pitch PID holds the camera angle level to prevent blurred or tilted frames.
- Depth PID maintains a constant altitude of ~0.5m above the coral garden for consistent scale across frames.
- Yaw PID holds heading during each leg of the survey pattern to prevent rotation drift.



2.4 PID Control & Stability

Role of PID :

PID (Proportional-Integral-Derivative) control is critical for two tasks:

- Task 1.2 – Coral Garden Ridge Modelling: The ROV must float manually around the coral garden in a stable, controlled pattern to capture overlapping photos for photogrammetry. Stability in all axes is essential for sharp, usable images.
- Task 1.3 – Transect Video: The ROV must hold a fixed position against current above the coral garden while recording video.

3. Network Configuration

All communication between the ROV and the surface uses wired Ethernet over the CAT6 tether, with WiFi excluded due to its inability to reliably penetrate water at competition depths. The network operates on the 192.168.1.0/24 subnet, assigning fixed IPs to the laptop, ESP32, and both cameras. Four protocols govern the system: WebSocket carries real-time telemetry from the ESP32 at 10 Hz as JSON packets containing pitch, yaw, roll, depth, gripper state, battery voltage, and temperature; RTSP streams live video from both cameras; HTTP serves the Flask mission GUI on port 5000; and I2C connects the IMU and depth sensor internally to the ESP32.



4. Camera System & Topside Control

The ROV carries two IP cameras, each assigned to specific competition tasks. Camera 1 is mounted at the front of the ROV frame, angled approximately 15 degrees downward, and serves as the primary sensor for Task 2.1 (Crab Detection) and the navigation camera for Task 2.2 (Iceberg Survey). It streams 1080p video at 30 FPS via RTSP to the laptop for real-time YOLOv8n processing.

Camera 2 is mounted at the bottom of the ROV in a nadir orientation and is used for Task 1.2 (Photogrammetry) and Task 1.3 (Transect Video), recording continuous downward footage during the coral garden survey. Both cameras are powered entirely through the CAT6 tether via PoE, eliminating the need for separate power wiring, and are housed in waterproof acrylic tubes with clear dome ports.

Topside control is centered on the PS4 DualShock 4 controller, mapped to intuitive ROV movements: the left stick controls forward and lateral strafing, the right stick controls yaw, and the R2 and L2 triggers govern ascent and descent. R1 and L1 operate the gripper, the Triangle button engages depth hold PID, Square engages heading hold PID, and the Options button triggers an immediate emergency stop that cuts all thruster output.

A Python script reads controller inputs via the pygame library, computes PWM values for each of the five thrusters, and dispatches command JSON to the ESP32 via WebSocket



Aquaventures Company

5. Mission GUI Architecture

The unified Mission Control GUI integrates all task software into a single operator interface. It consists of:

- Flask Python backend — serves the HTML GUI, runs AI inference, reads camera streams, receives ESP32 telemetry via WebSocket.
- HTML/CSS/JS frontend — displays live camera feeds, ROV telemetry (pitch, yaw, roll, depth, gripper state), and task-specific interfaces in separate tabs.
- Task tabs — one tab per mission task, each with relevant controls and data display.
- ROV telemetry panel — always visible sidebar showing live IMU and sensor data from the ESP32.



Figure 7- GUI

C. Control System

- The Command Center, At the surface station, the primary interface consists of a dedicated Ground Control Station (GCS) laptop. Unlike standard graphical interfaces, our custom-developed dashboard serves as the mission's "Brain," processing real-time telemetry data including depth, orientation, and system vitals. This software handles the complex task of translating high-resolution analog inputs into discrete digital commands, which are then transmitted via the Cat6 umbilical to the ROV's onboard logic unit.
- Precision Human-Machine Interface (HMI), Physical control is executed through multi-axis precision joysticks, offering a professional-grade tactile experience for the pilot. The control mapping is strategically divided to manage the vehicle's 4 Degrees of Freedom (4 DOF):
- Primary Navigation: Manages longitudinal surge (forward/backward) and lateral sway (sideways movement).
- Integrated Feedback Loop, A defining feature of the Normandy_2 control suite is the seamless integration of visual and sensory feedback. The ESP32 processes pilot inputs with microsecond latency, generating PWM (Pulse Width Modulation) signals that provide smooth, proportional thrust across the six-bilge-pump array. This ensures that even the smallest joystick movement results in a predictable and stable response from the ROV, a level of control that is essential for high-stakes tasks like those performed at leading institutions such as Alpena Community College.



Figure 8-
PS4_Controller

3.3 Payload and Tools

A. Digital Camera System

To ensure high-definition situational awareness, the Normandy SR-2 is equipped with a specialized 2MP IP Digital Camera, specifically selected for its superior underwater imaging capabilities and network reliability. Unlike standard analog or USB-based systems, this IP camera provides a high-resolution, low-latency video feed that is essential for the precise navigation and intricate inspection tasks required in the 2026 MATE competition.

The camera features a native waterproof and pressure-rated housing, allowing it to be mounted externally on the ROV's hybrid frame. This design choice eliminates the need for additional bulky enclosures and minimizes the risk of internal heat buildup within the main electronics tray.



Figure 9-
Digital Camera

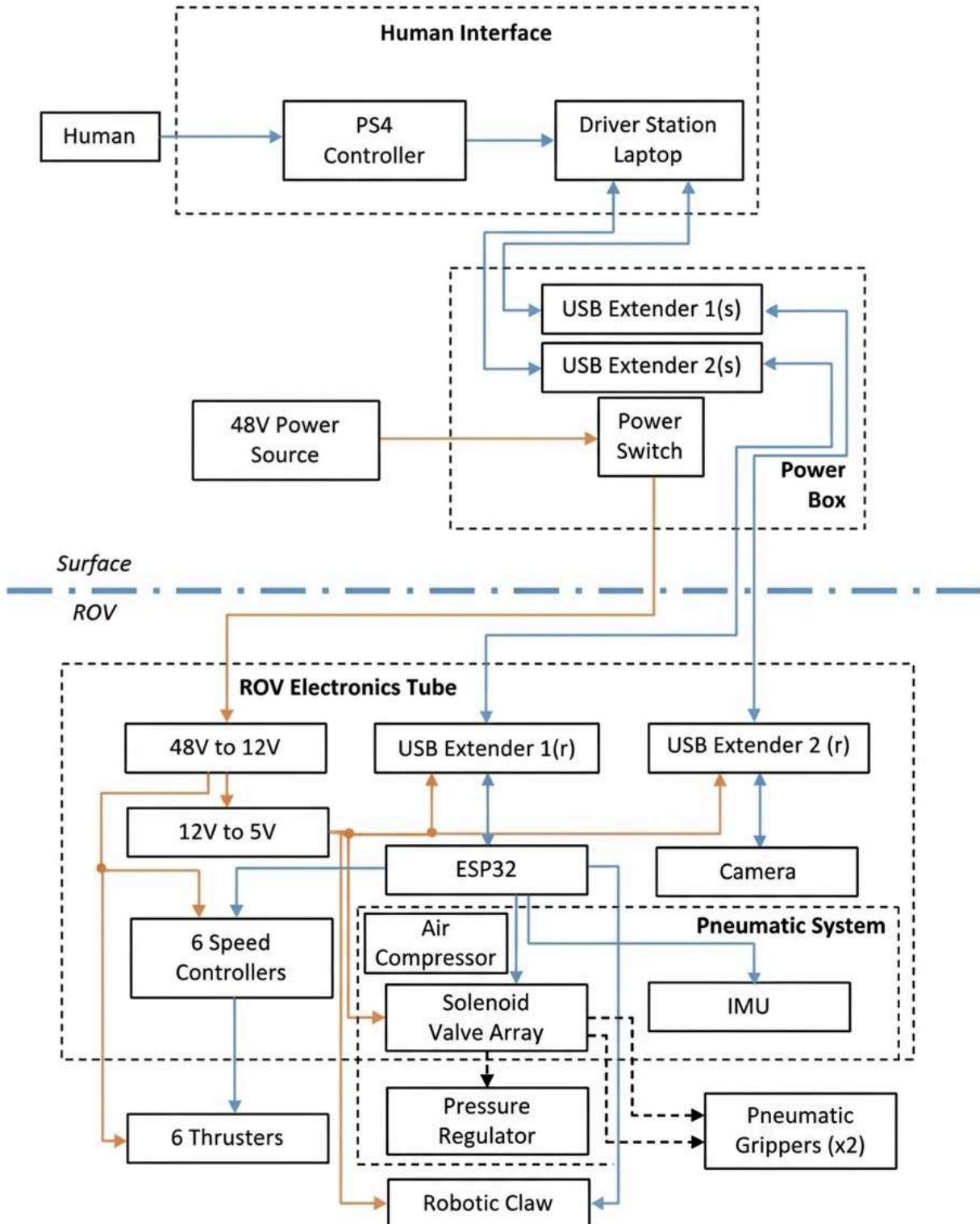
B. Retrieval Claw

The Normandy_2 features a specialized Dual-Axis Manipulator System, engineered for surgical precision in complex underwater recovery tasks. Moving beyond standard single-gripper designs, our platform incorporates two independent grippers—one horizontally and the other vertically oriented—to handle varied object geometries without the need for vehicle repositioning. Fabricated from corrosion-resistant materials and powered by the vehicle's regulated 12V power rail, each gripper utilizes high-torque, waterproofed actuators for proportional "Fine-Grained" control. This system is seamlessly integrated into the ESP32-based command architecture, allowing the pilot to actuate either gripper via dedicated joystick buttons with microsecond responsiveness. Supported by a macro-view HD camera feed, this dual-axis innovation ensures the Normandy_2 can execute high-stakes missions—from delicate environmental sampling to industrial debris removal—with professional-grade efficiency and reliability.



Figure 10-
Pneumatic Arm

6.SID





7.Safety

A. Safety Philosophy

At AquaVentures, safety is not just a requirement but a foundational engineering principle. Our Safety Officer meticulously ensures that the Normandy SR-2 adheres to all international and MATE-specific safety codes. This includes the rigorous verification of thruster shroud integrity, ensuring all propellers are properly guarded to prevent accidental contact. Furthermore, the tether system is equipped with a high-durability mesh covering and a robust strain relief mechanism at both the ROV and surface connection points.

B. Vehicle Safety Features

The Normandy_2 is engineered to comply with the highest safety standards, incorporating several built-in features to protect both the operators and the aquatic environment:

- **Thruster Protection:** All six thrusters are equipped with protective guards that strictly adhere to guidelines, preventing the ingress of objects or accidental finger contact.
- **Structural Safety:** The hybrid chassis—composed of PVC and sheet metal—undergoes a "deburring" process to ensure there are no sharp edges or points that could cause injury during deployment or recovery.
- **Tether Integrity:** Dual-point strain relief is implemented to protect the internal Cat6 and power conductors from mechanical stress, ensuring reliable communication and preventing electrical hazards underwater.



8. Conclusion

The development of the Normand_2 represents a significant engineering milestone for the AquaVentures team. By integrating advanced mechatronics principles—such as the 48V-to-12V power architecture, ESP32-based control logic, and a unique dual-axis manipulator system—we have engineered a robust, mission-capable ROV that balances industrial-grade durability with cost-effective innovation. Through rigorous testing and iterative design, our team has successfully demonstrated that a hybrid-frame vehicle can achieve high-precision maneuverability and operational reliability, meeting the demanding requirements of the 2026 MATE competition and beyond.

A. Acknowledgements

The AquaVentures team would like to express our deepest gratitude to the institutions and individuals whose support was instrumental in bringing the Normandy SR-2 to life.

- **Academic Support:** We extend our sincere thanks to the faculty of Benha University and Benha National University for providing the academic foundation and technical resources necessary for this graduation project. Their guidance throughout the 2025-2026 academic cycle has been invaluable.
- **Mentorship:** A special thanks to our project supervisors and mentors for their technical insights and for coaching us through the complex challenges of underwater robotics and control systems.

7. Company Structure & Job Description

