

Future University in Egypt

FUE Divers

MATE ROV Pioneer Class - Egypt 2026

Technical Report

Country: Egypt

Team Size: 18 members

Mentor: Dr. Amal Mahena

Team Organization

Electrical Team

Leader: Nouredin Bassem

Nouredin Bassem

Abraam Albert

Mohamed Ibrahim

Abdelrhman Fawzy

Mohamed Ashraf

Youssef Nabil

Faris Mohamed

Software Team

Leader: Omar Shaltoot

Omar Shaltoot

Abdallah Fathy

Ahmed Darwish

Mohamed Moataz

Youssef Elkhoully

Abdelrahman Sawan

Mechanical Team

Leader: Mostafa Ghaleb

Mostafa Ghaleb

Mohamed Walid

Youssef Atef

Contact Email: dalfathyoc@gmail.com

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Optimus
FUE Divers
MATE ROV 2026

Team Profile

Team Name: FUE Divers
Organization: Future University in Egypt (FUE)
Country: Egypt
Competition Class: Pioneer
Team Size: 18 members

Field	Details
Country	Egypt
Competition Class	Pioneer
Organization	Future University in Egypt (FUE)
Mentor(s)	Dr. Amal Mahena
Team Members	Noureldin Bassem, Abraam Albert, Mohamed Ibrahim, Abdelrhman Fawzy, Mohamed Ashraf, Youssef Nabil, Faris Mohamed, Mohamed Walid, Mostafa Ghaleb, Youssef Atef, Abdallah Mohamed, Omar Shaltoot, Youssef Amr, Youssef Elkhoully, Abdelrahman Sawan, Mohamed Moataz, Ahmed Darwish, Aly Maher
Contact Email	dalfathyoc@gmail.com

This technical documentation presents the engineering design, subsystem integration, and operational strategy of our Remotely Operated Vehicle (ROV), named **Optimus**.

1 Abstract

Optimus is a compact, cost-effective, and highly maneuverable Pioneer-Class ROV engineered by FUE Divers for the 2026 MATE ROV competition in Egypt. The vehicle features a lightweight PVC Schedule-40 space frame, dual Blue Robotics 6-inch watertight enclosures, and an innovative **bilge-pump-based propulsion system** that delivers reliable 5-DOF motion at a fraction of the cost of commercial thrusters.

High-definition USB cameras, green laser ranging, active buoyancy control, and a dual-computer architecture consisting of a Raspberry Pi 4 and ESP32 running **ROS (Robot Operating System)** enable precise navigation and real-time mission execution.

2 System Identification Diagram (SID) Electrical

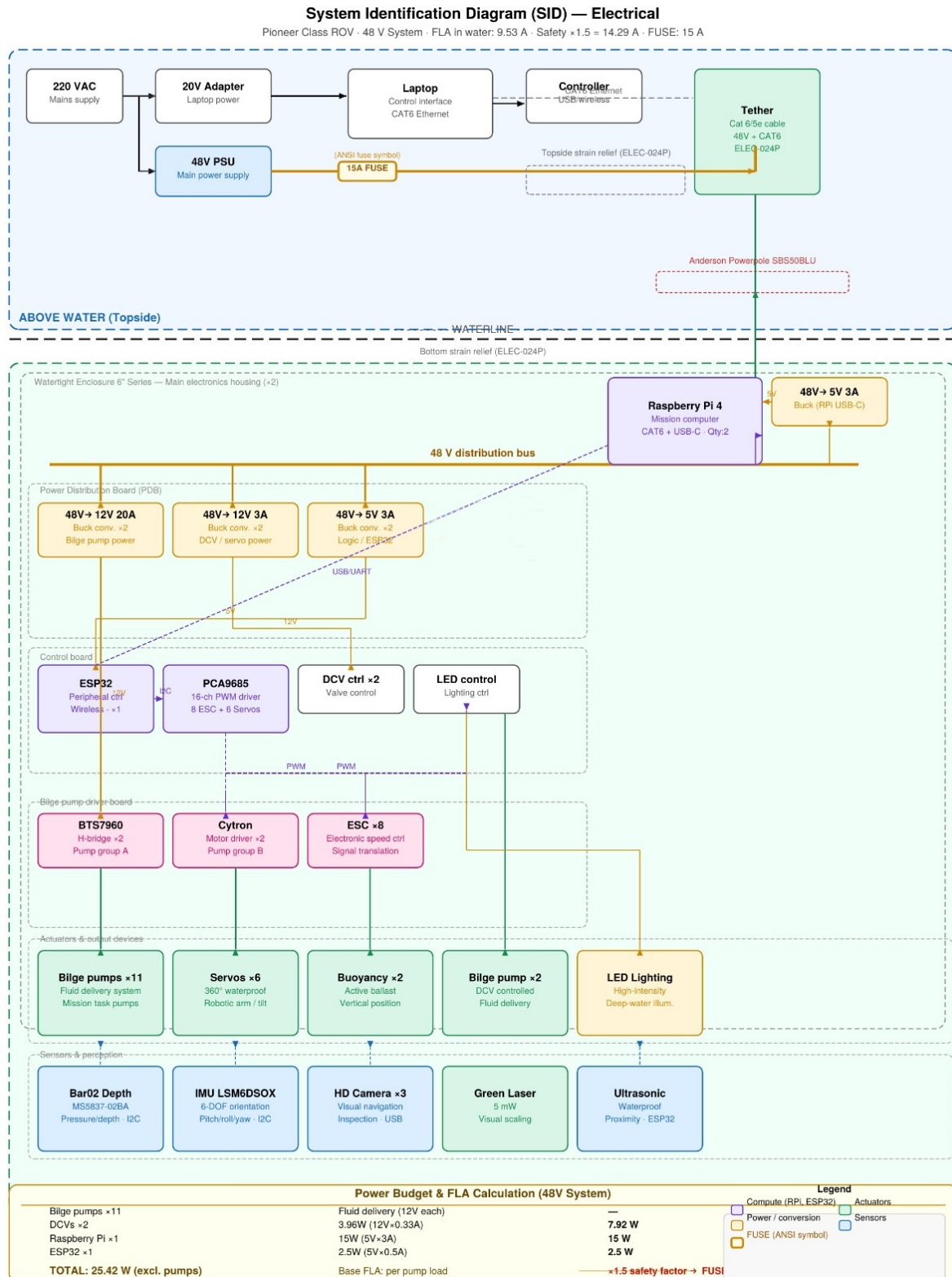


Figure 1: System Identification Diagram (SID) Electrical for ROV Optimus

3 ROV Design Philosophy & Primary Specifications

The ROV, designated as **Optimus**, is engineered as a compact and modular platform designed for high performance and ease of maintenance in dynamic underwater environments.

Design Goals

- Maneuverability: Stable and precise 5-DOF movement using bilge-pump propulsion.
- Waterproofing: Robust protection using dual 6-inch Blue Robotics enclosures.
- Control Architecture: Dual-computer system running ROS.
- Active Buoyancy: Integrated fluid-pump engines for precise vertical positioning.
- Navigation: Real-time HD video with green laser ranging.
- Power Protection: Redundant fusing for maximum reliability.

Key Specifications

Parameter	Value	Notes
Frame Material	PVC (Schedule 40)	Corrosion-resistant and inherently buoyant
Power Input	48 V DC	Delivered via tether from surface supply
Logic Voltage	5 V / 3.3 V	Buck-regulated on-board
Motor Voltage	12 V DC	Buck-regulated; 20 A per channel
Thruster Count	8	Managed via PCA9685 PWM driver
Servo Count	6	360° waterproof; for robotic arm and tilt
Main Camera	HD (1080p)	Primary navigation and inspection feed
Depth Sensor	Bar02 (MS5837-02BA)	± 2 mm resolution
IMU	LSM6DSOX (6-DOF)	Pitch, roll, and yaw stabilization
Tether	Cat 6/5e Ethernet	Combined data and power delivery
Depth Rating	< 100 m	Based on Blue Robotics O-ring sealed enclosures

4 Design Rationale & Innovations

Optimus was designed with simplicity, reliability, and cost-effectiveness as core principles. The team selected a PVC frame because it is corrosion-resistant, lightweight, easy to modify, and practical for fast maintenance. The most significant innovation is the **bilge-pump propulsion system**, which replaces more expensive commercial thrusters while still providing strong and controllable bidirectional thrust.

5 Mechanical Systems & Structural Integrity

5.1 Chassis and Frame

The ROV chassis is a space-frame structure constructed from PVC Schedule 40 pipe and fittings. This design offers a strong balance between low cost, easy replacement, mod-

ularity, and underwater durability. The open structure also improves access to internal subsystems during maintenance and testing.

5.2 Buoyancy and Trim Management

Buoyancy is managed using distributed buoyancy foam and careful placement of heavy electrical components at lower positions in the frame. This arrangement lowers the center of mass while keeping the center of buoyancy above it, increasing passive stability in the water.

Fine trim adjustments can be made by repositioning flotation material and balancing component placement across the frame.

5.3 Waterproofing Strategy

The main electronics are protected inside watertight enclosures that use O-ring seals and mechanically secured end caps. Cable penetrations are minimized and carefully sealed to reduce leakage risk. Before every water test, the team inspects seals, enclosure surfaces, and cable interfaces to verify integrity.

5.4 Propulsion System – Bilge Pump Implementation

Optimus achieves 5-DOF navigation using eight waterproof bilge pumps configured as custom thrusters. Each pump is paired with a 3D-printed coupler, T100-style propeller, and Kort nozzle to convert high-flow output into directed thrust.

Four horizontal pumps provide **surge**, **sway**, and **yaw**. Two vertical pumps provide **heave** and **pitch**. PWM signals generated by the ESP32 control pump speed via H-bridge drivers. The open-lattice PVC frame and low center of mass improve stability during aggressive maneuvers.

This approach significantly reduces cost while maintaining acceptable thrust and operational reliability for Pioneer-class tasks.

6 Electrical Architecture & Power Distribution

The electrical architecture is organized around a surface-supplied 48V power line distributed through the tether to the vehicle. On-board buck converters regulate this voltage for both logic and actuation subsystems. Sensitive electronics such as the Raspberry Pi, ESP32, and sensors operate from lower regulated voltages, while higher-current branches are allocated for motors and actuators.

Fuse protection is included across major branches to reduce the likelihood of catastrophic overcurrent failure. Connectors are selected and routed to simplify maintenance and reduce accidental miswiring.

7 Software Stack & Control Logic

7.1 High-Level Processing (Raspberry Pi 4)

The Raspberry Pi 4 runs **ROS (Robot Operating System)** as the core middleware. ROS enables a modular, multi-node architecture for camera streaming, computer vision, mission logic, and real-time H.264 video encoding.

This layer is responsible for operator feedback, mission sequencing, sensor integration, and higher-level control coordination.

7.2 Real-Time Control (ESP32)

The ESP32 handles low-latency tasks that require direct and responsive hardware interaction. These tasks include thruster signal output, servo control, fast sensor polling, and communication with the higher-level Raspberry Pi system.

Separating high-level logic from real-time actuation improves system responsiveness and makes debugging more manageable.

7.3 Navigation & Stability

Navigation is managed through a cascaded PID architecture implemented through ROS-connected control nodes. The outer loop maintains target depth using the Bar02 depth sensor, while the middle loop stabilizes vehicle orientation using the LSM6DSOX IMU.

This control structure helps the ROV maintain a stable heading and depth during task execution, especially when external disturbances or operator input create transient motion. The modular control design also allows tuning of individual loops without redesigning the full system.

8 Comprehensive Bill of Materials (BOM)

Item	Purpose	Quantity
Raspberry Pi 4	Primary mission computer for high-level tasks and video	2
ESP32 Microcontroller	Low-latency peripheral control and wireless interfacing	1
PCA9685 (16-Channel)	PWM driver for precise control of 8 ESCs and 6 servos	1
Depth Sensor (Bar02)	Pressure-based depth tracking and positioning	1
IMU Sensor (LSM6DSOX)	6-DOF orientation for stability	1
Green Laser (5 mW)	Visual scaling and distance measurement	2
Camera (HD)	Primary navigation and inspection feed	1
LED Lighting	High-intensity illumination for deep-water tasks	1
Ultrasonic Waterproof Sensor	Obstacle detection	1
Electronic Speed Controllers (ESC)	Signal translation for high-torque motor control	8
Waterproof Servo (360°)	Continuous rotation for robotic arms or tilt mechanisms	6
Buoyancy Engine	Active ballast control for vertical positioning	2
Bilge Pump	Fluid delivery system for propulsion / mission tasks	11
Power Supply (48V)	Main surface power source via tether	1
AGM / NiMH Batteries (12V / 9V)	Onboard auxiliary and backup power storage	Assorted
Buck Converter (48V to 12V, 20A)	High-current regulation for thrusters and pumps	8
Buck Converter (48V to 5V, 3A)	Logic-level power for Pi, ESP32, and sensors	8
PDB (Power Distribution Board)	Centralized routing for high and low voltage rails	1
Anderson Powerpole (SB50BLU)	Polarized main power connector	1
Tether Cable (Cat 6/5e)	Combined data transmission and power delivery line	1
Littelfuse Jcase (20A–30A)	Main circuit overcurrent protection	20
Blade Fuses (ATO/Mini)	Secondary protection for individual sub-circuits	10
Watertight Enclosure (6" Series)	Main atmospheric pressure housing for electronics	2
Watertight Enclosure (Small)	Housing for auxiliary sensors or battery isolation	1
O-Rings (Dynamic and Static Seals)	Waterproof sealing	20
PVC Frame	Structural chassis of the ROV	1
Buoyancy Foam / Syntactic Foam	Neutral buoyancy calibration	Assorted
Velcro / Insulation Materials	Cable management and thermal/electrical protection	Assorted

9 Safety Protocols & Risk Mitigation

The team follows a layered safety strategy covering electrical, mechanical, and operational hazards. Main power branches are fused, connectors are polarity-conscious, and all major systems are visually inspected before deployment. Rotating components are tested in controlled conditions, and the team uses a pre-operation checklist before every run.

Mechanical lifting is performed by multiple team members where required, and wet-area operation is managed carefully to reduce slip and electrical risks.

10 Testing, Validation & Mission Strategy

Testing is carried out in phases, beginning with dry electrical validation and subsystem checks, followed by controlled shallow-water trials. Individual subsystems such as propulsion, camera feed, sensor response, and stability control are tested independently before full mission integration.

The mission strategy prioritizes:

- fast deployment and recovery,
- stable navigation,
- simple operator control,
- and modular troubleshooting between runs.

11 Conclusion

The **Optimus** ROV represents a practical integration of dual-computer control, ROS-based software, active buoyancy management, and a cost-effective bilge-pump propulsion system. Our team of 18 students from Future University in Egypt, under the guidance of Dr. Amal Mahena, is prepared to demonstrate engineering capability and structured design execution in the 2026 MATE ROV Pioneer Class competition in Egypt.

12 Job Safety and Environment Analysis (JSEA)

FUE Divers

MATE ROV Pioneer Class

Team Members:

Noureldin Bassem, Abraam Albert, Mohamed Ibrahim, Mohamed Ashraf, Youssef Nabil, Faris Mohamed, Mostafa Ghaleb, Youssef Atef, Abdallah Mohamed, Youssef Amr, Youssef Elkhoully, Abdelrahman Sawan, Abdelrhman Fawzy, Mohamed Walid, Omar Shaltoot, Mohamed Moataz, Ahmed Darwish, Aly Maher.

12.1 Overview

This document provides a structured Job Safety and Environment Analysis (JSEA) for deck operations of the ROV system. It focuses on hazard identification, risk evaluation, and mitigation strategies during setup, operation, and shutdown phases.

12.2 Risk Assessment Methodology

A simplified Failure Mode and Effects Analysis (FMEA) approach is used:

- Severity (S): Impact level (1–10)
- Likelihood (L): Probability of occurrence (1–10)
- Detection (D): Ability to detect hazard before failure (1–10)

Risk Priority Number:

$$RPN = S \times L \times D$$

RPN Range	Action
190+	Immediate stop
140–189	Corrective action required
50–139	Monitor
< 50	Acceptable

12.3 Required Protective Equipment

- Non-slip shoes
- Electrical insulated gloves
- Safety goggles
- Lab-safe clothing (no loose items)

12.4 JSEA Task Analysis

12.4.1 1. Transportation and Setup

Task	Hazard	S L D	RPN	Control Measures	Responsible
Transport ROV	Back injury	7 5 3	105	Team lifting, proper posture	Team
	Dropping equipment	6 4 3	72	Secure grip, clear path	Team
Setup wiring	Loose wires	6 5 4	120	Cable management, inspection	Electrical
Power setup	Wrong polarity	8 4 4	128	Verify polarity before power	Electrical

12.4.2 2. Operation Phase

Task	Hazard	S L D	RPN	Control Measures	Responsible
Tether handling	Tether tangling / tripping hazard	6 3 8	144	Continuous monitoring, keep tether organized	Tether manager / Team
Manipulator use	Electrical failure / finger injury	6 6 3	108	Pre-check systems, clear communication	Electrical / Operator
ROV operation	Water interaction / slipping hazard	9 4 5	180	Stable stance, awareness, dry working zone	Team

12.4.3 3. Electrical and Mechanical Systems

Task	Hazard	S L D	RPN	Control Measures	Responsible
Battery connection	Overcurrent	9 4 4	144	Use fuse protection	Electrical
	Electrical shock risk	10 3 4	120	Insulated connectors	Electrical
Thruster testing	Entanglement	8 3 3	72	No loose clothing, safe distance	Team
Pressure systems	Leakage	8 5 4	160	Check seals and valves	Mechanical

12.4.4 4. Shutdown and Recovery

Task	Hazard	S L D	RPN	Control Measures	Responsible
Power shutdown	Electrical damage	7 4 3	84	Power off before disconnect	Electrical
ROV retrieval	Back injury	7 5 3	105	Proper lifting	Team
Packing	Equipment damage	5 4 3	60	Organized storage	Team

12.5 Equipment Check-Off Sheet (ECOS)

- Control box
- Power supply and connectors
- Tether properly wrapped
- ROV frame and tools
- Laptop / monitoring system

12.6 Safety Check-Off Sheet (SCOS)

- No exposed wires
- All components secured
- No sharp edges
- Thrusters protected
- Electrical connections verified

12.7 Environmental Considerations

- Prevent water contact with electrical systems

- Maintain dry working area
- Dispose of damaged components safely

12.8 Operational Flow Summary

1. Equipment unloading
2. System setup and checks
3. Dry testing
4. Deployment and operation
5. Retrieval and shutdown

13 Non-ROV Device Design

Company Name: Future University in Egypt
Team Name: FUE Divers
Class: Pioneer

2026 MATE ROV Competition

Non-ROV Device Design

Pioneer Class National Competition (Egypt)

13.1 Overview

Our company designed a compact vertical profiling float to serve as the team's non-ROV device for the 2026 MATE ROV Pioneer competition. The main objective of the device is to independently descend, record depth-related data, maintain stable orientation during motion, and return to the surface safely using an onboard buoyancy-control mechanism.

The design was developed to follow the MATE non-ROV device safety restrictions for Pioneer class. The system uses onboard 12V battery power only, contains no camera, and is built around a small embedded controller with protected internal wiring and fused power distribution.

13.2 Mechanical Design

The non-ROV device is built as a sealed cylindrical float inside a watertight enclosure. The enclosure protects the control electronics and battery while keeping the overall structure compact and easy to inspect. Dynamic and static O-rings are used at the sealing interfaces to maintain waterproofing.

The float uses a buoyancy engine to change its effective displacement and vertical motion in water. The buoyancy system is based on a small internal pumping arrangement using a bilge pump and controlled ballast volume. By moving water into or out of the ballast section, the float can increase its density to descend and decrease its density to ascend.

To improve stability, buoyancy foam is placed on the upper section of the structure so the center of buoyancy remains above the center of mass. This helps the device remain upright during vertical movement. A lightweight PVC structural frame supports the internal modules and keeps the enclosure layout organized.

13.2.1 Mechanical Features

- Cylindrical watertight main enclosure
- PVC support frame for internal mounting
- O-ring based sealing for pressure resistance and waterproofing
- Syntactic / neutral buoyancy foam for trim and stability
- Internal ballast buoyancy engine for controlled ascent and descent

13.3 Electrical Design

The electrical system is centered around an ESP32 microcontroller. The ESP32 handles sensor acquisition, buoyancy control logic, timing, and status monitoring. It was selected because of its compact size, low power consumption, and sufficient processing capability for a float-type mission system.

The main sensing element is the Bar02 depth sensor, which provides pressure-based depth measurements for tracking the float's vertical position in water. An IMU sensor is also included to monitor pitch and roll so the float can verify that it remains reasonably upright throughout operation.

The float is powered using an onboard 12V AGM/NiMH battery, which complies with the competition requirement for non-ROV devices to use onboard low-voltage power only. A buck converter (12V to 5V) supplies regulated power to the ESP32 and sensor electronics. A main blade fuse is installed close to the battery positive terminal to provide full-system overcurrent protection.

The design intentionally excludes components from the main ROV system that are not suitable for the non-ROV device, such as:

- Surface 48V power supply
- Tethered power delivery
- Cameras
- Raspberry Pi mission computers
- Thrusters and high-power ESC-based propulsion

13.3.1 Electrical Architecture

1. 12V onboard battery supplies the main power line.
2. A 5A blade fuse is installed on the positive battery line near the battery terminal.
3. The 12V line powers the buoyancy actuator / pump subsystem.
4. A buck converter steps 12V down to 5V for the ESP32 and sensors.
5. The ESP32 reads the depth sensor and IMU, then commands the buoyancy system according to the mission logic.

13.4 Power Calculations

Based on the selected non-ROV subsystem components, the float remains within the allowed 12V maximum power requirement for onboard operation.

Table 1: Estimated Non-ROV Device Power Consumption

Component	Voltage	Estimated Current	Estimated Power
ESP32 Microcontroller	5V	0.24A	1.2W
Depth Sensor (Bar02)	5V	0.03A	0.15W
IMU Sensor	5V	0.02A	0.10W
Buoyancy Pump / Actuator	12V	1.80A	21.6W
Buck Converter Loss Margin	12V	0.10A	1.2W
Total Estimated Load			24.25W

For a 12V supply, the estimated full-load current is:

$$I = \frac{P}{V} = \frac{24.25}{12} \approx 2.02A$$

Applying a safety margin for startup and transient load:

$$2.02 \times 1.5 \approx 3.03A$$

Therefore, a 5A blade fuse is selected. This remains within the MATE limit and provides suitable protection while preventing nuisance fuse blowing during motor startup.

13.5 Safety and Rule Compliance

The float was designed around the requirements listed in the MATE non-ROV device safety sheet.

Table 2: Compliance Summary

Requirement	Implementation	Status
Max 12VDC power, 5A max	Float uses onboard 12V battery system with protected 5A fuse	Compliant
No surface power for non-ROV device	Device is fully battery powered and untethered during operation	Compliant
No camera allowed	No camera is installed on the float	Compliant
Battery must be secured	Battery is mounted inside enclosure using internal supports / straps	Compliant
Single fuse for full shutdown	Main fuse installed on positive supply line	Compliant
Fuse near battery positive terminal	Main fuse positioned close to battery terminal in accessible holder	Compliant
Fuses must be inspectable	Blade fuse used in visible accessible holder	Compliant
Pressure release requirement	Enclosure is designed to release / open safely in case of internal overpressure	Compliant

13.5.1 Additional Safety Measures

- All wiring is insulated and routed away from moving parts.
- Low-voltage electronics are separated from the pump power line where possible.
- Connectors are mechanically secured to reduce accidental disconnection.
- The enclosure is opened and inspected before deployment to verify fuse condition, battery mounting, and seal integrity.
- Waterproof seals and enclosure interfaces are checked before every water test.

13.6 Selected Parts Used for the Non-ROV Device

The following items were selected from the team parts inventory because they are relevant to the non-ROV float:

Table 3: Non-ROV Device Bill of Materials

Item	Purpose in Non-ROV Device	Qty
ESP32 Microcontroller	Main embedded controller for logic, sensing, and control	1
Depth Sensor (Bar02 / pressure sensor)	Measures pressure and estimates float depth	1
IMU Sensor	Monitors orientation and stability	1
AGM / NiMH Battery (12V)	Onboard power source for the float	1
Buck Converter (12V to 5V)	Regulated supply for controller and sensors	1
Blade Fuse + Holder	Main overcurrent protection	1
Watertight Enclosure	Main pressure-resistant electronics housing	1
O-Rings Dynamic and Static Seals	Waterproof sealing for enclosure interfaces	Assorted
Buoyancy Foam / Syntactic Foam	Trim adjustment and upright stability	Assorted
Bilge Pump	Water transfer for buoyancy control	1
PVC Structural Elements	Internal mounting and external support frame	Assorted

13.7 System Operation

Before deployment, the float is powered on and initialized. The ESP32 checks the sensor status and confirms that the battery voltage is within the operating range. Once released into the water, the float records pressure and orientation data while controlling the buoyancy engine.

To descend, the float increases its effective weight by admitting water into the ballast section. To ascend, the system expels water and restores positive buoyancy. Throughout operation, the controller continuously reads the depth sensor and IMU to ensure stable profiling behavior. After surfacing, the device can be retrieved manually and the recorded data can be reviewed by the team.

13.8 System Identification Diagram (SID)

Figure 8 shows the electrical System Identification Diagram (SID) for the overall Pioneer-class system. The diagram presents the surface power path, tether connection, onboard power conversion, control electronics, actuation chain, and sensor integration. It is included here as a reference image for the team's implemented electrical architecture.

[Insert SID Diagram Figure 8 here]