



LEOPARD FLOAT NON-ROV DEVICE

The Wentworth Institute of Technology Remote Operated Vehicle (WITROV) team has designed the **Leopard float** (Figure 1) to be used in tasks to perform two vertical profiles of an underwater, cold, and hazardous environment semi-autonomously. The device communicates the sampled depth data during its submerged time underwater with the surface station when it surfaces.

The float consists of one large waterproof container that consists of the electronic unit and the buoyancy engine. Ten series connected **NiMh AA Batteries** are used to power the **NEMA 17** stepper motor and the **ESP32** microcontroller. Within 5cm of this 12 V battery pack (Figure 2) is a 1A ATO fuse protecting the electronics and nearby lifeforms in the case of a short. When surfacing, the float automatically opens a wireless communication with the mission station using **TCP** (Transmission Control Protocol) communication protocol by sending **XML** (Extensible Markup Language) packets.zx1`

The clear plastic housing allows for **fast visual inspection** of the inline fuses and the water intake levels. The motor rotation moves a lead screw that enable and disables the buoyancy engine. This engine changes the buoyancy of the float by intaking and expelling water from its surroundings with a **150 mL syringe**. Weights are added on the bottom compartment to shift the center of mass towards bottom end cap for keeping the float angled vertically in the water. The **O-ring end caps** at both ends of the device ensure safety in the case of high pressures.

LEOPARD BREAKDOWN

1. 801NYUB Ultrasonic
2. Bar02 Pressure Sensor
3. Air Pressure Valve
4. On/off switch
5. Battery Pack
6. Electronics Unit (fuse location)
7. NEMA 17 Motor
8. Syringe
9. O-Ring End Caps

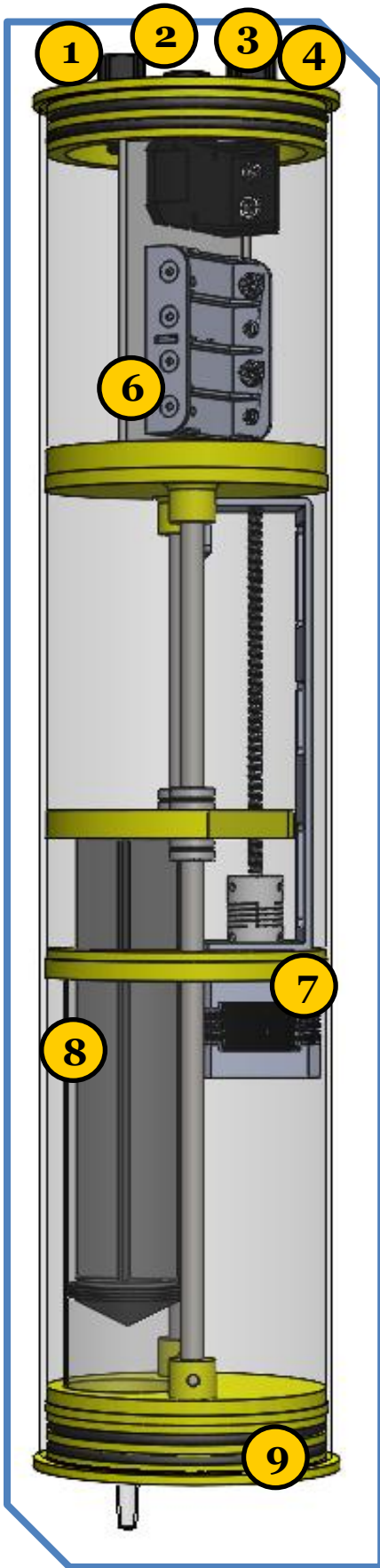


Figure 1. Leopard Float



Figure 2. 12 V Battery Pack

Full Load Amps (FLA):
Waiting Mode = 230.1 mA
Full Load = 576.7 mA
Fuze Size Selected = 1 A

2. Mechanical Design

2.1 Structural Design

The Leopard Float is designed around a vertically oriented cylindrical pressure housing that provides both waterproofing and structural rigidity. The clear acrylic tube allows operators to visually inspect internal components, including the fuse system, wiring, and water intake levels, without disassembling the device. This significantly improves troubleshooting efficiency and reduces maintenance time during field operations.

The float uses two O-ring sealed end caps to maintain watertight integrity under pressure. The upper compartment contains the electronics system and pressure sensors, while the lower section houses the buoyancy engine and ballast weights. This arrangement shifts the center of mass downward, improving vertical stability while submerged.

Internal mounting plates manufactured from lightweight materials secure the electronics and motor assemblies. The tethering and deployment structure is integrated directly into the lower cap assembly to ensure stable handling during launch and recovery.

2.2 Buoyancy Engine

The buoyancy control system is based on a syringe-driven variable ballast mechanism. A NEMA 17 stepper motor rotates a lead screw connected to a 150 mL syringe. By extending or retracting the syringe plunger, the float intakes or expels surrounding water, changing the overall buoyancy of the system.

This mechanism allows the float to perform controlled ascent and descent operations without requiring external propulsion systems. The use of a lead screw provides precise displacement control and prevents passive back-driving caused by water pressure.

The buoyancy engine was selected due to its:

- Low mechanical complexity
- High positional accuracy
- Reliable operation underwater
- Low power consumption
- Ease of maintenance

2.3 Materials

Component	Material
Main Housing	Clear Acrylic Tube

Component	Material
End Caps	Aluminum / 3D Printed Polymer
Internal Mounts	PLA / PETG
Seals	Rubber O-rings
Fasteners	Stainless Steel

Corrosion-resistant materials were selected to ensure long-term reliability in underwater environments.

3. Electrical System

3.1 Power System

The Leopard Float is powered using ten series-connected NiMH AA batteries producing approximately 12 V. This battery configuration was selected because of its:

- High availability
- Rechargeability
- Stable discharge characteristics
- Improved safety compared to lithium-based batteries

A 1 A inline automotive fuse is positioned near the battery pack to protect electronics and nearby systems from electrical shorts or excessive current draw.

Measured current consumption values are:

- Idle / Waiting Mode: 230.1 mA
- Full Load Operation: 576.7 mA

The power system is capable of supporting extended deployment durations while maintaining safe operating temperatures.

3.2 Electronics

The primary onboard controller is an ESP32 microcontroller responsible for:

- Sensor acquisition
- Motor control
- Communication management
- Mission state handling

The float includes the following sensors and electronics:

- Bar02 pressure sensor for depth measurement
- Ultrasonic sensor for surface detection
- Air pressure valve control system

- Wireless communication module
- Stepper motor driver

The electronics assembly is mounted above the buoyancy engine to reduce exposure to water intrusion risks.

4. Communication System

4.1 Surface Communication

When the float surfaces, the ESP32 automatically establishes a wireless TCP connection with the surface station. Sensor readings and mission telemetry are transmitted using XML packets.

This communication system enables operators to:

- Monitor sampled depth data
- Verify mission completion
- Retrieve diagnostic information
- Confirm float location and status

TCP communication was selected because of its reliability and packet integrity verification.

4.2 Data Handling

The float continuously monitors internal sensor values during operation. Critical telemetry includes:

- Depth measurements
- Internal pressure
- Battery status
- Mission timing
- Motor operation state

Once surfaced, the collected data is transmitted to the surface station for analysis and logging.

5. Depth Control System

The Leopard Float uses a closed-loop PID control system to regulate its underwater depth autonomously. The control system continuously compares the measured depth from the Bar02 pressure sensor with the target depth specified by the mission profile.

The depth error is calculated as:

$$e(t) = d_{target} - d_{current}$$

Where:

- d_{target} is the desired depth
- $d_{current}$ is the measured depth
- $e(t)$ is the depth error

The PID controller computes a correction value based on proportional, integral, and derivative terms:

$$u(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{de(t)}{dt}$$

The controller output determines the number of motor rotations required to actuate the syringe-based buoyancy engine. Positive output commands intake of water to increase negative buoyancy and descend, while negative output expels water to increase positive buoyancy and ascend.

The lead screw mechanism converts motor rotation into precise linear displacement of the syringe plunger, enabling accurate buoyancy adjustment and stable depth regulation.

The PID system improves:

- Depth holding accuracy
- Stability during ascent and descent
- Resistance to external disturbances
- Repeatability of profiling missions

Controller gains were experimentally tuned through pool testing to minimize oscillation and overshoot while maintaining responsive depth transitions.

6. Stability and Buoyancy Analysis

The float is designed to maintain a vertically stable orientation underwater. Stability is achieved by positioning ballast weights near the bottom end cap while maintaining buoyant air volume near the top section.

The buoyancy system operates according to Archimedes' Principle:

$$F_b = \rho g V$$

Where:

- F_b is the buoyant force
- ρ is the density of water
- g is gravitational acceleration
- V is the displaced water volume

The syringe-based buoyancy engine adjusts the displaced volume by controlling the amount of water inside the float. This allows the Leopard Float to transition between positive and negative buoyancy states during operation.

7. Safety Features

Safety was a major consideration throughout the design process.

Implemented safety features include:

- Inline fuse protection
- Waterproof O-ring seals
- Corrosion-resistant materials
- Low-voltage electrical system
- Clear housing for rapid inspection
- Secure internal mounting structures
- Stable center-of-mass distribution

The transparent housing also allows operators to quickly identify water intrusion or electrical issues before deployment.

8. Testing and Validation

8.1 Waterproof Testing

The pressure housing underwent repeated leak testing to verify O-ring sealing effectiveness and cable waterproofing integrity.

8.2 Buoyancy Testing

Pool testing was conducted to validate:

- Controlled ascent and descent
- Vertical stability
- Buoyancy engine repeatability
- Ballast placement effectiveness

The float successfully maintained stable vertical orientation during submerged operation.

8.3 Electrical Testing

Electrical testing included:

- Current draw measurements
- Fuse validation
- Battery endurance testing
- Wireless communication verification

All electronics operated within expected current limits during testing.

9. Future Improvements

Potential future improvements include:

- Higher-capacity battery systems
 - Improved pressure resistance
 - Closed-loop depth PID control
 - Additional environmental sensors
 - Reduced overall weight
 - Improved wireless communication range
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10. Conclusion

The Leopard Float provides a compact and reliable semi-autonomous underwater profiling platform capable of controlled buoyancy operation and wireless telemetry transmission. The combination of a syringe-based buoyancy engine, ESP32 control system, and waterproof pressure housing enables stable underwater profiling in hazardous aquatic environments. The modular design also allows future upgrades and continued development for advanced mission capabilities.