

TECHNICAL DOCUMENTATION

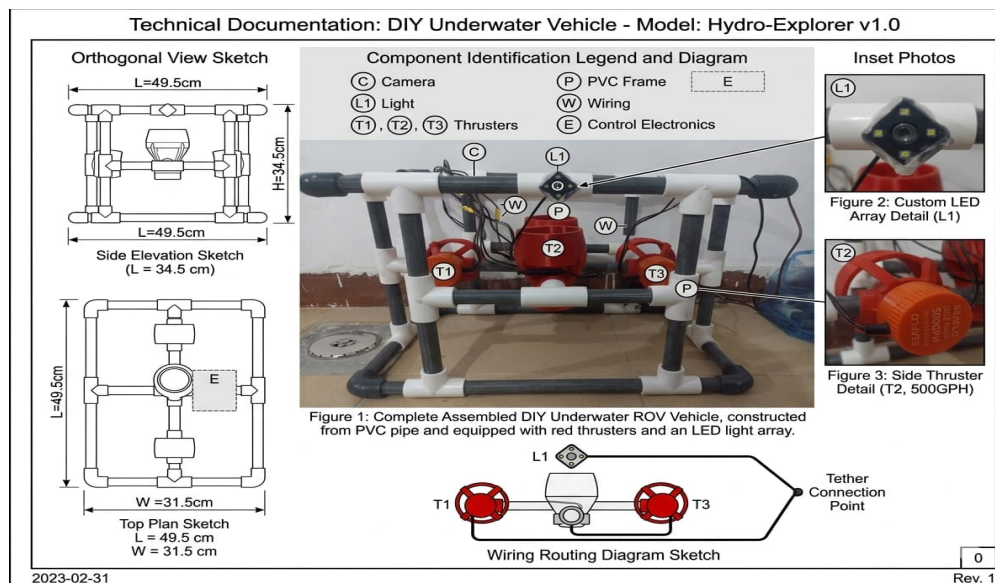
Triamisu Navigator

Ohmies, STEM Alex school (Borg el Arab, Alexandria, Egypt)

CEO: Dai, Zeina. **Mechanical:** Abdullah, Ahmed, Yassin. **Electrical:** Jana, Retaj. **Software:** Mohamed, Mohab. **Safety:** Alaa, Marwan. **Documentation:** Farida, Fatma

Abstract This paper presents the design and development of a cost-effective ROV intended for marine environmental protection tasks. The three-platform structure provides central stability: the upper part houses the camera for gripper control, the middle part contains the thrusters, and the lower part positions the gripper for proficiency. Custom 3D-printed X-connectors serve as an alternative to traditional PVC fittings, combining four connectors into one while distributing thrust force equally to reduce loss. These connect to 3D-printed motor holders that secure bilge pumps and prevent vibration. Custom propellers were designed in-house with safety considerations. To reduce cost, commercially waterproofed servos were replaced with an MG995 servo sealed using silicone, marine epoxy, and a rubber boot. All features were water-tested for performance, safety, self-stability, and manual controllability, demonstrating that these design innovations provide a lower-cost solution to help protect marine life.

Images



Acknowledgements and References

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Teamwork

Project Management

Company Overview

Ohmies is a student-led robotics team applying engineering principles to solve real-world problems through electronics, embedded systems, and mechanical design. We value creativity, problem-solving, and continuous improvement from concept to deployment.

Team Members

Role	Name(s)
CEO	Dai Mohamed Taher Metwally, Zeina Sameh Mohamed Kelany
Mechanical	Abdullah Mostafa Fathy Abo-Zaid, Ahmed Bassem Ahmed Khedr, Yassin Adel Mahmoud Gaber
Electrical	Jana Ibrahim Salah Radwan, Retaj Mohamed Mohamed Hassan
Software	Mohamed Ayman Abd El-Fttah Shaaban, Mohab Raafat Abdelrahman Mohamed
Safety	Alaa Mohamed Mohamed Raafat, Marwan Yasser Mohamed Ismael
Documentation	Farida Hamdy Fouaad Elakhriy, Fatma Hamdy Fouaad Elakhriy

Phase	Duration
Research & Design	1 week
Material Sourcing	3 days
Fabrication	1 week
Electronics & Programming	1 week
Waterproofing	3 days
Testing & Iteration	1 week
Documentation	Ongoing

Resource Management

We assigned clear roles, held weekly meetings to track progress, and used a shared digital folder for design files, code, and test data. Problems like servo failure and propeller issues were solved systematically: identify, research, fix, retest. This kept us on schedule and delivered a reliable ROV.

Design Rationale

Step-by-Step Planning & Design Process

We analyzed the MATE Navigator missions and split the ROV into three floors. Floor 1 holds the camera and buoyancy foam. Floor 2 contains four thrusters. Floor 3 carries the gripper. The frame is built from ½-inch PVC pipes with T-connectors and elbows. Each floor was tested separately: the camera in a water box, the thrusters with custom propellers, and the gripper with the waterproofed servo.

How Ideas Were Selected

The three-floor design puts the camera on top for clear vision, thrusters in the middle for balanced propulsion, and the gripper at the bottom for easy access to objects. Length was set to 49 cm to improve torque and stability. Mounting all thrusters in the middle floor keeps thrust aligned with the center of gravity. Buoyancy foam placed on the top floor ensures the center of buoyancy stays above the center of gravity, making the ROV self-righting.

Science Behind the Tasks

For buoyancy, we applied Archimedes' Principle. The ROV weighs 4.5 kg, so we calculated foam volume to achieve near-neutral buoyancy. For thrust, we used four 500 GPH bilge pumps: two horizontal for forward, backward, and turning, and two vertical for ascending and descending. This gives full four-directional control. The gripper is a 2-degree-of-freedom mechanism powered by an MG995 servo. We waterproofed it in-house using silicone coating, marine-grade epoxy, a rubber boot, and heat shrink.

Cost and Size Rationale

We built as much as possible in-house. The gripper mechanism was purchased, then modified and waterproofed by the team. The propellers were custom 3D-printed, and the PVC frame was built with standard hardware store parts. We purchased the ESP32, L298N motor drivers, and bilge pumps for reliability. The final dimensions are 49 cm in length, 33 cm in width, and 26 cm in height, with a total weight of 4.5 kg. Every choice balanced performance, cost, and reliability.

Innovation

1. The design depends on Three-floor modular structure, which are camera (top), thrusters (middle), and gripper (bottom) for balance and easy maintenance.
 2. Custom 3D-printed X-connectors for a stronger frame joint than the standard PVC fittings, while minimizing the required space. Furthermore, it decreases the loss of thrust force in the bilge pumps.
 3. Custom 3D-printed motor holders to secure bilge pumps and prevent vibration during operation.
 4. Custom 3D-printed propellers designed in-house and improved through iterative testing until efficient performance was achieved.
 5. Mechanical servo waterproofing (MG995 servo) sealed using silicone coating, marine epoxy, and rubber boot, as an alternative to purchasing commercially waterproofed servos.
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Problem Solving

We started every design challenge with team brainstorming sessions, then verified solutions using test data and past trial results.

The servo failure was our first real wake-up call. We bought a standard MG995, assumed it would survive underwater, and watched it die in minutes during our first in-water test. It just stopped responding. We had two choices: drain our budget on a pre waterproofed servo, or engineer a solution ourselves. We chose the second and spent days sealing every possible entry point. We applied silicone coating on the circuit board, sealed all external seams with marine grade epoxy, added a rubber boot over the output

shaft, and wrapped every wire entry point with heat shrink. When we retested it in the water box and it worked, we proved we did not need expensive parts to solve hard problems.

Then came the propellers. We designed them from scratch, printed them with high hopes, and watched them struggle in the pool. The material was too weak. They flexed under load and barely moved water. Instead of trashing the idea, we treated it as a design iteration. We ran multiple trials with different filaments, adjusted the geometry, and documented every failure. After several rounds, we finally got propellers that delivered real thrust. That process taught us that failure is only useful if you learn from it.

Every decision we made was based on what actually happened underwater, not what we hoped would happen. Every failed part became a lesson. Every successful fix became part of the final design. That mindset turned a rough prototype into a competition ready ROV.

Vehicle Systems

Aspect Description

Component & Material Selection The frame was built using PVC pipes (½ inch) for lightweight durability and ease of modification. Expanding foam was used for buoyancy. Electronics were selected based on availability, power requirements, and cost: ESP32 for control, L298N drivers for motors, and SFBP1-G500-01 bilge pumps as thrusters.

Design Evolution for Mission Requirements Early sketches evolved into a three-floor modular structure to physically separate the camera (Floor 1), thrusters (Floor 2), and gripper (Floor 3). This improved weight distribution, accessibility, and task-specific performance.

Thruster Number & Placement We used 4 bilge pump thrusters, arranged as: 2 horizontal for forward/backward and turning, and 2 vertical for depth control. This configuration balanced simplicity with adequate maneuverability for Navigator-class tasks.

Buoyancy Control Buoyancy was achieved using expanding foam placed on Floor 1, above the center of mass. This creates a righting moment, keeping the ROV stable and upright underwater. The foam volume was calculated to achieve near-neutral buoyancy, reducing strain on vertical thrusters.

Payload and Tools

Aspect Description

Mission-Driven Tool Design The gripper was designed specifically for Navigator tasks requiring object manipulation. It is a 2 DOF aluminum gripper, powered by an MG995 servo (mechanically proofed for waterproofing). The gripper opens and closes reliably underwater, as shown in testing documentation.

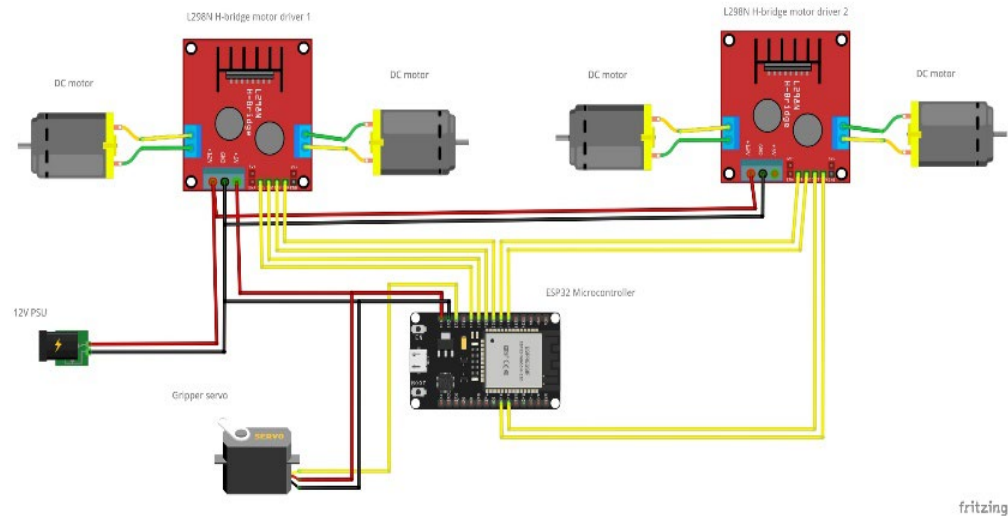
Build vs. Buy Decisions We chose to build in-house whenever possible to reduce cost and gain technical experience. The gripper mechanism, propeller design, and ROV structure were all custom-built. Pre-built items like the ESP32, L298N drivers, and bilge pumps were purchased because they are more reliable and cost-effective than attempting to build equivalent electronics from scratch.

New vs. Reused Components Most components are new and purchased for this competition to ensure reliability. The PVC frame materials and some connectors were reused from previous team stock after inspection to confirm they meet this year's requirements. This balanced cost savings with performance assurance.

Build vs. Buy, New vs. Used

Component	Build / Buy	New / Reused	Reason
PVC Pipes	Build	New	Strong, cheap, easy to modify
Thrusters (Bilge Pumps)	Buy	New	Reliable, cost-effective, readily available
PVC Connectors	Buy	New	Strong, readily available
Gripper Mechanism	Buy	New	Custom-designed for mission tasks
Servo motor(MG995)	Buy	New	Standard component, modified in-house
ESP32 controller	Buy	New	Industry standard, easy to program
L298N Motor Drivers	Buy	New	Compatible with thrusters, reliable
Camera	Buy	New	Water-resistant, night vision, tested
Propellers	Build	New	Custom 3D printed, iteratively improved
Buoyancy Foam	Buy	New	Expanding foam, shaped in-house

System Integration Diagram (SID)



Safety

In order to maintain safety we have taken steps to protect our employees, hardware and operations. This has included eliminating any exposed wires, being careful with electrical components and waterproofing the ROV. All Components will finish secure, power to be shutoff prior to any adjustments being made. The ROV has had numerous safety features designed into it including, waterproofing, insulated wiring and a stable mounting of the motors. Additionally, as the propulsions are sharp parts, they are covered with an enclosure to ensure that they don't cut the wires of the ROV and enable the users to work with it safely. To maintain the ROVs safety during operations, we have followed safety protocols while completing mission tasks.

Safety Features

Fuses prevent electrical overload. Waterproof connectors stop water from reaching wires. Strain relief protects the tether from pulling loose. Emergency shutoff cuts power instantly if needed. Smoothed edges prevent injuries during handling. Gloves protect hands when working with electronics. First aid kit is ready for any minor accidents.

Special Features

Three-floor structure separates systems for easy access and balanced weight. Custom X-connectors create stronger frame joints than standard fittings. Custom motor holders secure bilge pumps and reduce vibration. Custom propellers were designed and improved through testing for better thrust. Mechanical servo waterproofing is a cost-effective alternative to buying expensive waterproof servos.

Critical Analysis

Testing and Troubleshooting

Component Testing

Camera: The camera was first tested inside a sealed waterproof box filled with water. A paper with handwritten numbers was placed inside the box. The camera clearly captured all numbers with high readability, confirming perfect waterproof sealing and excellent image clarity underwater.

Gripper & Servo Waterproofing: The MG995 servo was initially assumed to be water-resistant. However, during the first in-water test, it failed to respond. We realized the servo was not waterproof, which caused signal loss.

We then applied a **mechanical proofing method** to fully seal the servo:

- The servo casing was opened and all internal electronics were coated with conformal silicone coating
- All seams and gaps were sealed using marine-grade epoxy
- The output shaft was greased and covered with a flexible rubber boot to allow movement while blocking water ingress
- Heat shrink was applied to all wire entry points for additional protection

After mechanical proofing, the servo was retested inside the water box. The gripper moved smoothly through its full range of motion at precise angles, confirming:

- Successful waterproofing
- Full mechanical functionality

Bilge Pumps (Thrusters): The four SFBP1-G500-01 bilge pumps were first tested dry (in air) to verify basic functionality. All motors spun properly with no issues. After assembly, they were tested again inside the pool. During the first wet test, the propellers, which we designed and 3D printed, did not perform well. The material we used was not strong enough, causing the propellers to fail or spin inefficiently. After multiple trials and adjustments, the propellers started working properly. This confirmed that the issue was material-related, not motor-related, and was solved through iterative testing and refinement.

Full ROV Testing After individual components passed testing, the camera, gripper, and thrusters were mounted on their dedicated platforms within the 3-floor ROV structure:

- Floor 1: Camera platform (foamed for buoyancy)
- Floor 2: Bilge pumps and propellers
- Floor 3: Aluminum gripper platform

The fully assembled ROV (495mm L × 315mm W × 345mm H, 4.2kg) was tested in the pool.

- The camera provided clear footage underwater
- The gripper responded instantly with full range of motion
- The thrusters and propellers successfully propelled the ROV after multiple propeller trials

Troubleshooting

Problem 1 - Servo Failure (Before Mechanical Proofing):

The MG995 servo failed during the first in-water test because it was assumed to be water-resistant but was not.

Solution: We applied a complete mechanical proofing process as described above. The servo then performed flawlessly in all subsequent tests.

Problem 2 - Propeller Performance:

The first version of our 3D printed propellers did not perform well underwater due to weak material.

Solution: After multiple trials and material adjustments, the propellers worked efficiently in later tests. This confirmed that iterative testing improved the design.

Testing Documentation

All testing phases are documented in the following Google Drive folder:

<https://drive.google.com/drive/folders/10CkR-lA-SD9P5rUfx9rEUR9tqtp7jAdW>

Accounting & Budget

Item	Quantity	Cost (EGP)	Cost (USD)	Source
ESP32 Microcontroller	1	300	\$6.00	Purchased
Bilge Pumps (500 GPH)	4	2,400	\$48.00	Purchased
L298N Motor Drivers	2	100	\$2.00	Purchased
Car Rear View Camera	1	300	\$6.00	Purchased

EasyCap	1	190	\$3.80	Purchased
Jumper Wires	20	250	\$5.00	Purchased
Gripper Mechanism	1	420	\$8.40	Purchased
MG995 Servo Motor	1	170	\$3.40	Purchased
PVC Connectors (T, elbows)	30	450	\$9.00	Purchased
PVC Pipe (½ inch)	8 m	240	\$4.80	Purchased
PVC Adhesive Cement	1	50	\$1.00	Purchased
Expanding Foam	1	100	\$2.00	Purchased
Aluminum (Gripper Material)	—	250	\$5.00	Purchased
3D Printing Filament	—	2,500	\$50.00	Purchased

Total: 7,570 EGP \$151.40 (Exchange rate: 1 USD ≈ 50 EGP)

Purchased, Reused, and Donated

Category	Items	Cost (USD)
Purchased	All components listed above	\$151.40
Reused	None	\$0
Donated	Technical mentoring, workspace, and 3D printing facilities	In-kind

Donations Acknowledgment

We thank *Eng. Mazen Elbially* for technical mentoring, workspace, and 3D printing facilities. All donations were in-kind; all monetary costs were covered by team members.