



ALESTA

Adana Science High School
Seyhan Youth Centre

2026 TECHNICAL REPORT



Vehicle Name:

HURRICANE

10th Grade

Mehmet Ulaç Girgin

CEO

10th Grade

Buğlem Nisan Ekinci

CFO

10th Grade

Kağan Kaya

CTO

10th Grade

Mustafa Kahramanoğulları

COO

9th Grade

Beyzanur Dizman

Mechanic, PR

9th Grade

Derin Nergiz

Mechanic

9th Grade

Emre Alperen

Software

9th Grade

Yiğit Köylü

Electronic

9th Grade

Ulaş Doruk Seyfettinoğlu

Software



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1. Abstract

Our company is a high school-based engineering group dedicated to designing and developing innovative underwater robotic systems for real-world applications such as underwater searchings . With 7 year of experience in robotics competitions, our team has consistently focused on improving both technical performance and teamwork.



Figure-1

Each member of the team is assigned specific roles based on their strengths, allowing us to work efficiently and collaboratively. Through this structured approach, we ensure that all aspects of the project from mechanical design to system integration are carefully managed.

Our primary goal is not only to successfully complete mission tasks but also to develop engineering skills, problem solving abilities, and effective communication within the team. By continuously learning from previous experiences, we aim to improve our designs and achieve higher performance each year.

Our team consists of 9 members, all of whom attend Adana Science High School. To make things more organized and easier, we work in four main departments: software, mechanics, electronics, and PR.

The software department creates the necessary algorithms for the vehicle, writes the software, and is responsible for artificial intelligence and image processing.

The mechanics department creates the mechanical design of the vehicle, performs assembly, ensures waterproofing and sealing, and is also responsible for the vehicle's stabilization.

The electronics department creates the electronic design of the vehicle, troubleshoots problems when they arise, and pilots the vehicle.

The PR department promotes the team on social media, does advertising, and provides financial support to the team.

2. Project Management

Adana Science High School is one of Türkiye's leading state high schools, known for its emphasis on science, mathematics, and technology. With its experienced teachers and success-oriented environment, the school aims to cultivate analytical, innovative, and successful students in both academic and technological fields.

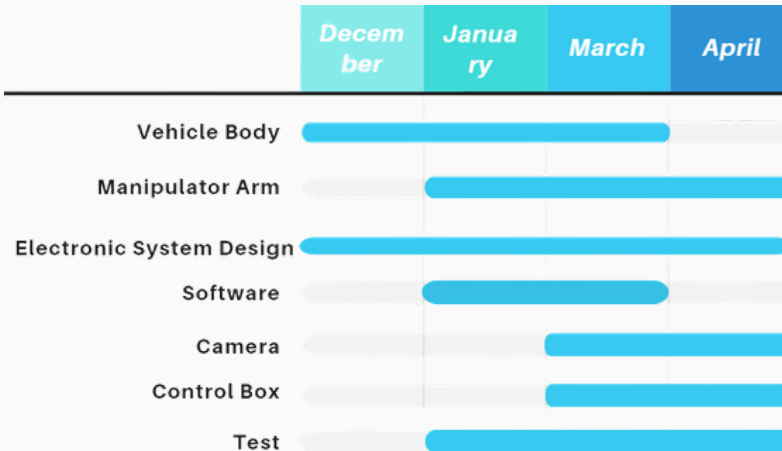


Figure-2

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3. Engineering Design Rationale

3.1. Mechanical Design

Manufacturing Method	Material	Application Area	Purpose / Key Advantage
Lathe (Turning)	7075 Aluminum	Plug components, simple geometries	Efficient production of simple, axisymmetric parts
6-Axis CNC Machining	7075 Aluminum	Main chassis	High precision and ability to manufacture complex geometries
Plexiglass Thermoforming	Acrylic (PMMA)	Camera dome, electronic enclosure tube	Transparency for visual inspection and camera operation
3D Printing	PETG-GF, TPU, PETG-CF, ABS	Outer shell, robotic arm parts, mounts, tray	Lightweight, customizable, and rapid manufacturing

Figure-3

The ROV, named Hurricane, was designed and manufactured to perform all mission tasks in the most efficient and reliable manner, with a strong emphasis on mechanical robustness, hydrodynamic efficiency, and operational stability. The manufacturing methods used in the production of the vehicle are presented in Figure 3. These methods include CNC machining of 7075 anodized aluminum components, the use of plexiglass pressure housings, and 3D-printed parts produced with water-resistant PETG material.

Hydrodynamic flow analysis of the vehicle was conducted using ANSYS software, and the results are illustrated in Figure 4. This analysis demonstrates the streamlined structure of the ROV and highlights the reduction of drag forces acting on the vehicle during operation, contributing to improved efficiency and stability underwater.

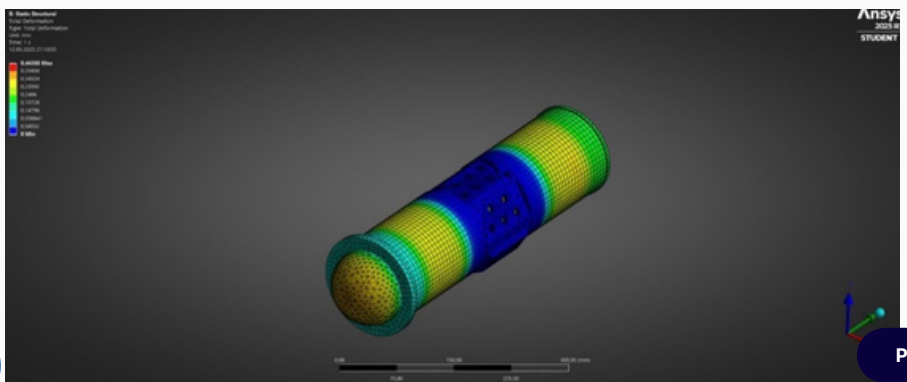


Figure-4

During the design process, multiple structural configurations were evaluated to determine the most optimal solution. A robust yet lightweight structure was selected to ensure durability without compromising maneuverability. In this context, the use of a plexiglass tube played a critical role, providing a strong pressure-resistant enclosure while maintaining low weight. This balance allows the vehicle to remain both durable and easily controllable underwater.

The internal placement of components was carefully engineered to achieve optimal weight distribution. By strategically positioning key elements such as batteries and electronic systems, the center of gravity was stabilized, minimizing unwanted tilting and improving overall control performance. This design approach significantly enhances the vehicle's stability during operation.

For the vision system, a dome structure was specifically designed for the camera module. This dome enables maximum utilization of the camera's field of view, allowing wider visual coverage and increasing efficiency during mission tasks such as object detection and navigation.

The propulsion system underwent a major optimization process. Initially designed with an 8 thruster configuration, the system was later redesigned into a 6 thruster configuration. Although the 8-thruster system provided higher thrust capacity, it introduced several disadvantages including increased energy consumption, additional weight, and higher system complexity. After evaluation, the 6-thruster configuration was selected as it provides a more balanced and efficient solution.

The 6-thruster system reduces power consumption while still delivering sufficient maneuverability for all required mission tasks. Furthermore, the reduced number of thrusters simplifies the electrical and control systems, thereby improving reliability and ease of maintenance. This optimization results in efficient movement, precise control, and extended operational duration without compromising performance.

Additionally, the ROV was designed with a compact form factor to enhance maneuverability and operational flexibility. The smaller size allows easier navigation in confined underwater environments, reduces hydrodynamic drag, and improves precision during complex tasks. It also contributes to lower material usage and overall weight reduction, increasing overall system efficiency.

A rendered image of the ROV design is presented in Figure 5, showcasing the overall mechanical structure and integration of system components.

Figure-5



3.2. Software Design

Software design is developed using the Python programming language, which stands out among currently used programming languages due to its easy-to-learn syntax, extensive library support, easy integration with systems, and rapidly evolving structure. Additionally, Visual Studio Code is used as a code editor because of its advantages such as integrated debugging and its fast and simple interface that provides ease of use.



Figure-6

During the software development process, certain libraries are required to meet the system's needs, along with the requirements of the competition tasks. Python's extensive library support best addresses this need. Thereby, libraries such as NumPy, OpenCV, ultralytics, and PyMAVLink can be used to efficiently meet the system's requirements.

Some competition tasks require the use of image processing techniques such as Object Detection and Image-Based Dimensional Measurement. The OpenCV library is used for preprocessing and analyzing images from the vehicle camera. OpenCV is an open-source library used for vision and image processing applications in systems, supporting operations such as image processing and object detection. Preprocessing is performed on the images obtained from the vehicle camera using OpenCV; this makes the data more suitable for image processing methods such as object detection and dimensional measurement. In addition, the NumPy library enables high-speed processing of the obtained image data and increases the accuracy of the operations in the process with mathematical operations. For object detection, the YOLO object detection algorithm, whose potential is increasing day by day, is used. YOLO (You Only Look Once) is a deep learning-based object detection algorithm that can perform real-time object detection and tracking on images and videos. YOLO can operate with high efficiency in many systems with its important features such as low latency, high speed and accuracy, and the ability to classify and detect multiple objects in a single pass. These features of the YOLO algorithm provide us with a significant advantage in competition tasks.

4. Innovation

Our company focuses on maximizing operational efficiency and functionality while minimizing costs during vehicle design. Instead of purchasing expensive commercial systems, we have focused our innovations on custom-designed, in-house solutions that directly improve the performance of our ROV for the 2026 missions.

Commercial power management boards are expensive, bulky, and often lack the specific customization our vehicle requires. To solve this, our company designed a custom, two tier Power Distribution Board (PDB) system. The primary board safely routes high current to the propulsion system, while the second board provides clean, regulated power to delicate electronics like the Raspberry Pi, fiber converter, and servo motors. To maximize system safety and reliability, we integrated 3-amp fuses across all power outputs, protecting every component from overcurrent. Furthermore, this custom architecture completely eliminated unreliable cable clutter inside our electronics enclosure. Ultimately, this in-house PDB provided our ROV with a safer, highly functional power infrastructure at a fraction of the cost.

Purchasing a commercially available 6 axis underwater robotic arm would have consumed a significant portion of our budget. However, precise object manipulation is critical for 2026 missions. Therefore, our company designed a custom 6 degree of freedom robotic arm. Producing this manipulator allowed us to customize the exact gripping power and dexterity required for the tasks. This innovation enabled us to successfully complete missions while keeping our overheads extremely low.

5. Problem Solving

During the development process, several issues were identified and resolved. Initially, the ROV used an eight-thruster system, but testing showed high power consumption and low efficiency. Therefore, the design was updated to a six-thruster configuration, improving energy efficiency and current usage while maintaining maneuverability. The control software was also updated to match the new propulsion system, resulting in more stable performance.

Additionally, the thruster mounting system was redesigned, moving from separate motor holders to integration with the main body shell. This improved structural strength and simplified the design.

Overall, these changes resulted in a more efficient and reliable ROV.

6. Systems Approach

Hurricane ROV was designed to efficiently complete the 2026 MATE Ranger missions. During our pool tests, we observed that reducing the pilot's workload directly increases our success rate on missions. Therefore, we focused our design on two main goals: autonomous stabilization and easy object manipulation.

To keep the vehicle stable, we integrated precise sensors into the control system. A 6-axis IMU controls the roll and pitch, a magnetometer controls the yaw, and a pressure sensor controls the depth of the vehicle.

To interact with objects easily, we built a custom 6-DOF robotic arm. Thanks to this system, the control software holds the ROV completely still underwater while the robotic arm performs the tasks. Moving only the arm instead of the entire vehicle prevents water disturbances and makes it much easier for the pilot to operate

7. Vehicle Structure

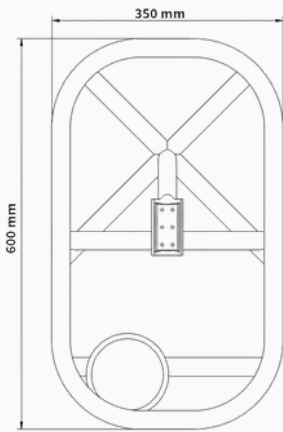


Figure-8

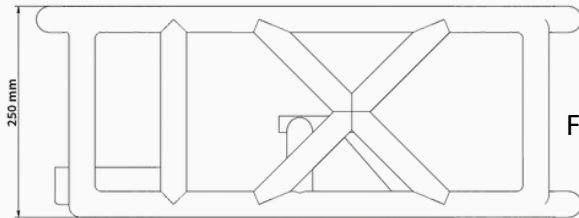


Figure-7

The ROV is designed with a compact and efficient structural layout to ensure both performance and compliance with competition constraints. The overall dimensions of the vehicle are approximately 600 mm × 350 mm × 250 mm, allowing for a balanced combination of maneuverability and component integration. Technical image of the Hurricane is presented in Figure 7 and Figure 8.

The structure is engineered to fit within a 750 mm diameter sphere, meeting the required size limitations. This compact design enables the vehicle to operate effectively in confined underwater environments while maintaining structural integrity.

8. Vehicle Systems



Figure-9

The external shell used in the vehicle is designed to protect the system against external factors during underwater operations and serves as the primary protective structure against impact, pressure, and mechanical stresses. This lattice (frame) structured design not only increases strength but also provides protection without negatively affecting the vehicle's hydrodynamic performance. Rendered image of the Hurricane is presented in Figure 9.

The external shell is positioned to integrate with the vehicle body and the robotic arm system. This ensures the internal components are securely fixed while minimizing vibrations and displacements that may occur during operation. Connection points located at the lower part of the structure allow the robotic arm system to be safely attached to the shell.

Within the shell, a Sigma profile is used as the supporting frame. Thanks to its modular design, the Sigma profile allows system components to be mounted in an organized and robust manner while distributing loads evenly to enhance structural strength. Its ease of assembly and maintenance also contributes significantly to its selection for this application.

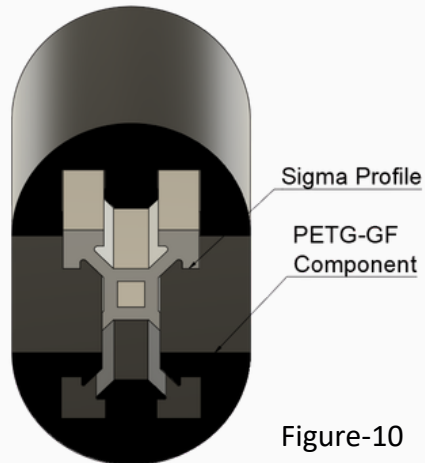


Figure-10

PETG-GF (glass fiber reinforced PETG) material has been chosen for the external shell. Compared to standard PETG, this material provides higher mechanical strength, rigidity, and impact resistance. The addition of glass fibers increases the shell's resistance to deformation under high loads and ensures that its structural integrity is maintained during prolonged use. Additionally, PETG-GF offers chemical resistance suitable for underwater conditions along with ease of manufacturing. Rendered image of the sigma profile and PETG-GF is presented in Figure 10.

To evaluate the mechanical performance of the structure, a static stress analysis was conducted on the external shell. The analysis examined the stress distribution under potential loads and identified critical regions. The results indicate that the external shell design has sufficient load-bearing capacity and provides structural strength against impact effects. Furthermore, the combination of the Sigma profile used in the main supporting frame and the PETG-GF material on the outer surface enhances overall system rigidity and reduces the risk of deformation.

In conclusion, the designed external shell meets the criteria of high strength, modularity, protection, and stability, making it a critical structural component that directly contributes to the overall performance of the vehicle.

9. Electrical System

9.1. ROV Electrical System

9.1.1. Raspberry Pi 4 8GB

A Raspberry Pi 4 8b is used to connect Hurricane and the control station. The Raspberry Pi transmits sensor and camera data to the control station and relays movement commands received from the control center to Pixhawk.

9.1.2. Pixhawk 2.4.8

The vehicle controller will be Pixhawk 2.4.8. Pixhawk will provide autonomous stabilization based on data from the sensors and control the motors by sending PWM signals to the ESCs according to motion commands from the Raspberry Pi. Pixhawk uses its embedded 6-axis IMU sensor to provide stabilization on the Roll and Pitch axes.

9.1.3. ESC

The Hurricane has 6 thrusters. A total of 6 electronic speed controllers (ESCs) are used to control each thruster. The ESCs control the direction and speed of the motors according to the PWM signals from the Pixhawk.

9.1.4. Fiber Media Converter

A Fiber Optic Media Converter was used to convert the Raspberry Pi's Ethernet connection to a fiber optic connection.

9.1.5. Sensors

As external sensors, the Matek Systems RM3100 magnetometer was used for yaw axis stabilization and the Lenta Marine M300 pressure sensor was used for depth stabilization. The depth sensor is connected via I²C, and the magnetometer is connected via Canbus.

9.1.6. CanBus

A voltage and current sensor from Matek Systems was used to instantaneously measure the voltage entering and exiting the vehicle. The connection to the Pixhawk was made via CanBus.

9.1.7. Camera

To complete underwater tasks, our ROV uses a single Lenta Marine 1080p Low Light camera, which is powered directly by the onboard Raspberry Pi. A servo motor drives a custom tilt mechanism, allowing the pilot to shift the view between the forward environment and the robotic arm below without moving the entire vehicle. This mechanism allows tasks to be successfully completed using a single camera. The camera utilizes H.264 hardware compression for the 1080p video, ensuring the high-definition feed uses minimal bandwidth.

9.1.8. Main PDB

Main Power Distribution Board (PDB) receives the main 12V supply via a XT60 connector and safely routes it to the driving Electronic Speed Controllers (ESCs) and the secondary PDB using seven dedicated XT30 outputs. By localizing all high-current paths on this single PCB, wiring clutter is effectively eliminated and heat buildup is minimized. Each output can handle a maximum continuous current of 30 amps.

9.1.9. Secondary PDB

Secondary PDB has a single 12V input and 7 different voltage outputs with 7 different 3A switching regulators. One regulator provides 5V power to Raspberry Pi, onboard fiber media converter, and the servo motor that drives the camera's rotation. The remaining six 3A regulators are entirely dedicated to the servo motors of the 6 DOF robotic arm. Power to the servo motors is supplied via MT30 connectors, and the servo PWM signals from the Pixhawk are routed directly through precision JST GH ports integrated onto the PCB. To guarantee system safety, each output is protected by a 3 amp fuse.

9.2. Topside System

The topside control station is designed for operational simplicity and safety compliance. The setup consists of a custom topside control box and a laptop. To ensure precise maneuverability, the pilot operates the ROV using a standard game controller connected to the laptop.

For data management, the control box houses the surface fiber media converter. This unit enables bi-directional optical communication through the tether.

It translates incoming optical signals into a standard Ethernet connection to deliver low-latency video and sensor data to the laptop, while simultaneously converting and transmitting the pilot's controller inputs back down to the ROV's control system.

For safety, the topside box features an Emergency Stop (E-Stop) system to adhere to MATE safety protocols. Rather than routing the main ROV power directly through a mechanical switch, the E-Stop button triggers an 80-amp relay. Given our system's maximum continuous draw of 25A, this 80A rating provides a massive safety factor, completely eliminating the risk of contact welding.

Furthermore, a 30-amp main system fuse is integrated directly into the topside box. Thanks to the surface placement of this main fuse, power is cut off in the event of any short circuit, whether inside the vehicle body or along the 16-meter connecting cable. This relay and topside-fuse architecture safely isolates the high-current path, maximizing both operator safety and component reliability.

9.3. Tether

Our custom 16 meter tether consists of two 8 AWG power cables and one waterproof fiber optic cable. The fiber optic line ensures high-speed, reliable data transmission between the ROV's Raspberry Pi and the topside control station. For power transmission, we selected heavy-duty 8 AWG cables. To ensure our custom primary and secondary PDBs receive a stable supply, we mathematically validated our wire choice by calculating the maximum voltage drop over the 16-meter run. Assuming a maximum continuous system draw of 25A and an 8 AWG resistance of roughly 0.002 ohm/m the calculation is: Voltage Drop = Current x (2 x Length x Resistance) Voltage Drop = 25A x (2 x 16m x 0.002 ohms/m) = 1.6V

10. Control System (Software Based)

10.1. System Architecture and Data Flow

The ROV's control system has three main parts: a surface laptop with an Xbox controller, an onboard Raspberry Pi companion computer, and a Pixhawk vehicle controller. The laptop reads the pilot's commands and sends them to the ROV through a fiber optic tether without delay. The Raspberry Pi receives these commands and quickly passes them to

the Pixhawk using the MAVLink protocol. This two-way fiber optic connection allows us to send movement commands down to the ROV and bring camera and sensor data up to the surface instantly.



Figure-10

10.2. Telemetry and Video Streaming

We use QGroundControl (QGC) software on the laptop to manage the mission and view data. The Raspberry Pi processes the HD video from the cameras and sends it directly to the QGC screen via the fiber tether. Along with the fast video feed, QGC shows a clear dashboard. This helps the pilot easily check important data like depth, temperature, and the ROV's angle. The software is very stable and allows easy sensor calibration, which makes driving the ROV safe and easy.

10.3. Vehicle Stability and Sensors

To keep the ROV stable underwater and fight against water currents, we use a PID control algorithm inside the ArduSub software. This algorithm needs accurate, real-time position data to work. To get this data, the Pixhawk uses an Extended Kalman Filter (EKF) to combine information from three sources: its internal 6-axis IMU for tilt, an external RM3100 magnetometer for direction, and a Lenta Marine M300 pressure sensor for depth. The Pixhawk constantly checks this combined sensor data and automatically adjusts the thrusters using PID. This stops the ROV from shaking or drifting, which makes the pilot's job much easier.

11. Propulsion

The propulsion system of Hurricane utilizes six Blue Robotics T200 brushless DC thrusters, chosen for their high power-to-efficiency ratio. While an 8-thruster setup was initially considered, a 6-thruster configuration was ultimately implemented to optimize current consumption and allow for a more streamlined, innovative frame design. To ensure operational safety, each thruster is equipped with custom 3D-printed protective housings that prevent debris interference and algae accumulation (see Figure 11).

This optimized configuration ensures high-performance maneuvering and precise stabilization while significantly minimizing the overall electrical load on the system.

The strategic placement of the thrusters enables full control over the vehicle's maneuverability:

- **Vertical Control (Heave, Roll, Pitch):** Two forward-facing vertical thrusters and one rear-mounted vertical thruster manage depth and stability.
- **Horizontal Control (Surge, Yaw):** Two thrusters mounted at 90 degrees provide forward/backward thrust and rotational movement.
- **Hybrid Stabilization:** A final thruster, mounted at a 45-degree angle underneath the vehicle, generates combined force components that assist in both vertical and longitudinal motion while fine-tuning stabilization across all axes.

This optimized configuration ensures high-performance maneuvering and precise stabilization while significantly minimizing the overall electrical load on the system.



Figure-11

12. Buoyancy and Ballast

Hurricane achieves static underwater stability through a combination of a sealed acrylic pressure hull and precise mass distribution. During the design phase, a digital twin model was developed in Fusion 360 to calculate mass and volume, ensuring the vehicle's average density remained near 1 g/cm^3 . To maximize stability and minimize unwanted moments, the heaviest component—the battery pack—is positioned at the vehicle's geometric center, aligning the Center of Gravity (CoG) with the structural axis.

The system features a modular ballasting configuration to adapt to varying operational environments:

- **Positive Buoyancy:** Closed-cell foam and custom-designed, foam-filled 3D printed components provide lightweight, adjustable lift.
- **Ballast and Fine-Tuning:** Removable lead weights are utilized to achieve near-neutral buoyancy and precise CoG alignment. This modularity allows the ROV to be rapidly reconfigured for peak performance in both freshwater and saltwater conditions, ensuring controlled and stable motion.

13. Payload and Tools

13.1. 6 DOF Robotic Arm

The 6-DOF robotic arm is designed for high-dexterity underwater operations, allowing for precise material handling across all spatial axes. It provides a full range of movement without compromising the stability of the vehicle, making it highly effective for complex sampling or maintenance tasks in challenging aquatic environments.

The arm is powered by high-torque servos specifically allocated based on joint-load requirements. The base joint (DOF 1) utilizes a DS 5160 servo with a 60 kg lifting capacity to manage cumulative torque, while joints 2 through 6 are driven by DS 3225 servos capable of 40 kg each. The final mechanical design and the orientation of its six kinematic axes are illustrated in Figure 12.

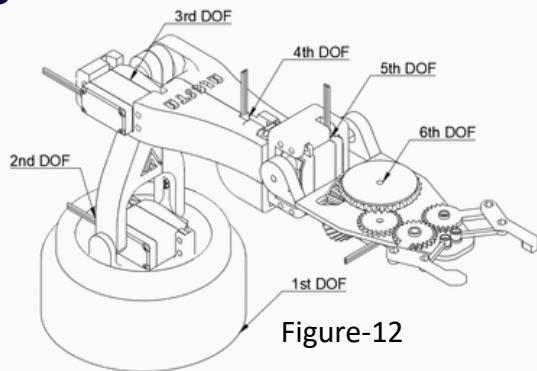


Figure-12

13.2. Non-ROV (Float)

Figure-13



Storm is a profiling float that achieves vertical motion through a variable buoyancy engine rather than traditional thrusters. By using a NEMA 17 stepper motor to actuate a syringe mechanism, the vehicle adjusts its internal water volume and net density. This allows it to transition between positive and negative buoyancy states based on Archimedes' Principle, enabling energy-efficient vertical exploration through the water column.

The mechanical structure features a 110 mm plexiglass tube sealed with custom-lathed 7075 aluminum end caps. These caps are secured by a redundant dual-layer O-ring system to ensure watertight integrity at depth. To maintain a stable upright orientation during dives, the design employs an aggressively low Center of Gravity (CoG) through strategic ballasting, as shown in the 3D render in Figure 13.

14.BUILD VS BUY

To optimize our project, we evaluated every component based on three criteria: cost, effectiveness, and building time. We chose to build parts that required task-specific customization, and we bought parts where manufacturing from scratch would waste time and reduce reliability. Here are some examples of our decisions:

Power Distribution Boards (Build): Commercial boards were too bulky and did not provide our exact voltage outputs. Building custom PCBs saved internal space and reduced wiring complexity.

6-DOF Robotic Arm (Build): Commercial 6-axis underwater manipulators are extremely expensive. By designing and 3D printing our own robotic arm, we saved our budget and created custom grippers specifically for MATE tasks.

Surface Control Station (Building): Instead of purchasing an expensive commercial top unit, we built our own portable and cost-effective system using a standard laptop, an Xbox controller, a fiber optic media converter, tethering, and a 25-amp fuse and emergency stop button to protect the vehicle.

Thrusters (Buy): Designing, manufacturing, and perfectly sealing custom brushless motors requires too much building time and carries a high risk of leaking. Buying proven, commercial thrusters guaranteed reliable movement and allowed our team to focus on software and payload development.

15.SYSTEM INTEGRATION DIAGRAM

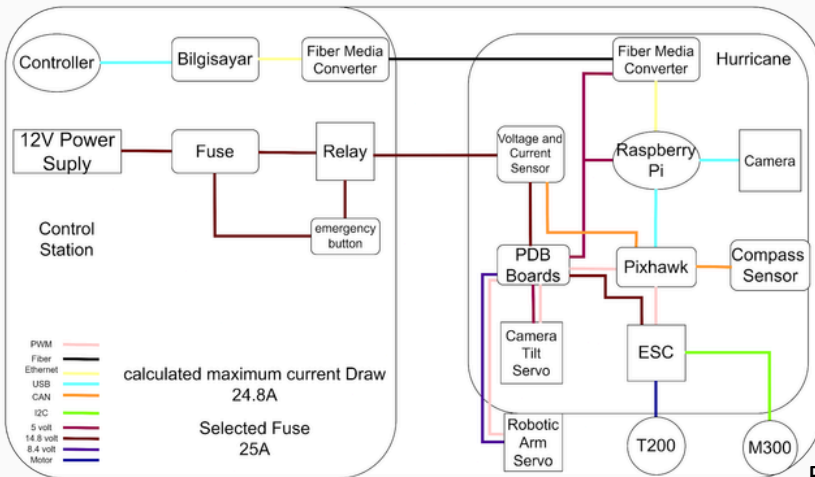


Figure-14

16.SAFETY

16.1. Team Member Safety

Shield: We use shields during cutting, soldering, etc. operations to protect against possible injuries.

We wear protective eyewear.

Gloves: We ensure skin damage and prevent injuries.

Closed-toe shoes: We avoid wearing slippers for our safety.

All devices are unplugged after work to prevent electrical risks.

16.2. Vehicle Safety

All edges of the vehicle were smoothed using the Fillet command in Autodesk Fusion 360, eliminating sharp corners. In addition, protective guards were integrated around the propellers, ensuring that no sharp edges remain and enhancing overall safety and durability.

For electrical safety, both vehicles use inline fuses connected directly to the positive terminals power supply. Hurricane uses a 25A fuse, and the autonomous float Storm uses a 3A fuse to prevent short circuits.

To turn the Storm float on and off without drilling holes in the watertight tube, we designed a contactless magnetic switch. A reed switch inside the tube activates a power relay. Placing a magnet on the outside turns the float on, and removing it cuts the power completely. This simple design eliminates water leak risks and short circuits.

16.2. Sealing and Waterproofing

Ensuring reliable waterproofing is a critical aspect of the Hurricane ROV design. Multiple sealing methods have been implemented to prevent water ingress under operating conditions.

The main structural components consist of acrylic (plexiglass) pressure tubes and CNC machined 7075 aluminum parts. The aluminum components are anodized to improve corrosion resistance in underwater environments. Sealing between mechanical interfaces is achieved using O-ring gaskets and interference (press-fit) fits, providing strong and reliable sealing. Additionally, penetrators are used at cable entry points to maintain watertight integrity.

All external 3D printed components are manufactured using PETG-based filaments, which are preferred due to their low water absorption and resistance to degradation in water.

The propulsion system uses brushless DC motors, specifically Blue Robotics T200 thrusters, which are inherently waterproof and designed for underwater use. For actuation, servo motors are used. Although waterproof servos (DS Dervon series) are selected, they are not fully suitable for high-pressure underwater conditions. Therefore, additional modifications are applied.

Each servo motor is filled with mineral oil, allowing internal pressure to equalize with external water pressure while preventing water from entering. Since mineral oil is electrically non-conductive, it protects internal electronic components. The outer casing of the servo is coated with epoxy resin to further isolate it from water. An O-ring seal is also placed at the rotating shaft to ensure complete sealing of moving parts.

For electrical connections, epoxy-sealed cables are used, and no exposed wiring is present in the system. All cable interfaces are carefully insulated to prevent leakage.

After manufacturing, all acrylic and aluminum components are subjected to leakage and pressure tests to verify waterproofing performance before final integration.

16.3. Penetrator Safety

Waterproof penetrators are used to ensure safe cable entry and exit points, isolating motor and sensor connections from the external environment. To prevent damage caused by irregular cable movement, fastening elements are applied and the cable layout is optimized, reducing the risk of mechanical wear and water contact.

A cable holder manufactured from TPU is designed to secure and organize the connection between the power and fiber optic cables. This component prevents clutter and minimizes damage caused by friction and tension during operation. The holder features a dual-diameter hole design (6 mm upper, 7 mm lower), allowing easy screw insertion and secure fastening with a nut, simplifying assembly. It is mounted onto shafts integrated with the motor mounts. The rendered view of this component, along with annotated explanations, is presented in Figure 15.

For the main structure, PETG-CF material is preferred due to its high stiffness, mechanical strength, and water resistance, making it suitable for load-bearing components. Standard PETG is used in non-critical parts for its ease of manufacturing. The TPU material, with its flexible and high-friction properties,

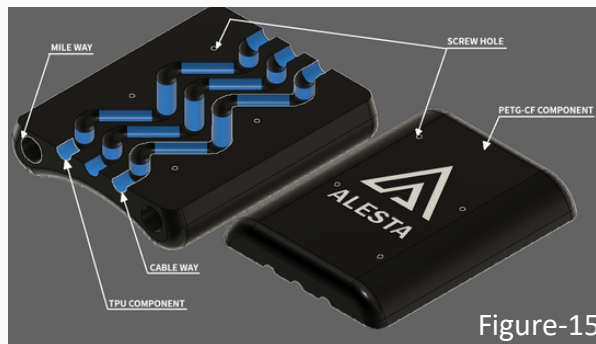


Figure-15

securely grips the cables without causing damage and prevents slippage.

Additionally, the cable holder transfers mechanical loads caused by cable pulling from the penetrators to the chassis, reducing stress on sealing points and increasing system reliability. Its curved geometry ensures that cables remain securely in place under external forces. Overall, the design provides sufficient mechanical strength and durability under operational conditions.

17. TESTING AND TROUBLESHOOTING

Throughout the development process, the ROV was subjected to multiple testing phases to evaluate its performance, reliability, and overall functionality. These tests were conducted in controlled environments to simulate real underwater conditions as closely as possible.

Prior to physical production and assembly, structural and design analyses were carried out using ANSYS and Autodesk Fusion 360. These simulations allowed the team to test and optimize individual components in terms of strength, durability, and feasibility before manufacturing.

Initial physical tests revealed several issues related to stability, buoyancy, and component integration. Based on these observations, necessary modifications were implemented. For example, adjustments were made to the buoyancy system to achieve neutral balance, and the frame structure was reinforced to improve durability.

In addition, all software systems were thoroughly tested before underwater deployment. The code was verified through simulations and dry testing to ensure proper functionality and to minimize potential failures during operation. Electrical systems were also evaluated, and minor issues such as connection weaknesses and signal delays were identified and resolved through improved wiring and code optimization.

Waterproofing was another critical aspect of the testing process. All electronic housings and components were subjected to leakage and sealing tests. These tests were repeated multiple times to ensure complete water resistance and to guarantee safe operation under underwater conditions.

After implementing all improvements, repeated testing confirmed that the ROV performed more efficiently and reliably. The testing and troubleshooting process ensured that all systems were functioning as intended and that the vehicle was fully prepared for operational tasks.

RISK RATING COLORS		1	2	3	4	5
		Very Low	Low	Medium	High	Very High
RISK		RISK LEVEL		DEPARTMENT		CONTROL MEASURE
 Short circuit due to water contact		4		ELECTRONIC		Use sealed waterproof housings
 Contact with exposed electrical wiring may cause electric shock.		4		ELECTRONIC		Insulate all wires and use waterproof connectors
 Sharp edges on fram		2		MECHANICAL		Sharp edges on fram
 Entanglement with cable		4		MECHANICAL		Organize and secure cables
 Water leakage into ROV		5		MECHANICAL		Perform sealing and pressure tests
 Motor overheating		2		ELEKTRONİK		Allow cooling intervals
 Short circuit due to water contact		4		ELECTRONIC		Use sealed waterproof housings
 Battery chemical leakage		4		ELECTRONIC		Handle with protective gloves
 Loss of ROV control		2		SOFTWARE		Test communication systems
 Poor ventilation during charging		4		MECHANICAL		Charge batteries in ventilated area
 Propeller injury		5		MECHANICAL		Install protective guards
 Fire hazard from electrical fault		5		ELEKTRONİK		Keep fire extinguisher nearby
 Loose components on ROV		4		ELECTRONIC		Tighten all fasteners
 Poor visibility underwater		2		GENERAL		Use proper lighting
 Noise exposure from motors		4		MECHANICAL		Limit exposure duration
 Overloading electrical system		5		ELECTRONIC		Use correct rated components
 Fire hazard from electrical fault		5		ELEKTRONİK		Keep fire extinguisher nearby

SAFETY CHECKLIST

18.SAFETY CHECKLIST

Team Members Safety

- ☒ Using shields during dangerous operations to protect against possible injuries.
- ☒ Wearing goggles to protect eye area.
- ☒ Ensuring skin damage and preventing injuries by wearing gloves.
- ☒ All devices get unplugged after we are done using it.

Vehicle Safety

- ☒ Sharp corners get rounded.
- ☒ Vehicle is designed to be completely watertight, suitable for underwater conditions.
- ☒ Water ingress is prevented by using rubber seals at the body and lid connection points.
- ☒ Waterproof penetrators are used to ensure safe cable entry and exit points within the vehicle. This isolates the motor and sensor connections from the external environment.
- ☒ To prevent damage from irregular cable movement, fastening elements are used and the cable layout is optimized. This reduces the risk of both mechanical damage and water contact.

Electronic System Safety

- ☒ To protect electronic components, the entire system is located within a closed and insulated space.
- ☒ To reduce the risk of possible short circuits, connections are insulated and appropriate cable selection is made.
- ☒ Furthermore, precautions have been taken against sudden current changes in the system, ensuring the safe operation of the components.
- ☒ The placement is designed to completely prevent contact of electronic equipment with water.
- ☒ A fuse is added to prevent excessive current draw.

Emergency Button

- ☒ The control station includes a button connected to a relay designed for use in emergencies.

19.BUDGET

Our company receives financial and material support from multiple sources. Our company is affiliated with Adana Science High School and the Seyhan Youth Centre, which provide essential resources and infrastructure. Adana Science High School contributes by offering material support, workshop facilities, and covering competition registration fees. Seyhan Youth Centre also provides material support and covers travel and accommodation costs for international competitions.

In addition, as a team with a 7 year history, we have access to previously used equipment and components, which further reduces expenses. Our PR department continuously engages in sponsorship discussions to secure additional funding.

Currently, we have a prepared budget of approximately \$12,800 USD, obtained from sponsorships. Combined with institutional support and access to prior materials, this funding ensures that the team can efficiently manage construction, testing, and participation in both national and international competitions.

20.COST ACCOUNTING

Fiber Media Converter	1	40,50\$
Raspberry Pi 4 8GB	1	229,52\$
Pixhawk 2.4.8	1	190,55\$
8 AWG Red Power Cable	16 Meters	77\$
8 AWG Black Power Cable	16 Meters	77\$
M300 Pressure Sensor	2	450\$
RM3100 CAN Magnetometer	1	130,50\$
CAN Digital Power Monitor	1	93,38\$
Microsoft Xbox Controller	1	101,26\$
Shielded Fiber Optic Cable	50 Meters	10,35\$
LittleBee 30A ESCs	6	65,26\$
PCBs	2	52,3\$
T200 Thrusters	6	1380\$
Nema17 Stepper Motor	1	13,46\$
Stepper Motor Driver	1	2,43\$
60KG Digital Servo Motor	1	48,60\$
35KG Digital Servo Motors	5	162\$
Plexiglass Tube and Dome		225\$
Aluminum Plug	4	112,50\$
TOTAL		3.461,61\$

21. REFERENCES

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