RoboSub 2026 Technical Documentation Report

Bangladesh University of Engineering and Technology

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Abstract- Team Black Pearl develops an underwater autonomous vehicle named “Dubojan” for Robosub 2026. The focus of our team is to develop a new lightweight AUV with the ability to perform all the tasks and also leave some room for future modification also. The work is divided into four sub teams: Mechanical and Design Team, Electronics Team, Software Team, Media and Outreach Team. Our focus is to gather experience and to do as many tasks as possible.

I. COMPETITION STRATEGY

As a newcomer to this competition, we are determined to perform the basic tasks first with our single AUV. To do that, this team is subdivided into three sub-teams: Mechanical and Design sub-team, Electrical sub-team and Software sub-team.

The competition strategy is centered on accuracy rather than performing more tasks. For this reason, the design philosophy of Dubojan is to limit complexity in performing tasks while increasing accuracy in each selected task.

A. Vehicle Strategy

Team Black Pearl will compete with one AUV named Dubojan. It focuses on fundamental and high probability tasks to perform first like gate detection, path tracking, object detection and station keeping. Tasks having high precision manipulation are considered secondary priority which will depend on perception and control systems’ stable performance during testing.

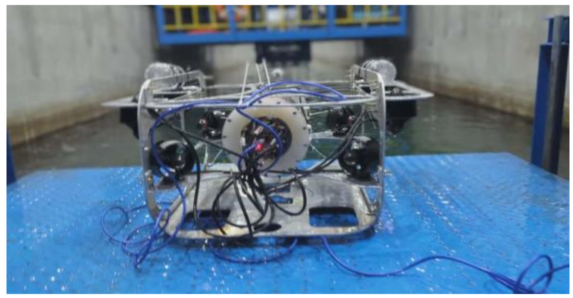

Figure 1: Dubojan

B. Course Strategy

Our strategy is to use sensors mounted with Dubojan like sonar and cameras to detect objects with Machine Learning (ML) technique. Again, countering acoustic signals from pingers will help us to locate and identify the objects like buoys, dropper, torpedo targeting zones etc.

Again, aligning the vehicle is the main priority where precise detection and control system will help to estimate the target position and vehicle position and path creation and tracking will be done by pre assumed inputs. As the course keeping will be predefined, aligning the vehicle by detecting the objects will be the main part of every task.

At the gate task and slalom task the object detection, aligning towards the object and then making the vehicle keep the course in a predefined way and again detecting the object again to check and realign the vehicle is the core strategy of our team at the course.

II. Design Strategy

A. Mechanical Subsystem

1) System Overview

Dubojan is a compact and modular Autonomous Underwater Vehicle (AUV) with emphasis on lightweight construction, maintainability, and ease of fabrication. Since this is the team's first underwater vehicle, the mechanical design focused on achieving reliable operation using locally available manufacturing resources and materials.

Aluminium was chosen as the main structural material owing to its good strength-to-weight ratio, corrosion resistance, and relative ease of machining. The propulsion system relies on eight thrusters, four vertical and four horizontal. By angling the horizontal thrusters at 45°, we achieve vectored thrust which ensures precise maneuvering and full 6-DOF control needed underwater.

The overall layout was arranged to keep subsystems tightly integrated and well-balanced which allows reasonable access to components during maintenance.

2) Pressure Hull Design

The pressure hull uses a transparent acrylic cylindrical tube, 160 mm in diameter and 17 inches in length. Cylindrical geometry was chosen partly for its structural behavior, as it distributes external hydrostatic pressure more evenly, and partly because it simplifies both fabrication and internal component arrangement.

Nylon flanges were custom-machined and threaded onto the acrylic tube for the purpose of sealing. The end caps are held in place using a standard nut-and-bolt arrangement, with rubber O-rings compressed at the flange-to-end-cap interfaces to achieve a watertight seal. One practical advantage of this setup is that the hull can be opened and put back together multiple times during maintenance without the seal losing its effectiveness.

3) Frame and Structural Design

Several versions of the frame were developed before the final design was selected. Ease of fabrication, structural strength, and hydrodynamic performance were checked each time during the design stage. The drag characteristics and flow of water around the structure were analysed by CFD simulations. Areas where the flow was disturbed were identified and improvements were done.

The rectangular frame was chosen among different configurations as it performed better in terms of transverse stability and subsystem arrangement. It also simplified the installation of internal components compared to the other concepts considered during the early stages of development.

Material selection was carried out by comparing stainless steel and aluminum under the same design requirements. Weight, corrosion resistance, structural behavior, and the availability of local manufacturing facilities factors were considered. In order to provide adequate strength while keeping the vehicle relatively lightweight, a 4 mm aluminium plate was selected for the frame construction after evaluation.

Structural analysis was conducted under expected operating conditions after finalizing the frame geometry and material. The analysis mainly focused on bending, buckling and deflection of the structure. According to the results, the frame could safely withstand the loads generated by the thrusters and payload components without undergoing significant deformation.

4) Payload Mechanisms

4.1 Marker Dropper Mechanism

The marker dropper is designed to release two spherical markers in sequence during a mission. Space inside the vehicle structure was limited, so the marker housing tube was designed with a slight curvature to fit within the available space while still providing a clear release path for each marker.

Figure 2: Dropper

Actuation is handled by a servo-driven rotary locking system built into the housing assembly. The first marker is released with a 90° servo rotation, and a further 90° rotation deploys the second. The assembly sits close to the downward-facing camera, which helps improve deployment accuracy during operation.

4.2 Gripper Mechanism

The gripper is intended for underwater object manipulation and uses three servos driving a claw-type end effector. The first servo handles the opening and closing motion of the claw through a gear-driven linkage. A second servo manages deployment by rotating the gripper from a horizontal stowed position down to a vertical operating position, making it easier to reach objects on the pool floor. To avoid placing sustained load on the deployment servo, a dedicated locking mechanism was added using a third servo. When stowed, this lock mechanically holds the gripper in place, significantly reducing the holding torque

Figure 3: Gripper

required from the deployment actuator. Prior to operation, the locking servo rotates 90° to disengage the lock and permit deployment.

4.3 Torpedo Launching System

The torpedo launching mechanism is designed to deploy two torpedoes using a compact servo-actuated rack-and-pinion arrangement. The launcher consists of two cylindrical torpedo holders integrated directly into the main frame structure.A servo motor drives a pinion gear that converts rotational motion into linear displacement through the rack mechanism. The resulting linear motion actuates the locking system of the launcher, enabling controlled release of the torpedoes.

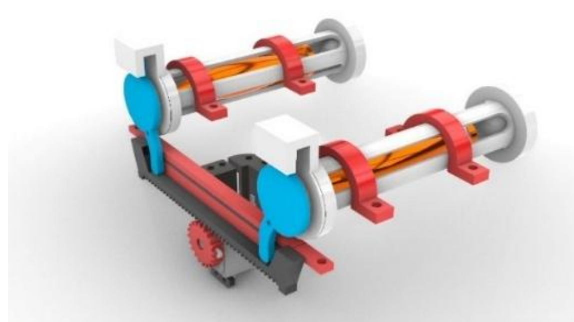

Figure 4: Torpedo System

The mechanism was designed with emphasis on compactness, mechanical simplicity, and lightweight construction while maintaining reliable operation under underwater conditions.

B. Electrical Subsystem

1) Power System and Battery Architecture

A custom-built 16V Lithium-Ion battery pack is used for high endurance, stable power delivery, and compact integration inside the pressure hull. The battery pack is configured in a 4S3P arrangement using high-performance Molicel 21700 cells, providing a total capacity of 12.6Ah. Selected Lithium-ion source offers improved energy density, thermal stability and longer operational lifetime compared to conventional LiPo solutions.

An integrated real-time power monitoring module is used which can measure voltage, current, and total power draw throughout the mission monitoring system health and power consumption. This allows the operators to analyze energy consumption patterns and identify abnormal power conditions. At Appendix-B the power architecture diagram is shown.

2) Safety and Kill Switch System

Safety and fault tolerance were major priorities in the electrical design of the AUV. To ensure immediate emergency shutdown capability, the vehicle incorporates a custom high-current MOSFET-based electronic kill switch rated for 100A continuous operation.

To instantly disconnect the main power supply during emergencies, the kill system uses an NPN MOSFET based switching design with external push button quickly. Again, to reduce mechanical wear and improve resistance to vibration and corrosion a solid-state design is used.

Additionally, a leak detection sensor is used which continuously monitors the hull for water ingress and immediately alerts the operators if abnormal moisture is detected.

3) Flight Controller and Low-Level Control System

A Pixhawk flight controller running ArduSub firmware is being used to handle the low-level stabilization and motion control of the Dubojan. This PID based controller processes IMU and onboard sensor data to maintain stable six-degree-of-freedom movement. Pixhawk also acts as the primary interface between the high-level computing system and the vehicle actuators.

4) High Level Computing and Communication

NVIDIA Jetson Orin Nano is used as the main onboard computer for autonomy, computer vision, high decision making and control. It communicates with Pixhawk through MAVLink protocol for exchange of telemetry, sensor data and control commands.

The AUV is equipped with two waterproof HD cameras for real time visual perception, underwater navigation, and object detection. Communication with the surface station is maintained by a 20-meter ethernet tether cable.

5) Propulsion Electronics and ESC System

The propulsion subsystem is controlled using eight BLHeli-based brushless electronic speed controllers (ESCs). Each ESC independently controls one thruster and receives PWM control signals directly from the Pixhawk flight controller.

The BLHeli ESCs were selected due to their fast response time, smooth throttle control, and compatibility with high-performance brushless thrusters. Their compact design and efficient switching characteristics improve overall propulsion responsiveness and reduce electrical losses during operation.

To simplify maintenance and improve modularity, the ESC system was organized to allow rapid replacement and streamlined wiring management inside the hull. This modular electrical layout

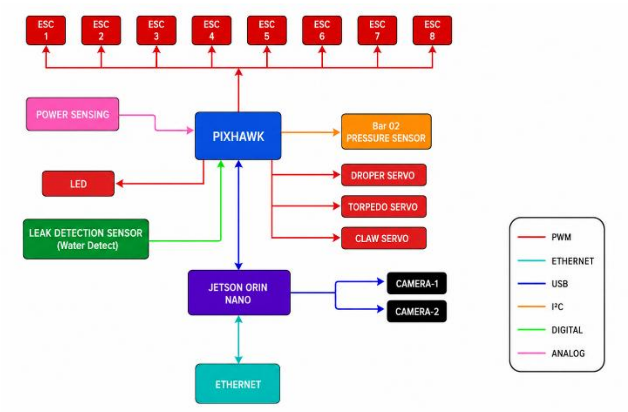

Figure 5: Communication Architecture Diagram

significantly reduced debugging time during test and improved overall system maintainability.

C. Software and Control Subsystem

1) Control System

The control system uses a Model Predictive Controller (MPC), which plans and executes trajectories. This also optimizes a sequence of future control actions over a receding horizon. Path generation is handled through quintic polynomial interpolation which produces smooth, continuous trajectories with well-defined velocity and acceleration profiles. A key feature of our MPC implementation is its target-centric trajectory formulation. The controller targets the estimated center point of a detected object. This enables precise and high accuracy navigation toward mission-relevant goals.

2) Decision System

Mission execution is managed by Decision Tree architecture. This handles task completion and behavioral logic in a structured way. Each node in the tree encodes a discrete decision that allows the vehicle to progress sequentially through pre-defined task sequences. This architecture

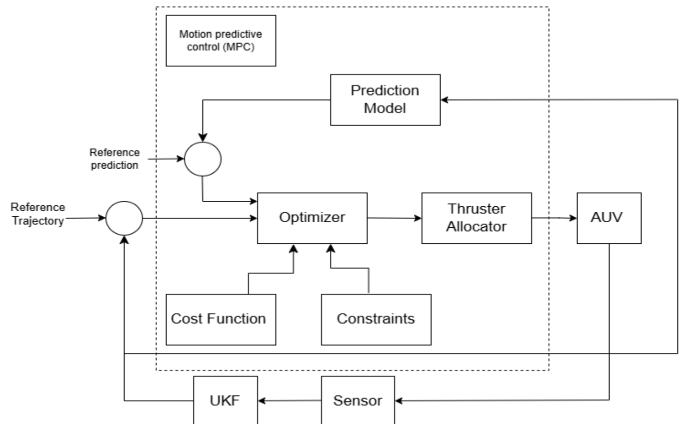

Figure 6: Control system block diagram

simplifies the debugging and validation of mission logic.

3) Perception Pipeline

The perception pipeline adopts a hybrid approach. This combines classical Digital Image Processing (DIP) techniques via OpenCV with deep learning models like YOLOv8. Complex and irregular obstacle geometries are handled by our YOLOv8 detection model, which provides robust recognition under varying conditions. Simpler targets defined primarily by distinctive colors and geometric shapes are handled through DIP-based methods. This method also handles color

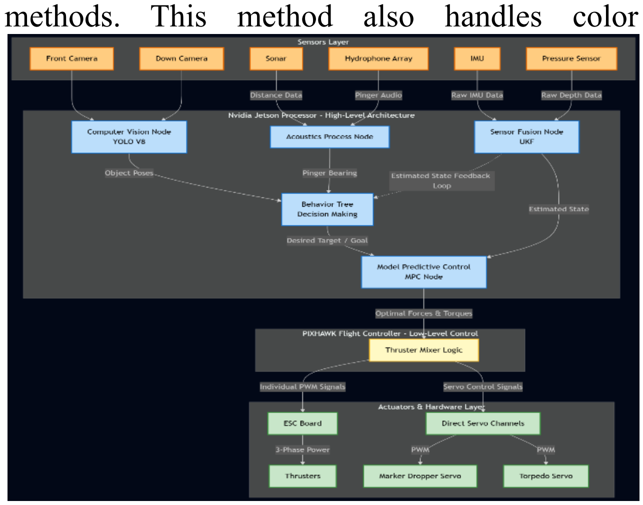

Figure 7: AUV software architecture

thresholding, contour analysis and morphological filtering.

A principal challenge encountered during development was the degradation of color fidelity in the underwater environment. Overcoming this required careful tuning of our OpenCV pre-processing stages including white balancing, histogram equalization and adaptive thresholding.

III. Testing Strategy

1) Whole structure and Torpedo Testing

The bare-hull structure of the robot was hydrodynamically analyzed using ANSYS 2021 R2 software. The pressure and velocity fields are provided in Appendix E. The primary objective of the team was to minimize the drag acting on the structure to reduce power consumption. Several design analyses were conducted and the final optimized structure achieved a minimum bare-hull resistance of 1.645 N.
The Torpedo is also analyzed in the same software. Hydrodynamic analysis was performed to minimize the drag of the torpedo which ensures improved accuracy and target performance.

2) Electrical system Reliability and Testing

The electrical subsystem underwent extensive validation under both laboratory and underwater testing conditions. Continuous power test was performed to verify battery endurance, voltage stability and thermal performance under full load.

Kill switch, leak detection functions were validated several times. Communication between Jetson Orin Nano and Pixhawk was tested during autonomous test operations while finding live data and video transmission.

3) Software Simulation and Validation

Before pool trials, all software subsystems were validated within the Gazebo simulation environment. A realistic model of our AUV was deployed within a simulated pool model. The AUV was tested for the control, decision and perception pipelines against the tasks. The Appendix-C shows the Gazebo simulation of gate detection.

Acknowledgements

Team Black Pearl expresses its heartfelt gratitude to Bangladesh University of Engineering and Technology for their administrative and laboratory support throughout the project. Thanks to the Department of Naval Architecture and Marine Engineering for letting us to use Ship Model Testing Center, Underwater Robotics Lab, Marine Structure Lab etc. Furthermore, we are very grateful to Dr. Zobair Ibn Awal, whose guidance and motivation were a beacon for us. We would like to extend our deep gratitude to BUET Batch'90 for their generous monetary support which gave us the courage to do this project, and they are the lead sponsor of Dubojan. Again, we are also very thankful to LOBDHI, as a co-sponsor of our AUV. We are also very thankful to two of our alumni Imon Ghosh Pranta and M Abrar Muhit for their monetary contributions.

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Appendix-A: Components Specifications

Component	Model	Vendor	Specifications/ Quantity	Custom/ Purchased	Cost
Frame	Aluminum 6061-T6	Local	-	Customized	$1020.00
Electronics enclosure	Acrylic Tube 4-6in	Local	Quantity – 1	Customized	$162.00
Thrusters	T 200	Rove maker	Quantity - 8	Purchased	$170.00
Custom Li-Ion Battery Pack	Molicel 21700,		4S3P, 16 V, 12.6 Ah		
MOSFET Kill Switch	High Power MOSFET Module 100A	Blue Robotics	Quantity – 1	Purchased	$28.00
Power Monitoring Module	Pixhawk Power Module V1.0	Roboticsbd	Quantity – 1	Purchased	$10.00
QS8-S Connector Set	-	Blue Robotics	Quantity – 1	Purchased	$17.00
Binder 770 Bulkhead Connector	-	Blue Robotics	Quantity – 3	Purchased	$20.00
SOS Probe Tips	-	Blue Robotics	Quantity – 1	Purchased	$35.00
WetLink Penetrator - M10 - 6.5 mm - LC	-	Blue Robotics	Quantity – 12	Purchased	$11.70
Bar High-Resolution Depth/Pressure Sensor - Bar02 (0–2 bar)	Bar-02	Blue Robotics	Quantity – 1	Purchased	$80.00
Leak Detection Sensor	Water contact sensor, hull-mounted	Blue Robotics	Quantity – 1	Purchased	$35.00
Flight Controller	Pixhawk PX4 2.4.8	Radiogearbd	Quantity – 1	Purchased	$15.00
High-level Control	Raspberry Pi 4	Raspberry Pi	Quantity – 1	Purchased	$39
Mission Computer	Nvidia Jetson Orin Nano	Nvidia	Quantity - 1	Purchased	$529.00
Electronic Speed Controllers	BLHeli Brushless ESC	Little Bee	(4S compatible)	Sponsored	-
DeepWater Exploration exploreHD Camera	HD Waterproof USB Camera (front + bottom)	Blue Robotics	Quantity - 2	Purchased	$325.00
Tether / Comm. Link	20 m Ethernet (Cat6), direct to base station	.	Quantity - 1	Purchased	$10.00
IMU	VectorNav	-	Quantity - 1	Purchased	$1500.00
2D Scanning Panoramic Sonar	Vast Sea Tech Marine	SV1006 Triple-Frequency	-	Purchased	$3258.94

APPENDIX-B

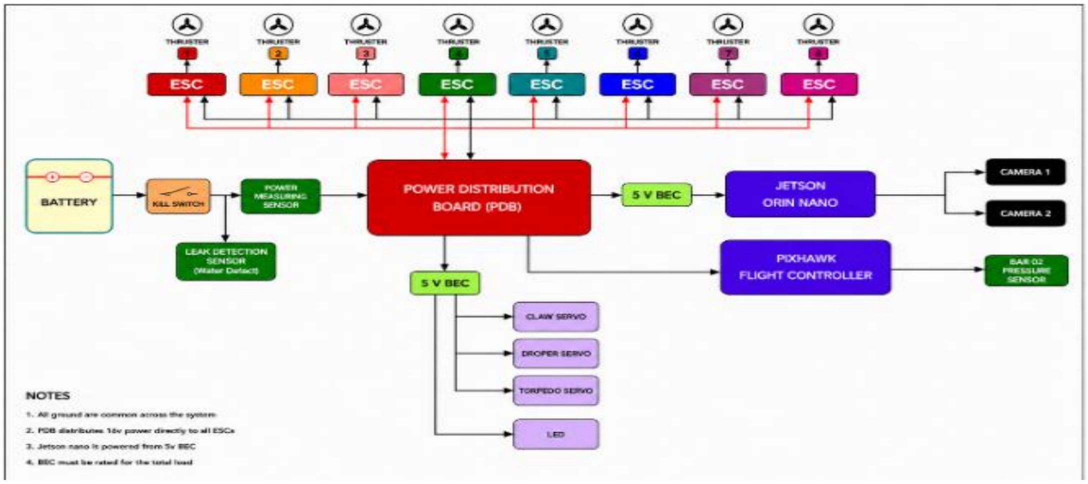


Figure 8: Power Architecture Diagram

APPENDIX-C

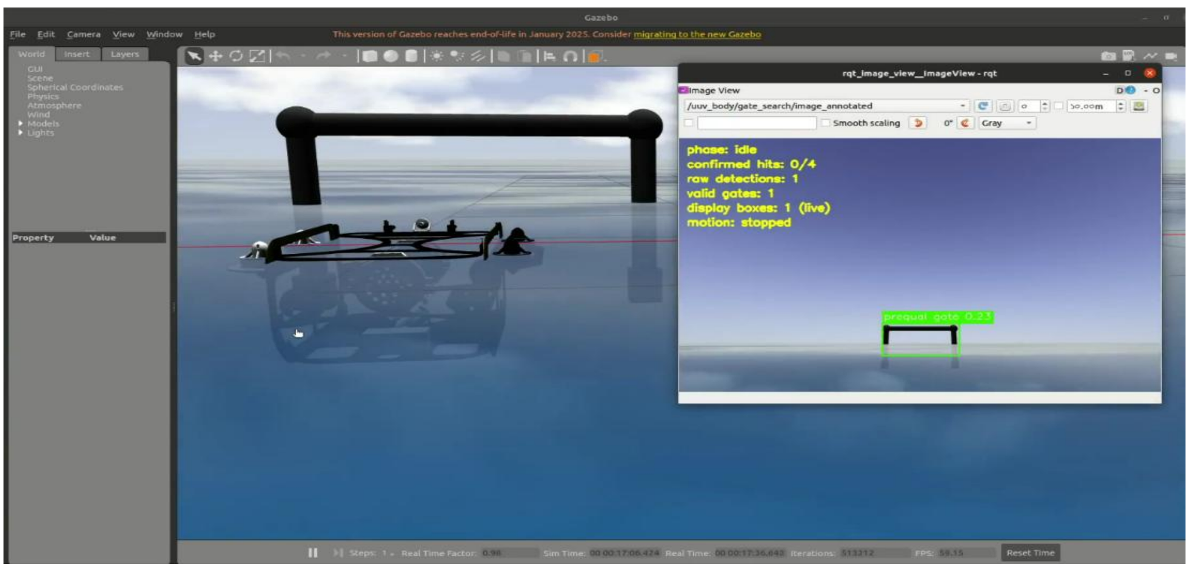
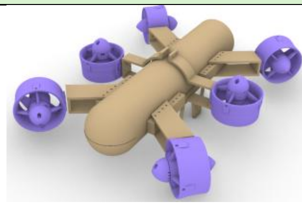
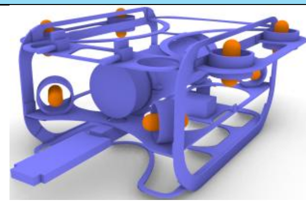
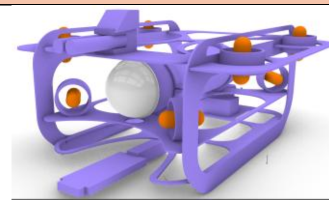
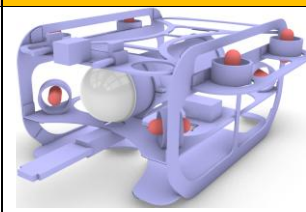


Figure 9: Gazebo Simulation of Gate detection

APPENDIX-D: DESIGN IMPROVEMENT PHASES

As Team Black Pearl is participating in ROBOSUB 2026 for the first time, several design iterations were performed for the underwater vehicle design. The design and mechanical team developed multiple concepts with different advantages and disadvantages.

Table 1: Design development of the vehicle structure

	Initial	Prototype	Integrated	Final
Design version	 Design v1.0	 Design v2.0	 Design v3.0	 Design v4.0
Description of new	• The initial design of the vehicle. • Compact design. • Very low resistance. • Need less power to run the vehicle • Only 6 thrusters can run the vehicle	• A separate frame is incorporated to hold all the other parts • Main structure is included for giving a seat for all secondary equipment.	N/A	N/A
Improvement from previous	N/A	• More space for two cameras and torpedoes • Tube design can be flexible • Gripper can be installed in the frame with simple configuration. • 8 thrusters for better maneuvering.	• Incorporated a dome structure at the front of the tube to minimize resistance. • Weight reduced by cutting plate. • Deep water camera incorporated which can be installed outside of the tube.	• Middle plate placed lower by a small margin. • A vertical rod is incorporated on both sides to increase structural stability. • Top plate cutting conducted to remove weight from the top section and increase the vertical stability.
Challenges	• The design is not suitable for incorporating torpedo • Very less space for including camera • More robust tube design required. • Gripper installment needs more critical configuration.	• Resistance increased due to skin friction. • Drag increased at the front part of the tube. • Weight increased due to aluminum plate • Tube needs more space for installing camera inside it. • The vertical instability due to higher position of vertical center gravity.	• Still has the problem of vertical stability. • Torpedo placement too close for operation.	N/A

APPENDIX-E: CFD ANALYSIS

The CFD analysis is conducted in ANSYS 2021 R2 software. For generating 3D solid geometry of the bare-hull structure, Rhinoceros software is used. The domain is created according to ITTC guideline for CFD analysis of underwater vehicle to neglect the wall shear effect of the domain in CFD analysis. Using 4 million cells, the mesh is generated with better skewness and orthogonal quality which ensures stable results obtained from CFD analysis.

For computational setup to introduce turbulence k-omega (SST) turbulence model is used. Using hybrid initialization and drag force as a output parameter the analysis is started. The pressure contour shown in Figure 10 is provided for design modification decision-making. The pressure contour helps to identify vulnerable regions for structural parts of the vessel too. From the pressure contour outcome the special structural care is also finalized.

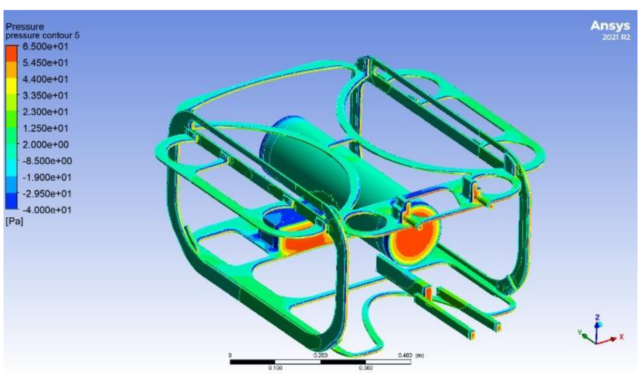


Figure 10: Pressure contour of bare hull structure

After the convergence of the result the final drag result is taken for decision making of the design and further improvement in the design of the vessel.

The velocity vector of the flow field is provided in the figure below.

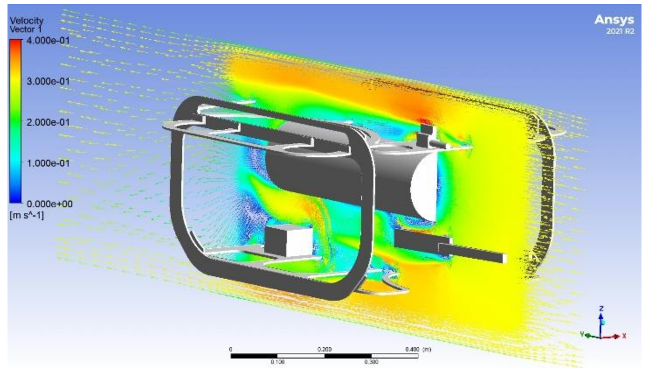


Figure 11: Velocity vector of the flow field

The torpedo model is also analysed using same CFD model. The drag minimization approach is also a key factor in this analysis. The pressure field across the full torpedo structure is provided in the Figure 12.

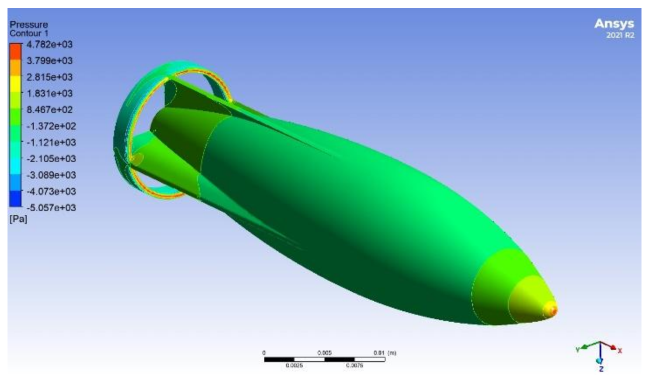


Figure 12: Pressure contour of torpedo structure

The velocity vector of the torpedo is also analyzed for the further direction of flow field around the torpedo structure shown in Figure 13

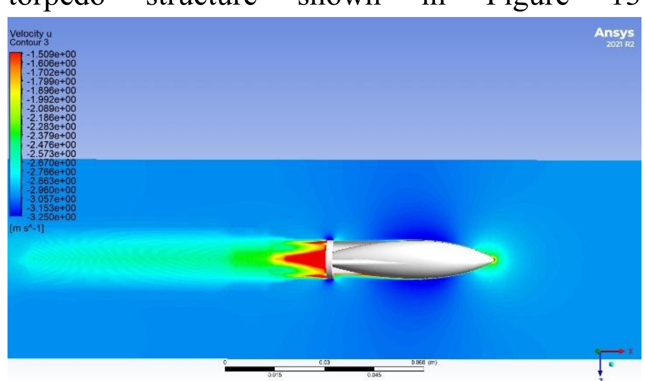


Figure 13: Velocity contour of torpedo

APPENDIX-F: OUTREACH ACTIVITIES

Our RoboSub team actively worked to promote underwater robotics and marine technology research in Bangladesh through outreach programs involving academia, alumni, and industry professionals. These activities helped us share our project goals, connect with supporters, and encourage interest in robotics and engineering innovation.

BUET AUV Showcase and Sponsor Engagement

We organized an official AUV showcase event at Bangladesh University of Engineering and Technology (BUET) in the presence of the Vice Chancellor of BUET, the Head of the Department

of Naval Architecture and Marine Engineering, the Dean of Mechanical Engineering, the Director of Student Welfare (DSW), faculty members, alumni representatives, and students.

During the event, we presented our Autonomous Underwater Vehicle (AUV), explained our mission and vision, and shared our development progress and preparation for RoboSub 2026. The program created an important platform to introduce underwater robotics research within the university community.

A major highlight of the event was receiving sponsorship support from the BUET 91 Batch Alumni Association, who officially contributed USD 8000 to support our project and competition activities.

BUET Alumni Club Chittagong Exhibition and Industry Outreach

Our second outreach activity took place during a day-long Eid reunion organized by the BUET Alumni Club, Chittagong. The event was attended by BUET alumni along with their families, as well as owners, chairmen, and representatives from major industries and shipyards in Bangladesh.

At the event, we arranged an exhibition booth to display our AUV and present our RoboSub project. Visitors showed strong interest in our work, and we explained our project goals, vehicle design, and future plans for participating in RoboSub 2026. Many attendees appreciated the initiative and encouraged our efforts in underwater robotics research.

To make the exhibition more interactive, we also organized RoboSoccer demonstrations and robotics-based activities, which attracted significant attention from both children and adults. The event also provided valuable opportunities to connect with industry leaders and shipyard representatives, helping us strengthen collaboration between academia and the maritime industry in Bangladesh. Through these outreach activities, our team aimed to promote robotics, encourage collaboration, and inspire interest in marine technology research in Bangladesh while preparing to represent the country in RoboSub 2026.