RoboBoat 2025: Technical Design Report

Military Technical College Team

Abstract— The Military Technical College team focuses on outdoing the team's previous achievements in the RoboBoat competition. This year, the 'Mandjet' design comes with major upgrades, including a redesigned mechanical structure for better performance and advanced electrical systems that integrate the latest technology for improved sensor and power management. The team has also developed custom embedded systems for real-time processing, cutting down on latency and optimizing decision-making. On top of that, the team has created a unique dataset to train the machine learning models, making image processing more accurate with improving object recognition and obstacle detection. These innovations make sure our system can complete tasks efficiently, with both precision and flexibility.

I. Competition strategy

This year, the team will participate in the RoboBoat competition alongside the autonomous surface vehicle (ASV), Mandjet. the primary objective is to reestablish their presence in the competition and enhance their performance compared to two years ago participation. Following extensive research and development efforts focused on refining the stability and control models of the vehicle, the team opted to replace the previous ASV for Mandjet due to its enhanced maneuverability and cost-effectiveness. Emphasizing speed and maneuverability, the aim for this year is to accomplish all tasks with the maximum score needed.

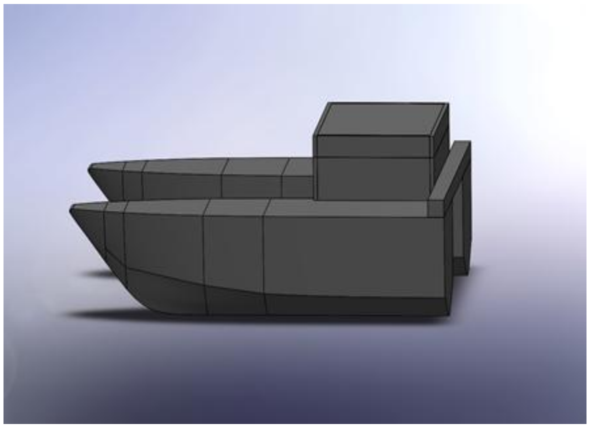


Figure 1 : 3D model of Mandjet

II. Course strategy

All tasks will be approached using advanced computer vision and control algorithms. For Task 1, the primary objective is to detect the red and green buoys and calculate the distance between them and the ASV using the ZED-camera. Successful completion of Task 1 involves autonomously detecting and navigating through two pairs of buoys with high accuracy [2]. This will serve as a prerequisite for starting Task 2.

The successful execution of task 2(follow the path) will rely on the object avoidance algorithm, coupled with trained image processing model. Additionally, the ASV's ability to maintain stability and rapidly adjust to external water currents will be crucial for precise and clear movement through narrow paths. Reporting with Method 2 (The number of identified objects may visually be reported on the ASV operator control system provided by the teams. The teams must notify a judge to be ready to observe the report at the end of the task. This visual display must be clear to read) will be the optimal strategy for minimizing reporting time, as it demands enhanced stability to ensure that the yellow buoys remain within the ASV's field of view. This approach will enable more accurate path-following and efficient task completion.

the approach to Task 3 (Treacherous Waters) focuses on quick and accurate decision-making, powered by the trained model, which can recognize and distinguish different shapes and colors. The ASV will first check for the presence of a vessel and assess whether it's suitable for docking. Once the decision is made, a path planning algorithm will take over to guide the ASV accurately to the docking bay, as long as the vessel isn't there and the docking bay's shape and color are correctly identified.

For Task 4, the strategy centers on high-speed propulsion and quick decision-making to guide the ASV through tough conditions. The ASV will use T200 thrusters, which are perfect for high-speed operation in strong water currents, like what we would find in open lake environments. These thrusters offer fast and stable responses to control signals, ensuring smooth movement. In addition, quick decision-making is key in this task because it directly affects how well the object detection model performs. To tackle this, the team has developed a fast decision-making algorithm using YOLO. The AI team has trained this model on a diverse dataset that includes various shapes and colors of objects and buoys, so it can accurately detect and classify anything the ASV needs to avoid or report. To make sure the ASV responds as quickly as possible, the team has chosen the same reporting method as in Task 2, which minimizes delays. This combined approach ensures both speed and accuracy, making it critical for completing the task successfully.

For Task 5 (Object and Water Delivery), the ASV is equipped with a water gun that will continuously spray when it detects the structure of the boat and the black triangle shape. The ASV will position itself at just the right distance, ensuring the nozzle is aimed to target the area effectively. Instead of storing water onboard, the ASV will pump it directly from the surrounding environment, helping to reduce weight and improve stability. Additionally, the ASV has a 'ball gun' that will be used to shoot a squash ball at the target shape. Both the ball gun and the water gun will stay inactive until the target has been steadily within the frame for at least 3 seconds and remains within a certain range of movement. This ensures precise targeting and minimizes any interference from unintended objects or movement.

Before each task, the ASV will record its starting position as a backup, in case the connection is lost. Before the mission starts, the ASV will save the starting point using GPS and an inertial measurement unit (IMU), allowing it to track its location throughout the operation. the ASV will use these saved coordinates, along with its onboard path planning algorithm, to automatically return to the starting point (Home).

III. Design strategy

A. Mechanical Sub-System

This year, Mandjet is designed to optimize our capabilities to its peak. The team utilized a more unique design that is easily maintainable and focused on details hindering maneuverability and stability and safety.

1) Hull Design & Arrangement

This year, the team has designed a V-shaped hull with a catamaran structure to improve stability and rigidity. Learning from the previous boat design, the team have increased the size of each hull and added a chin to the design, which enhances overall volume, hydrostatic force, and displacement below the waterline [8]. Also fiberglass is a suitable choice for the hull material, as it strikes the perfect balance between buoyancy, flexibility, and durability, providing the necessary structural integrity. This design change is focused on improving maneuverability and load-bearing capacity while ensuring the boat remains strong and reliable in different conditions.

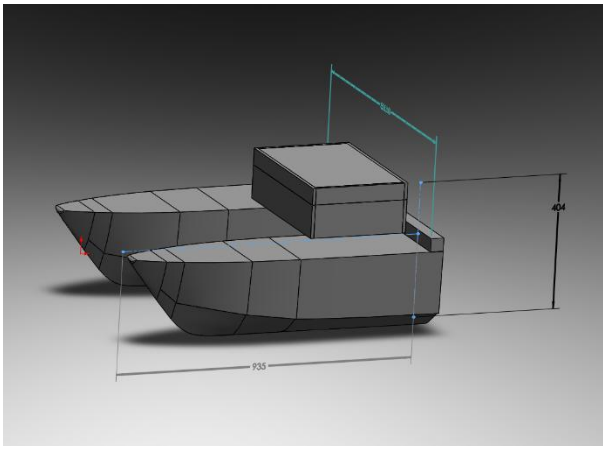


Figure 2 : Dimensions of Mandjet

2) Propulsion System

To ensure a reliable and robust propulsion system, the team has implemented a configuration of two T200 thrusters, each positioned to the back of the ASV's. This configuration provides full control over the two axes of motion—surge and yaw enabling precise maneuverability. While a previous design with two thrusters inclined by 45 degrees relative to the main axis would have offered an additional degree of freedom (sway), it was determined that this would introduce unnecessary complexity to the control system without providing a significant performance advantage. The current configuration simplifies the system while maintaining optimal functionality and efficiency.

3) Waterproofing

One of the team's primary concerns this year was isolating and waterproofing the electrical system, as this was a setback in the previous participation due to direct water contact with critical components. To address this, the team have designed a single-opening enclosure made from acrylic material, which ensures that water will not affect the electrical components. This material provides excellent dielectric properties, high thermal stability, and resistance to moisture infiltration, therefore safeguarding the integrity of the electrical system.

4) Shooting mechanism

The team decided to design a launching system that includes a primary inclined tube, holding three balls. Following that, the launching stage consists of a chamber with two high-speed servos that make direct contact with the ball as it exits the chamber. The motors are wrapped in rubber to increase friction with the ball, giving it a higher initial velocity. For the water shooting system, the team incorporated a 12V, 2000GPH bilge pump. This pump operates quietly and without vibration, ensuring that the shooting aim remains stable and unaffected after the signal is sent.

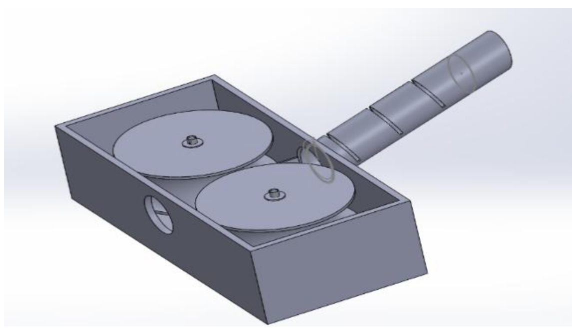


Figure 3: Ball shooter

B. Electrical Sub-System

The electrical team explored various systems in pursuit of their objectives and alignment with the competition strategy and plan.

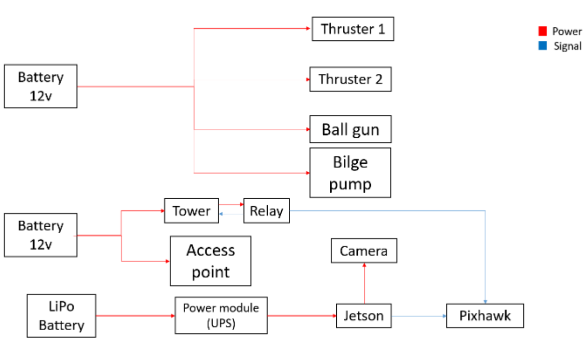


Figure 4: Electrical system diagram

1) Control and navigation

the electrical system team found out a simpler system yet more effective using Nivida Jetson TX2 and Pixhawk. The TX2 is connected to the ZED camera and to the Pixhawk simultaneously. The Pixhawk processes commands from the TX2 and give signals to the propulsion system which is connected to it. Although the Pixhawk is equipped with an onboard GPS, the team have integrated an additional GPS module to enhance positional accuracy and reduce the margin of error. This dual-GPS setup ensures improved navigation precision and greater reliability in the ASV's operation, optimizing overall system performance.

2) software

This year, the electrical team concentrated on rebuilding our codebase to enhance maintainability and allow easy modifications in critical situations. the team concentrated on optimizing key aspects such as object detection, path planning, and localization. To do that, the team used ROS [4] (robotic operating system) as it offers for us the perfect framework for the communication and integration between the different components of our ASV.

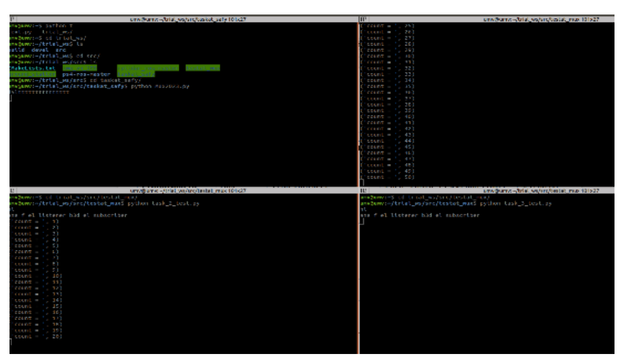


Figure 5: Tasks algorithms on ROS

3) Communication

As the ASV have manual mode, the communication in that mode is mainly based on the TP-link access point found in the ground station and the directive on the ASV, the communication is done via Wi-Fi. This setup enables effective real-time control and monitoring during manual operations. However, in autonomous mode the team used communication protocol called MAVLINK [6] for the ASV and employed a Python implementation of the protocol known as Pymavlink. With this protocol, it is possible to develop Python scripts to both retrieve sensor data and send commands to the TX2.

4) Computer vision

Perceiving and understanding the AUV environment was a big challenge, but the team has solved it by using the ZED camera along with a computer vision (CV) deep learning model to identify objects. the team initially tried the Old OpenCV framework, but the team ran into a lot of issues, like high error rates, poor accuracy in different lighting conditions, and having to write separate code for each task, which ended up being inefficient and time-consuming. After some extensive research, the team switched to the YOLO (You Only Look Once) [7] algorithm, and it turned out to be a much better fit. Specifically, YOLOv4 worked best with the NVIDIA Jetson TX-2 Dev-Kit. With its powerful backbone network, CSPDarknet53, YOLOv4 strikes a solid balance between speed and accuracy. It can run real-time inferences on the GPU and uses regularization and optimization techniques to improve stability and speed up training. To make the model work, the team created a custom dataset and trained the model using it. starting by collecting almost 400 images for each object across eight classes, adding up to 3,150 annotated photos, all labeled with "labelImg." [5] To avoid overfitting, the team used data augmentation techniques. also added color masks, contour functions, and shape approximations to help them recognize specific shapes and colors in RGB frames when needed.

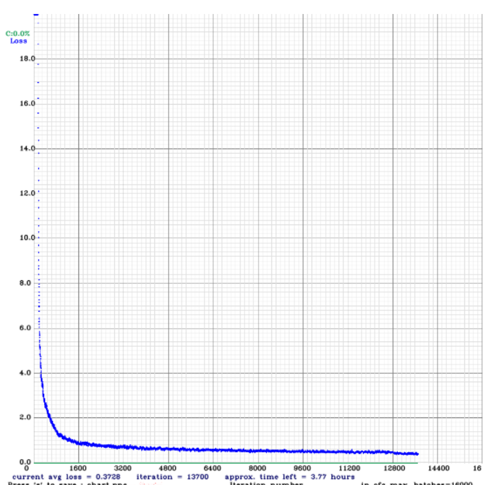


Figure 6: Training our model

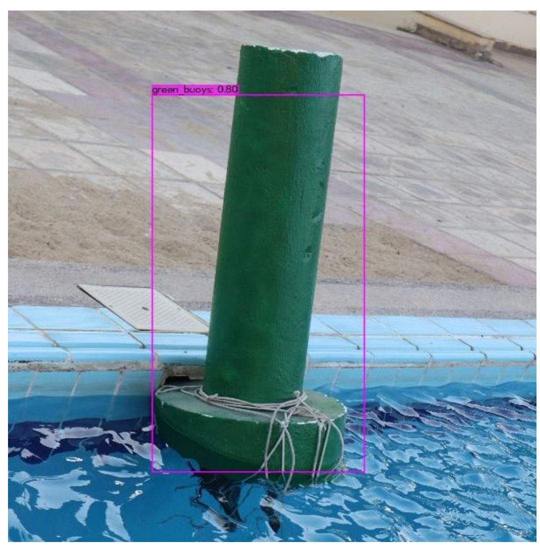


Figure 7: Testing the dataset in our pool

IV. Testing Strategy

To make sure the system works as intended, the whole team carried out a two-phase testing process: one for the electrical system and one for the mechanical system, followed by an overall ASV integration test. For the mechanical system, the mechanical team first ran a series of simulations using ANSYS and MAXSURF to analyze the hull's pressure, velocity, resistance, and stability before moving on to construction (Appendix B). the team also performed in-water tests on the propulsion system to check performance and signal transmission. During these tests, the team confirmed that the AUV didn't leak and could handle up to a 40kg payload without issues. For the electrical system, the electrical team tested the object detection algorithm to make sure it accurately detects, classifies, and identifies objects. the team also put the QGroundControl and Mission Planner software to the test by navigating the AUV to predefined waypoints [3]. Based on these tests, the team found that QGroundControl worked better for our needs, thanks to its communication protocol and flexibility in adjusting control parameters. Finally, after putting everything together on the AUV, the team ran several test runs to ensure that both the electrical and mechanical systems worked smoothly together. the team verified that the ZED camera performed well for object detection, helping the system identify the task at hand. also made sure that data transmission to the onboard TX2 computer was stable and reliable throughout the entire operation.

V. Acknowledgments

The whole team want to sincerely thank the Military Technical College for all the support they have given us in building our ASV, Mandjet, for the RoboBoat competition. A special expression of gratitude is due to Brigadier General Hossam Ragheeb for his invaluable guidance and leadership throughout this project. The team is really proud to represent the college in this competition, and so grateful for the trust you have put in us and the chance to show off what the team have worked so hard on.

VI. Conclusion

In conclusion, the design and preparation of the ASV, Mandjet, for the RoboBoat competition have been challenging and collaborative. the focus on functionality and reliability has resulted in a boat with advanced technologies. we are confident in Mandjet's ability to excel in the competition, demonstrating both technical aspects and teamwork. As we continue to innovate and push boundaries, we look forward to the challenges and successes.

VII. References

[1] K. Nonami, F.Kendoul, S.Suzuki, W. Wang, D. Nakazawa (2010) Autonomous Flying Robots for Unmanned Aerial Vehicles and Micro Aerial Vehicles.

[2] Team Handbook - RoboBoat 2025

[3] Ardupilot, "Mission Planner," Ardupilot, 2023.https://ardupilot.org/planner

[4] “ROS Documentation”, OSRF. Available: http://wiki.ros.org/Documentation.

[5] LabelImg - image annotation tool, retrieved from https://github.com/HumanSignal/labelImg

[6] Mavlink protocol overview, retrieved from https://mavlink.io/en/

[7] H. Deshpande, A. Singh, and H. Herunde, "Comparative analysis on YOLO object detection with OpenCV," *Int. J. Res. Ind. Eng.*, vol. 9, no. 1, pp. 46–64, 2020.

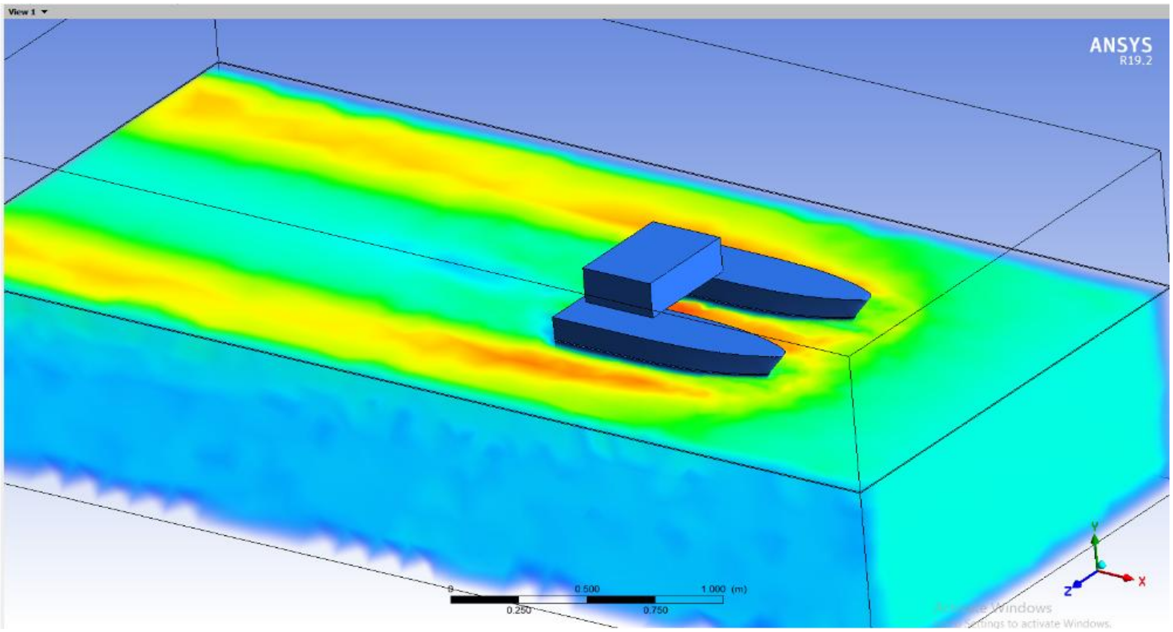
[8] B. Müller-Graf, D. Radojčić, and A. Simić, "Resistance and propulsion characteristics of the VWS hard chine catamaran hull series '89"

APPENDIX A: COMPONENT SPECIFICATIONS

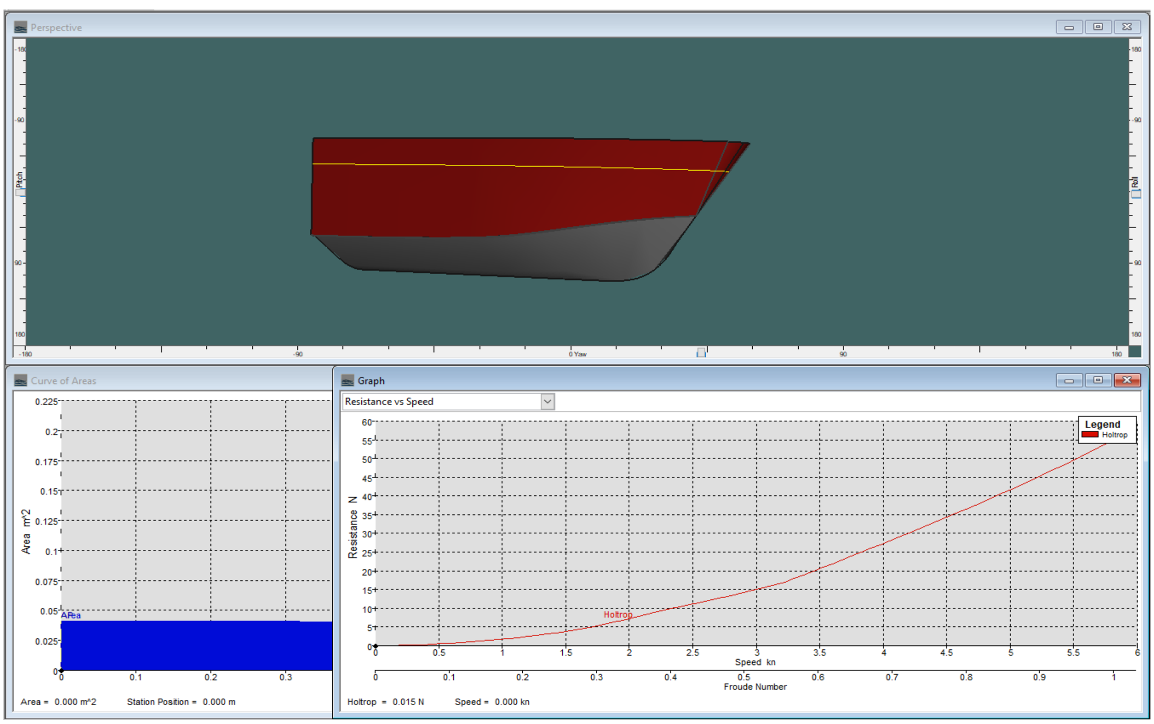
ASV Mechanics and Electrical System

Component	Vendor	Model/Type	Specs	Custom/Purchased	Cost	Year of Purchase
ASV Hull Form/Platform	N/A	Catamaran	Fiberglass acrylic	Custom	20$	2024
Propulsion (2 Motor)	Blue robotics	T200 Thrusters	https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/	Purchased	200$	2022
Motor Control	Blue Robotics	ESC	7-26 V 30 A	Purchased	38$	2022
CPU	NVDIA Developer	Jetson TX2	https://www.waveshare.com/wiki/Jetson_TX2_Developer_Kit	Purchased	600$	2024
Communication (Router)	Amazon	TP-Link AC2300 Smart Wi-Fi	https://www.tp-link.com/eg/business-networking/outdoor-ap/eap110-outdoor/	Purchased	40$	2022
Power System	Multiple	LiPo battery	12V , 18Ah	Purchased	39$	2023
IMU	Pixhawk	Version 4 mini	https://ardupilot.org/copter/docs/common-holybro-ph4mini.html	Purchased	160$	2024
Camera	Stereo Labs	ZED	1080p@30fps	Purchased	550$	2022
Compass	Pixhawk	Version 4 GPS module	IST8310 compass and tri-colored LED indicator	Purchased	60$	2024
Water Pump	N/A	Bilge pump	DC 12 V Water Pump 8 watt	Purchased	28$	2024
Waterproof Connectors	Blue Robotics	WLP	N/A	Purchased	12$	2024
Algorithms	N/A	MW algorithm	N/A	Custom	N/A	2024
Vision	N/A	YOLO, openCV	N/A	Custom	N/A	2024
Open-Source Software	Linux	ROS, Ubuntu	N/A	Custom	N/A	2024

APPENDIX B: MECHANICAL SIMULATIONS



Velocity flow contours of water around the hull at ASV speed 5 knots

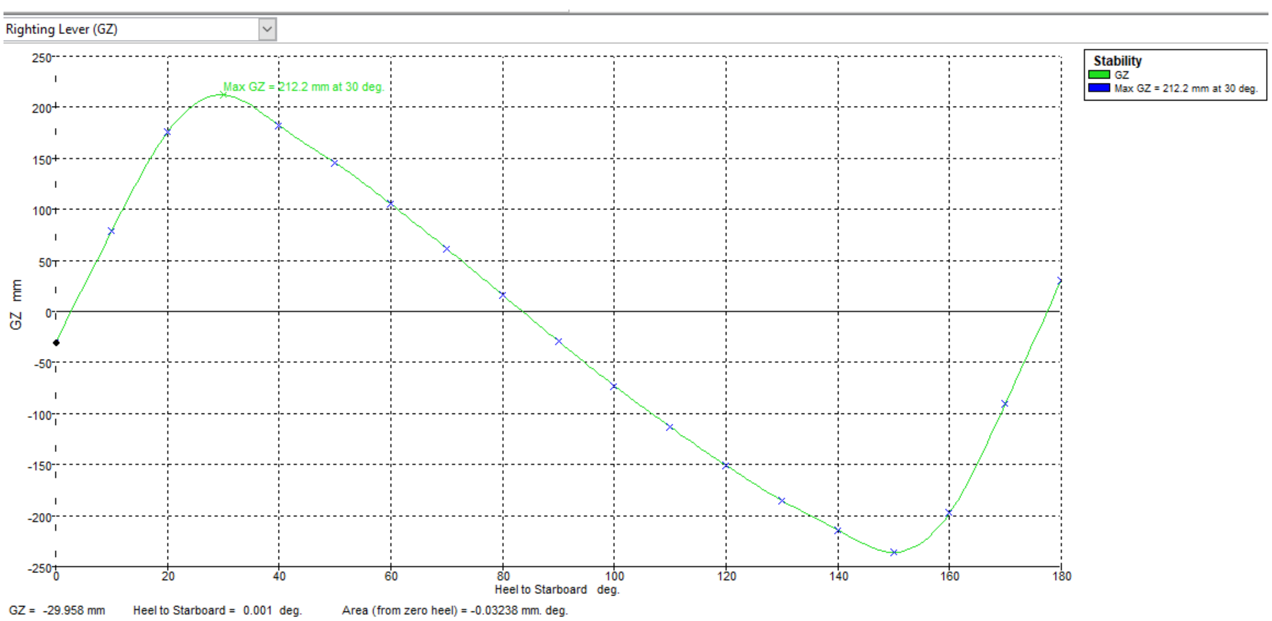


Maxsurf analysis (Resistance Vs Speed curve calculated on Maxsurf resistance)

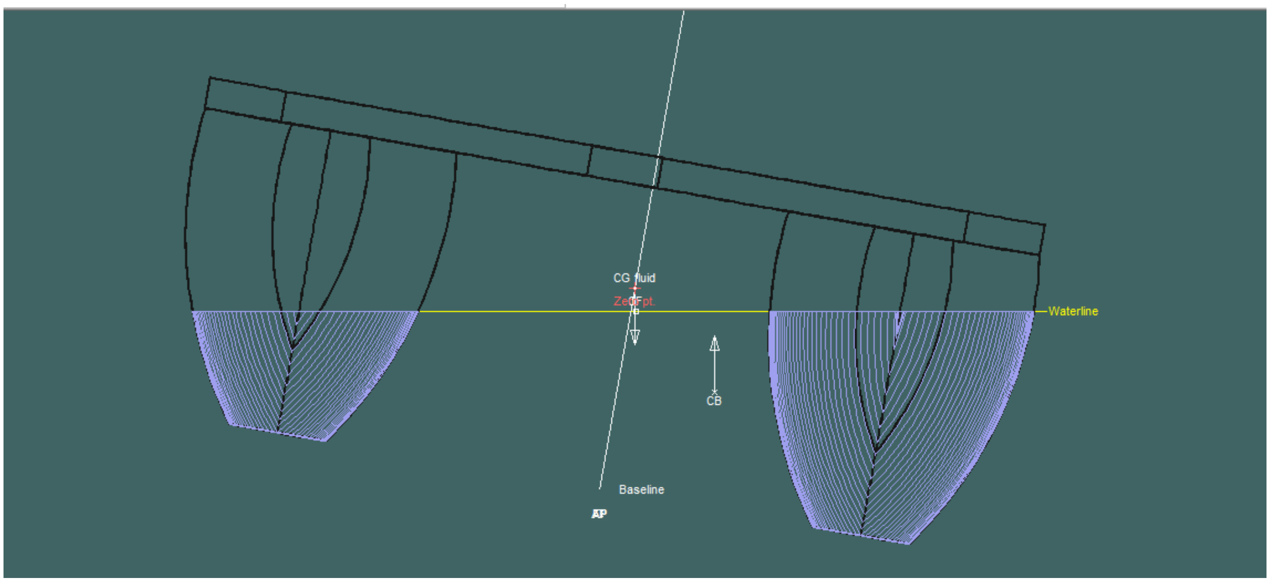
Hydrostatics at DWL

	Measurement	Value	Units
1	Displacement	28.56	kg
2	Volume (displaced)	28557.05	cm^3
3	Draft Amidships	20.00	cm
4	Immersed depth	20.00	cm
5	WL Length	91.16	cm
6	Beam max extents o	24.59	cm
7	Wetted Area	4339.49	cm^2
8	Max sect. area	410.05	cm^2
9	Waterpl. Area	1908.16	cm^2
10	Prismatic coeff. (Cp)	0.764	
11	Block coeff. (Cb)	0.637	
12	Max Sect. area coeff	0.834	
13	Waterpl. area coeff.	0.851	
14	LCB length	36.07	from z
15	LCF length	39.84	from z
16	LCB %	39.563	from z
17	LCF %	43.706	from z
18	KB	11.77	cm
19	KG fluid	20.00	cm
20	BMt	2.88	cm
21	BML	38.21	cm
22	GMt corrected	-5.34	cm
23	GML	29.99	cm
24	KMt	14.66	cm
25	KML	49.99	cm
26	Immersion (TPc)	0.002	tonne/c
27	MTc	0.000	tonne.
28	RM at 1deg = GMt.Di	-2.66	kg.cm
29	Length:Beam ratio	3.707	
30	Beam:Draft ratio	1.230	
31	Length:Vol^0.333 rati	2.983	
32	Precision	Medium	58 stati

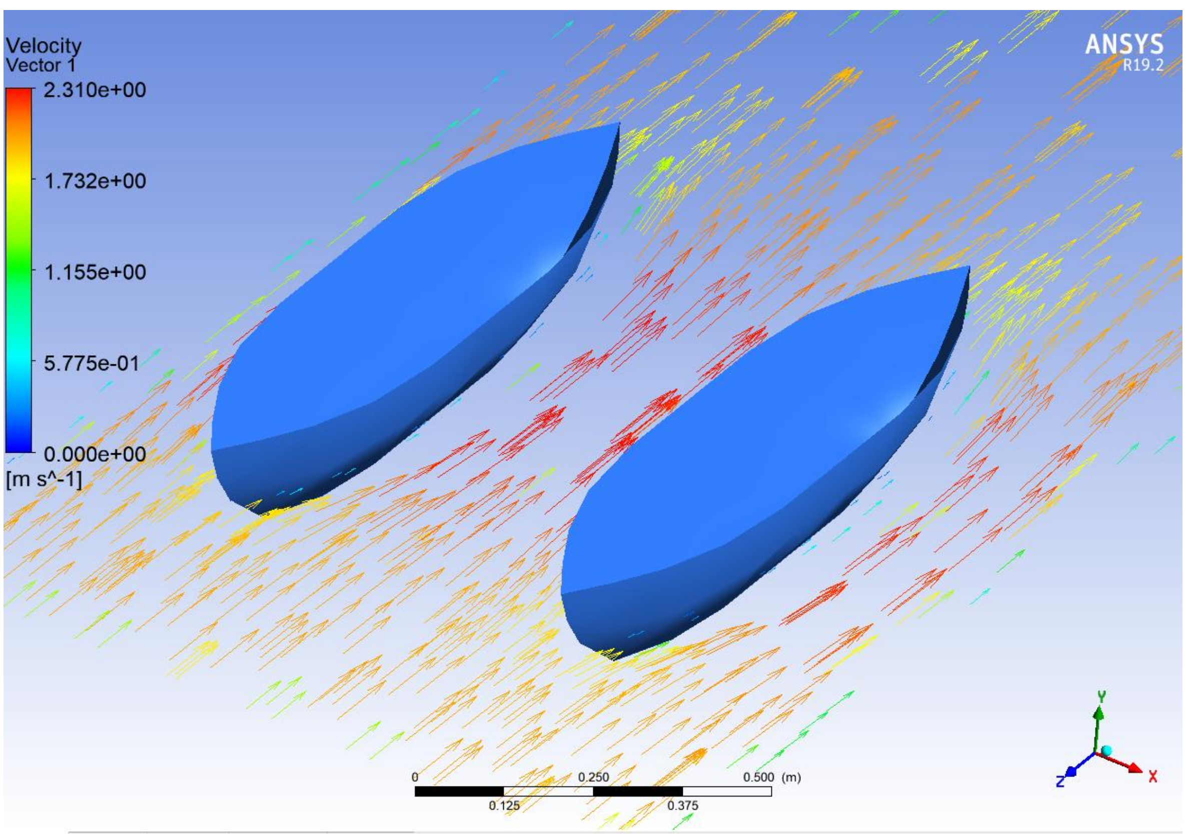
Hydrostatic Calculations (calculated on Maxsurf modeler for each hull at depth 20cm)



GZ righting moment arm curve (Max. GZ at 30 degrees heeling)

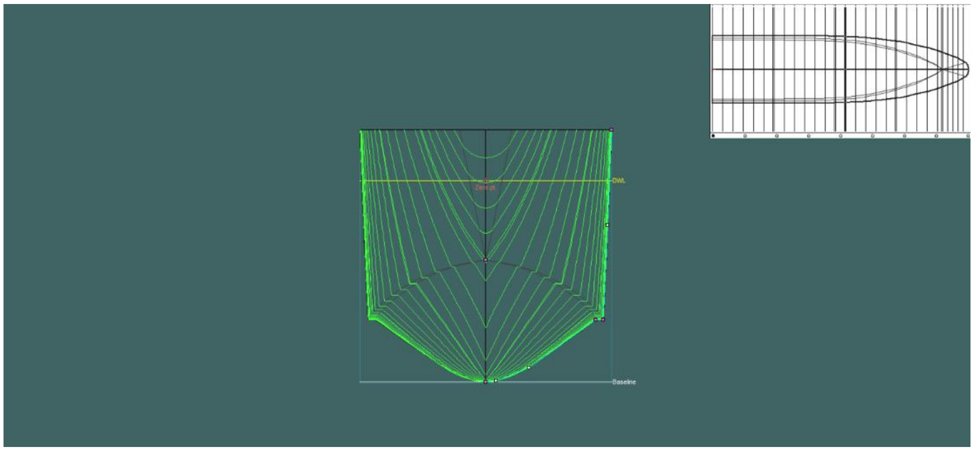


Large angle stability analysis on Maxsurf stability

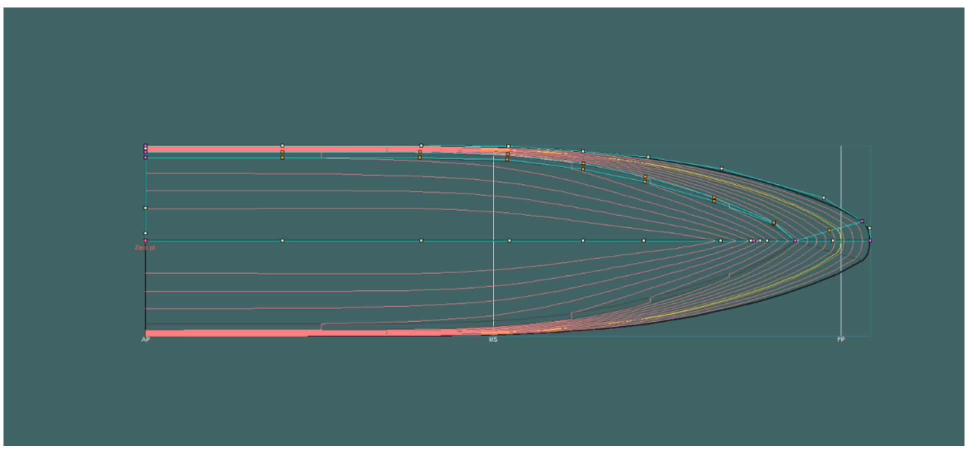


water stream lines around the hull at speed of 5 knots

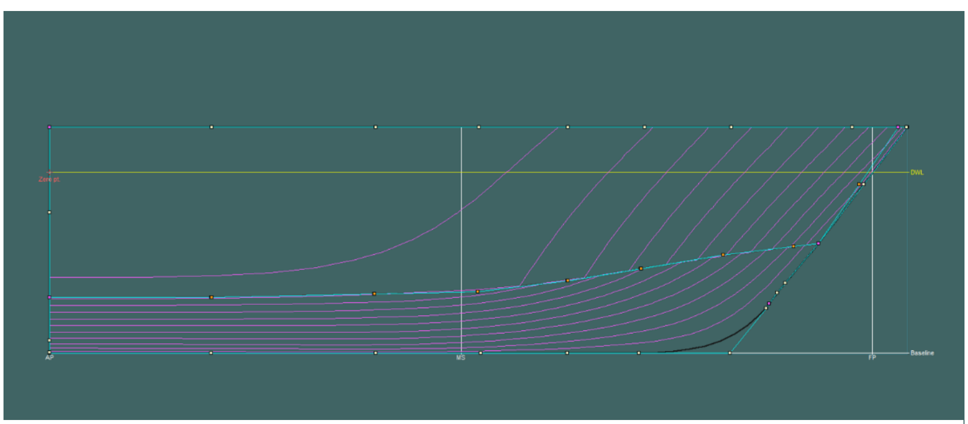
APPENDIX C: HULL'S VIEW



Body view

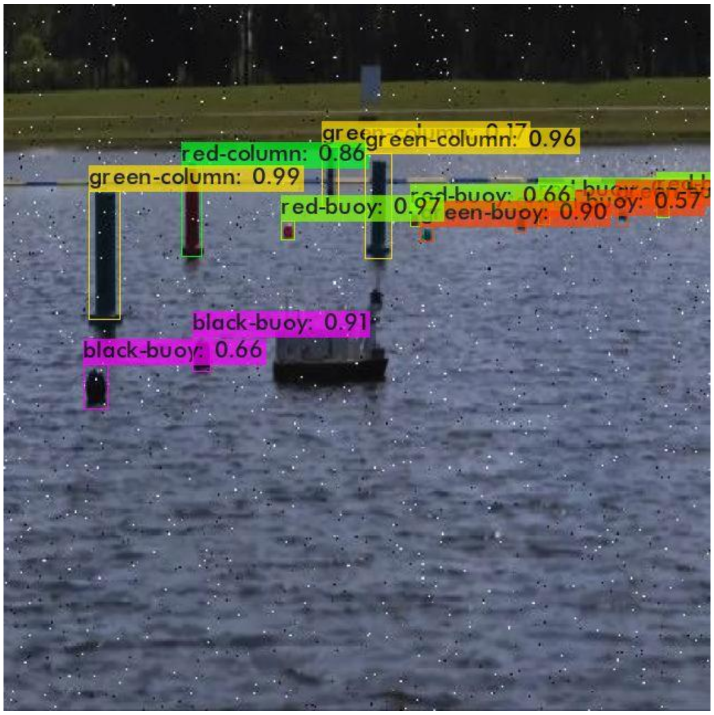


Plan view



Profile view

APPENDIX D: IMAGE PROCESSING MODEL TEST AND NAVIGATION TEST



Testing our model from Roboboat 2023 participation

Testing the navigation with waypoints