# Changing the Tide of Automated Marine Research: A Custom Autonomous Surface Vessel for the 2026 Roboboat Challenge

Jessica Besonen, Hailey Greenleaf, William Peltier, Nathan VanAntwerp, Landon Westerby, and Edoardo I. Sarda

***Abstract* – Team Autonomous Maritime Operations and Robotics Engineering (AMORE) from Lake Superior State University has developed an Autonomous Surface Vessel for the 2026 Roboboat Challenge. AMORE designed a new Autonomous Surface Vessel (ASV) to complete multiple missions. The ASV integrates a simplified perception system; a redesigned Guidance, Navigation, and Control system (GNC); and several other modular systems for Roboboat and future research. This paper outlines the design and implementation of the ASV Superior with a focus on the vessel's configuration for the 2026 RoboBoat competition.**

***Keywords – Artificial Intelligence (AI); Autonomous Surface Vessel (ASV); Light Detection and Ranging (LiDAR); Guidance, Navigation, and Control (GNC); Computer-aided design (CAD).***

## I. Introduction

Team AMORE (Autonomous Maritime Operations and Robotics Engineering) is a student-led competition team from Lake Superior State University (LSSU) located in the Upper Peninsula of Michigan that competes in various marine robotics competitions, including the Maritime RobotX Challenge, RoboBoat, and the Njord Challenge. Thanks to continuously growing support, AMORE has progressed from an entry-level to a competitive team that consistently makes progress and advancement in the field. AMORE's work has spanned five engineering senior design projects, a research course, international collaboration with other robotics institutions, and published academic research in both robotics and biology across the Laurentian Great Lakes region [1], [2], [6].

For the 2026 RoboBoat Challenge, the team is bringing a brand-new and improved ASV. This is the first RoboBoat where AMORE has fully designed and manufactured the entire vessel in-house.

## I. Competition Strategy

With the new ASV ready for competition, AMORE developed a competition strategy based on the lessons learned from previous AMORE vessels and other RoboBoat teams. This allowed AMORE to focus on developing subsystems to attempt every task for RoboBoat 2026. We incorporated multiple aspects from each design iteration of the ASV for this year's competition. Figure 1 highlights the design of the ASV that AMORE has used for each RoboBoat competition.

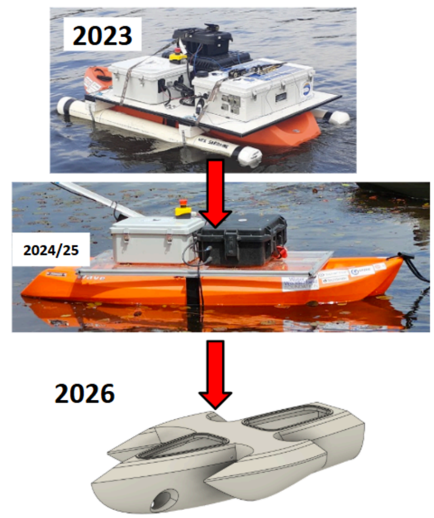


Figure 1. ASV design iterations for RoboBoat

For RoboBoat 2023, AMORE utilized the control system from their 2022 WAM-V design and adapted a kayak hull for competition use. The hull was fitted with a wooden deck and additional flotation for stability as can be seen in Figure 1.

For RoboBoat 2024, a dedicated control system was developed by AMORE for the ASV and was mounted onto a hull and deck that was developed in partnership with Florida Atlantic University (FAU). Working with FAU clearly showed the importance of properly developing a hull.

The RoboBoat 2025 iteration introduced an upgraded main processor while retaining many of the proven components from the 2024 system. A newly designed deck constructed from 6000-series aluminum extrusion was implemented to support the expanded hardware and improve modularity while reducing weight and drag. Significant improvements were also made to the perception system during this iteration.

Building on these developments, the current ASV design draws inspiration from both AMORE's previous vessels and successful competitor platforms. The vessel is intentionally over-actuated, which enables greater maneuverability and finer control during complex navigation tasks. AMORE's software plans to leverage this new mobility to execute maneuvers in tighter spaces and reduce the risk of collisions.

Throughout each competition, the perception mast, consisting of a LiDAR and stereo camera, has stayed the same. However, the Jetson Tx2, used for vision processing, was replaced with a more powerful processor, the Jetson Orin AGX.

Using the ASV's built-in perception system, the vessel will be able to locate and identify each of the buoys in Task 1. AMORE's Path planner will then determine the quickest and safest route to navigate through each obstacle. Our pathplanner then stores the location of each gate and the time taken to reach each obstacle to the judges.

The ASV's approach to Task 2 uses the same fundamental components. With the inclusion of black buoys and vessels for another task, the pathplanner will store the location of each found object on the water. Each task provides the vessel with more data to safely navigate to and from each task. The fully created map is then used in Tasks 4,5,and 6 to safely approach the competition area. For example, once an audio signal is received from the harbor in Task 6, the path planner uses the pre-built map to find the best way to approach the marina or emergency response zone based on the signal received.

## II. ASV DESIGN STRATEGY

The hull of the ASV was custom fabricated to best suit the purpose of the competition; it is mostly composed of an internal structure consisting of several layers of extruded polystyrene foam carved to shape on a three-axis CNC router and a fiberglass skin. The "skeleton" was chosen to be made out of foam for its low weight, ease of cutting, and high strength relative to its weight. The fiberglass "skin" offers rigidity and impact resistance while being impervious to corrosion and easy to form over the complex curves of the hull. Despite being the first vessel entirely designed and built in-house, the vessel performs much better compared to the previous iteration due to the inclusion of two additional thrusters. $Fy_{STRN}$ and $Fy_{BOW}$ in Figure 2 represent the two new thrust vectors acting on the ASV.

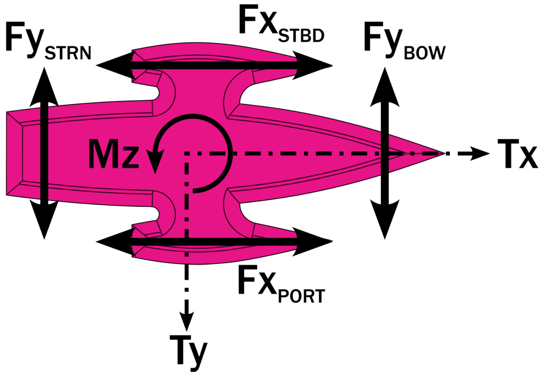


Figure 2 . Free Body Diagram of forces acting on ASV

Advantages over the preceding vessel include better hydrodynamic efficiency, increased payload and battery capacity, and flexibility in accessories and instrumentation. On the base hull, AMORE has added a variety of systems for unmanned operation. The first being the GNC system seen in section A. Section B explains the ASV motion with the propulsion system and its control. The perception system in Section E, including vision, enables the ASV to make decisions based on its surroundings. The communication system (section D) allows monitoring of the ASV from shore. There is also a safety system built natively into AMORE's GNC system. A model of the hull design of the ASV for RoboBoat 2026 is shown in Figure 3.

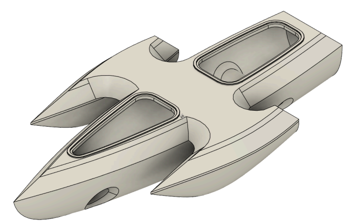

Figure 3. ASV design for RoboBoat 2026

### *A. Guidance, Navigation, and Control System*

The GNC box is located inside the vessel and is responsible for all communication aboard the ASV. The GNC box (Figure 4) houses the first Jetson Orin AGX computer, a Teensy 4.1 microcontroller, a Pixhawk 6C flight controller, and the integrated safety system. The main function of the GNC box is to act as a management device for all sensors and components aboard the ASV. This is achieved using Robotic Operating System (ROS) as middleware to communicate between various sensors and components in software. Using ROS, the low-level controllers aboard the ASV have access to vital peripheral data, such as the current GPS location, that may be used to dynamically adjust the propulsion system's output to reach a desired state and respond to changing environmental conditions. This setup should allow the ASV to achieve accurate and reliable movement, essential for tasks such as navigating complex waterways, performing scientific data collection, and conducting autonomous operations.

Acting as the GNC Box's master controller, an Arduino Teensy 4.1 is part of a larger battery monitoring system (BMS) board. The PCB also includes the Radio Link receiver directly on board. The design of the PCB centers around its modular design allowing it to control the ASV Superior and other vessels within AMORE's fleet (Figure 5). Because of this, the board requires two 12V batteries for power, while the rest of the system requires 24V power to be distributed to the thrusters, and other onboard components.

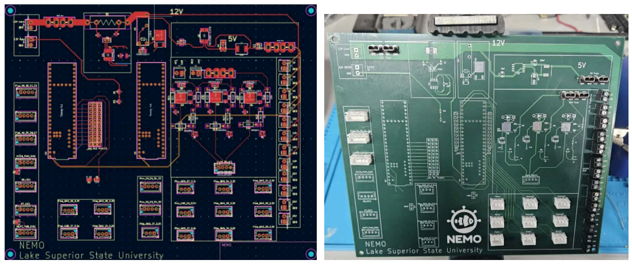


Figure 5. ASV Superior's Battery Monitoring and GNC PCB Footprint and Initial Prototype

### *B. Propulsion and Control*

Thrust and directional control is provided to the ASV through several different thrusters. Main forward thrust is provided by two large thrusters (Figure 6, Right) located amidships on the outside hulls. This placement allows for effective turning authority through the use of differential thrust, as well as simplifying the computation necessary for precise control. While these main thrusters are more than sufficient for normal operation, their use alone does not allow for accurate station-keeping or side-to-side motion. To overcome these shortcomings, the ASV is outfitted with two smaller thrusters (Figure 6, Left) located on the front and rear of the hull and perpendicular to the direction of the main thrusters. All maneuvering of the ASV is achieved through a series of four thrusters in a cross-shaped configuration. This eliminates the need for any mechanical solution which could compromise the reliability and watertightness of the hull.

Figure 6. Thruster used on the ASV

In order for the ASV to operate autonomously, a low-level controller is required to dictate the behavior of the vessel while operating in autonomous mode. There are two separate Proportional Integral Derivative (PID) controllers that fill this role. During waypoint navigation, a Heading and Speed controller utilizes the thrusters with differential thrust, providing sufficient speed and maneuverability. For Station keeping, the thrusters operate similar to the Heading and Speed controller, using differential thrust to maintain position and heading.

### *C. ROSBOAT Low-Level Software Package*

Over the past four years, the design of AMORE's low-level control architecture has been a recurring challenge. In previous iterations, significant effort was required to implement and maintain low-level control, often limiting progress on higher-level autonomy, perception, and path-planning systems.

For the 2026 season, AMORE's sponsor, Aquairyx, provided an adaptable low-level control software package that significantly reduces this development burden. ROSBOAT package manages core hardware and control functions, including:

- Initial subsystem start up (Camera, Lidar, PID Controllers).
- Communication between the GNC PCB Teensys and ROS2.
- Reads current,voltage, and amperage outputs from the battery.
- Uses task data provided from the mission control software module to decide how to approach the task (Heading and Speed control, Station Keeping control, Monitoring surrounding objects for future use).
- Takes in a Goal Point from the Path Planner Software.
- Uses ROSBOAT's built-in auto-tuning PID controllers to output thrust values for the ASV to use. [8]
- Creates a graphical display (GUI) that can show the ASV's current state and incoming data from onboard peripherals.

With these portions of the software being covered by the provided ROSBOAT package, AMORE will be able to focus on to the higher level of automation and design.

### *D. Perception Subsystem*

The transition to a new ASV platform required a redesign of AMORE's perception subsystem. The standalone Vision Box used during the 2024–2025 competitions was incompatible with the new vessel due to legacy hardware dependencies and the absence of a dedicated mounting location. As a result, the perception architecture was simplified and integrated into a centralized in-hull GNC enclosure. AMORE's Perception system primarily consists of two modular components: The Jetson Orin AGX [7] for processing incoming data, and the perception mast. The perception mast is designed around a VLP-16 LiDAR (1) and a Zed 2i stereo camera (2) as seen in Figure 7.

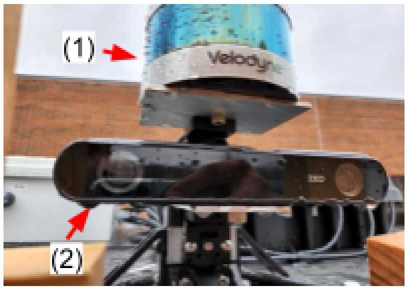


Figure 7. Perception mast previously mounted on Team AMORES's WAM-V

The perception subsystem serves as a primary source of information for the ASV's autonomous systems. The perception system is able to identify objects near the ASV, localize the found objects in reference to the vessel, and generate a 2-dimensional map of the 180° area immediately surrounding the bow of the ASV.

Previous senior project teams have had mixed success with implementing darknet YOLO v3 and v11 object detection algorithms [7]. However, these tests were extremely limited by the collection and processing capabilities of their perception subsystem.

AMORE's recent senior project researched and compared different up to date Object Classification models for AMORE. The team found RF-DETR as the best choice for the design. [7] Looking at the performance metrics of the RF-DETR model, it currently performs better than YOLO's most recently published model version 12 and many other models.

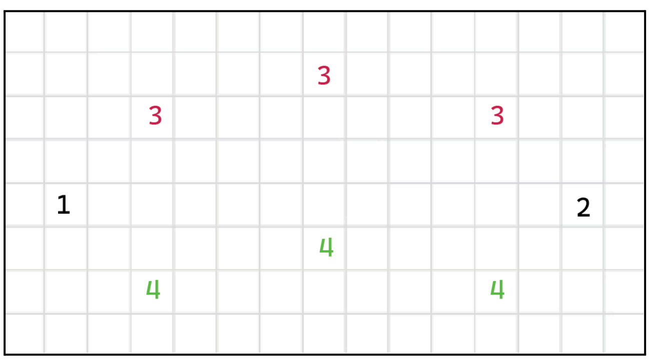


*Figure 8. Example Initial Map Generated by the AI Vision and LiDAR Data Fuser Software*

In order to support autonomous navigation, fused Artificial Intelligence (AI) vision and filtered LiDAR outputs are used to identify and classify all detectable objects in the ASV's field of view. These objects are encoded into a grid-based map represented as an integer matrix, where each object type, like the various colors of buoys and light indicators, are assigned a unique identifier. This representation allows the path planner to efficiently reason about object type and location during route generation (see Figure 8).

### *E. Mission Controller and Path Planning*

For the ASV to complete the navigation of missions, it must be able to navigate around the water without hitting obstacles, and sometimes maneuver between specific obstacles. The perception system of the ASV, as previously mentioned, utilizes a blend of LiDAR and AI vision data to create a two-dimensional map of the surrounding water surface. The method by which the ASV calculates the optimal route through this map is a system called path planning. A specific objective of the ASV is to navigate through a channel on the water's surface, demarcated by green and red buoys (and avoiding black buoys, by some margin), as pictured below.

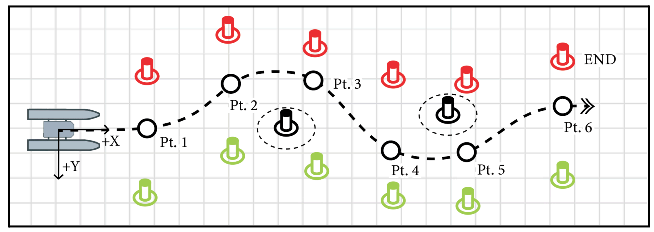


*Figure 9. Example channel navigation*

Several types of path planning algorithms are frequently used in the maritime robotics domain, some of which employ different methods for organizing search. AMORE's senior project will focus on using graph-based search algorithms since they employ a grid-based search map. This meshes well with the characteristics of GPS coordinates (longitude and latitude), as well as the local Cartesian coordinates of the ASV (XY plane). There are a few worthy choices for graph-based path planning, including: A* (A Star), Dijkstra's Algorithm, and D* (D Star). Of these three, the D* algorithm makes the most sense for the kind of navigation the ASV will be doing.

Dijkstra's algorithm is basic, but slow, and is best used when the navigational map is static and the goal is known from the beginning. A* is very widely used and accompanies a multitude of existing resources for its implementation, and it is faster than Dijkstra's. Still, it also works best when the map is totally or nearly static, which may or may not be the case in the maritime environment where buoys and boats are moved by waves, wind, and current. Finally, the D* algorithm includes a computationally more efficient planning sequence, accommodates a dynamically updating map environment, and is also very commonly used in robotics. An example of D* path planning is shown in Figure 10. [7]

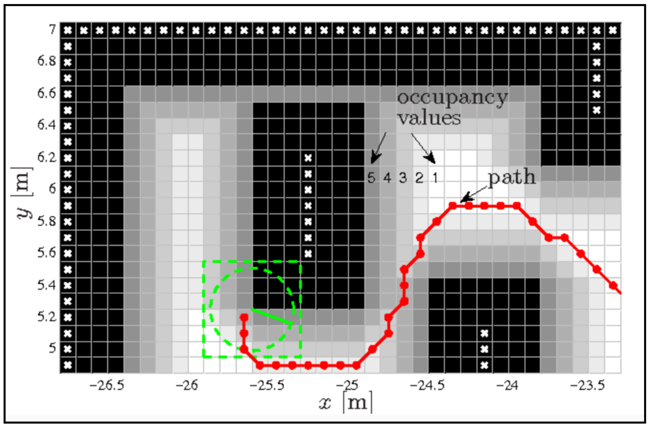


*Figure 10. D* algorithm path planning example*

The mission controller module acts as the ASV's hierarchical head of autonomous software. It is responsible for selecting the ASV's current task and determining the following steps to achieve the current objective. The user will be able to select which task to proceed with before the autonomous mode is officially engaged. Once the mission controller receives confirmation from the ASV's hardware that autonomous mode is active and the system is not in an unsafe state (hardware or software E-Stop), it can proceed with the task at hand. Based on the user's selection, the system will use the onboard perception hardware and software to provide data to the path planner. The mission controller's main focus at this stage is to decide which objects need to be marked, navigated to, or avoided.

## IV. TESTING STRATEGY

In order to guarantee Competition readiness, Team AMORE conducted a comprehensive testing campaign on the ASV's critical subsystems, with emphasis on propulsion, control, and perception systems. Both the propulsion and perception subsystems were significantly updated for RoboBoat 2026, making validation essential to overall mission success.

### *A. Propulsion and Control*

Extensive on-water testing was performed to validate the propulsion system under conditions representative of competition environments. Testing with a full operational payload in strong winds and currents enabled evaluation of system robustness and highlighted areas for refinement.

Stress testing was originally planned to be conducted on the St. Marys River in Sault Ste. Marie, MI, providing realistic environmental disturbances for controller evaluation. However, the rough winter weather and freezing of Lake Superior made it impossible to test full system integration on a larger body of water. While the development of AMORE's new hull continued, data collected on previous designs informed tuning and optimization of the propulsion controls, improving system stability and performance under high stress. These tests also provided insight into expected performance at the RoboBoat 2026 venue in Sarasota, FL. Following validation of the propulsion hardware, a structured testing plan was developed to verify low-level control performance during on-site operations in Sarasota. This plan is summarized in Table 1.

Table 1. Propulsion and Control system testing plan

| Step | Description | Focus | Validation |
|---|---|---|---|
| 1 | Dry Testing | Controller Response | Thruster and ROS functionality |
| 2 | Dry Testing | Vision Integration | Trajectory Generator Output |
| 3 | Pool Testing | Heading and Speed | PID controller output |
| 4 | Pool Testing | Station Keeping | PID controller output |
| 5 | On-site Testing | Heading and Speed | ASV Behavior and PID controller output |
| 6 | On-site Testing | Station Keeping | ASV Behavior and PID controller output |
| 7 | Dry Testing | PID Controller Switching | PID controller output |
| 8 | Pool Testing | PID Controller Switching | PID controller output |
| 9 | On-site Testing | PID Controller Switching | ASV Behavior and PID controller output |
| 10 | Pool Testing | Vision Integration | Trajectory Generator Output |
| 11 | On-site Testing | Vision Integration | Trajectory Generator Output |

With the hull fabrication still under way, AMORE planned to test steps 1-4 independently on campus to prove their functionality before heading to Sarasota. These tests were able to be performed during the winter months, while we prepared for our final tests on-site in Florida.

### *B. Perception*

A new perception architecture, including an upgraded vision processor, was integrated into the ASV and required thorough validation. Initial testing was conducted in simulation using Gazebo and the Virtual RobotX (VRX) environment. Gazebo is an open-source robotics simulation platform, while VRX extends Gazebo with maritime-specific environmental models, including wind, current, and competition-relevant objects such as buoys and light stacks [4]. These tools were used to validate buoy detection algorithms under realistic conditions. Simulation results confirmed reliable buoy detection, as shown in Figure 11.

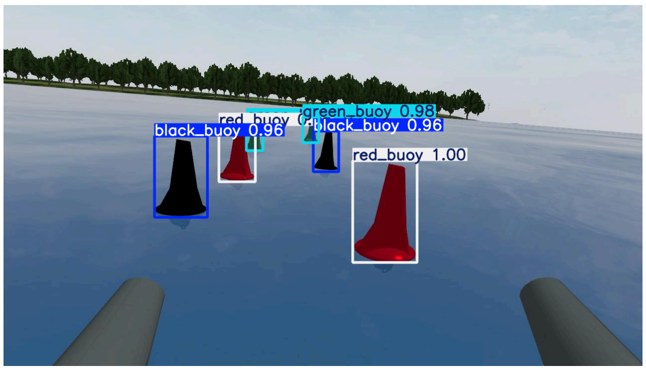


Figure 11. Simulated Object detection of multiple buoys performed before Pool Testing

Subsequent in-water testing was performed to validate real-world perception performance. The ASV was deployed with red and green buoys positioned to replicate gate configurations used in RoboBoat and RobotX competitions. The system successfully identified buoy color and relative position, with the green buoy on the starboard side and the red buoy on the port side.

Figure 12. Annotation of extra competition datasets for AMORE's AI vision models

With buoy detection trained (see Figure 12), path planning performance was evaluated using a gate configuration representative of dynamic channel navigation tasks [3][5]. Real-time planner outputs confirmed successful buoy localization using LiDAR and stereo vision, color classification, and midpoint generation between the buoy pair. The ASV navigated to the computed waypoint, demonstrating correct integration of perception and planning. Based on these results, the perception system was deemed competition-ready for RoboBoat 2026.

## V. CONCLUSION

The ASV Superior highlights multiple years of lessons learned from both inside and outside of competition. AMORE leveraged the skills found within the team, to ensure the reliability and operation of the new vessel for many years to come. With the new robust systems on-board and rigorous testing performed before competition, the ASV is ready to demonstrate AMORE's success at Roboboat 2026 and in future marine robotics research opportunities.

## VI. ACKNOWLEDGEMENTS

Team AMORE would like to thank Lake Superior State University and the Sault Ste. Marie Tribe of Chippewa Indians for continuing to support and allow us to attend competitions across the world. Ranging from the donation of supplies for the team to use, to volunteering transportation methods and funding new opportunities. AMORE wants to express our gratitude to all our sponsors who have provided the funds and equipment which has allowed the team to compete at RobotX, RoboBoat, and Njord. In addition, the team would like to thank the LSSU School of Engineering and Technology for providing laboratory space, equipment, and software; and to all the faculty for providing ongoing technical expertise and encouragement.

A massive thanks to our faculty advisor Dr. Edoardo Sarda for his indispensable support in technical contributions, cooking, and assisting wherever he possibly can; and finally to our community for their never-ending support and assistance in attending competitions.

## VII. REFERENCES

[1] X. Vicent, C. Wilson, E. I. Sarda. "Accurate Autonomous Launch and Recovery of an UAV from a Station Keeping USV." In IEEE Oceans Halifax, Sept 2024.

[2] Z. Kassuba, M. Goldenbogen, C. Jannetta, X. Vicent, E. I. Sarda. "Development of a Water Quality Monitoring System on a USV." In IEEE Oceans Halifax, Sept 2024.

[3] RoboNation. (2024). RoboBoat 2026 Team Handbook. [Online]. Available: https://robonation.gitbook.io/roboboat-resources/section-3-autonomy-challenge/3.2-task-descriptions

[4] B. Bingham *et al.*, "Toward maritime robotic simulation in Gazebo," *OCEANS 2019 MTS/IEEE SEATTLE*, Oct.

2019. doi:10.23919/oceans40490.2019.8962724

[5] RoboNation. (2024). RobotX 2024 Team Handbook v2. [Online]. Available:https://robonation.org/app/uploads/sites/2/2024/09/2024-RobotX_Team-Handbook_v2.0.pdf

[6] J. Besonen, H. Greenleaf, C Jannetta, C. Bohm. "Developing Autonomous Systems: Undergraduate Students Conduct Marine Technology Research" In The Journal of Ocean Technology, V20N2 - Ocean Monitoring Keeping Watch. 2025 Avalible: https://www.thejot.net/article-preview/?show_article_preview=1637

[7] "Team NEMO Design Review Technical Packet", *J. Besonen, C.Brehm, L. Mandoka, V. Parodi, J. Rodriguez*, Nov. 2025.

[8] X. Vicent, "PID AUTO-TUNING FOR USVS: A MULTI-EVOLUTIONARY OPTIMIZATION AI APPROACH" (2025). Electronic Theses and Dissertations. 14. [Online]

https://digitalcommons.fau.edu/etd_general/14