RoboSub 2025 Technical Design Report

Widener University

Mateo Stipe, Felipe Lafosse, Isaiah Moreef, Ronald Carr, Hunter Ward, Patrick Darrah, Xiaomu Song, Bruce Weinberg

Abstract - This design report presents the latest developments made by the Widener University's Pride Team to the AUV (Voyager) in preparation for RoboSub 2025. Substantial enhancements have been made to AUV for hardware and software. For hardware, a larger electronic enclosure is used to accommodate a newly added communication cable. An additional vision camera was added facing downward to monitor the operation of the gripper. The AUV body frame was redesigned to improve weight balance and component modularity. For the software, a new motion control algorithm was implemented that integrates information from multiple sensors to enhance autonomous navigation and motion control.

I. Competition Strategy

As the second team from Widener University to attend the RoboSub Competition, we inherited the AUV from last year's team, and renamed it to be "Voyager". We have further developed its design to engage in four of the six challenges in RoboSub2025. These challenges include Collecting Data, Navigate the Channel, Drop A BRUVS (baited remote underwater video system), and Return Home. The completion of each challenge will heavily depend on Voyager's capability to utilize its vision and motion control algorithms to dictate the output control of its thrusters.

A. Collecting Data

Once Voyager has chosen a marine life image to recognize, it will change its course heading and position to move forward into the gate. This will also be assisted by its detection of the red and black colors on the vertical poles of the gate.

B. Navigating the channel

After the first challenge is completed, the AUV will then advance to this next obstacle setup. For it to maneuver through the PVC pipe channels, Voyager will perform its detection of the red and white pole pairs to keep the AUV at the midpoint of each pair as it advances forward through the task.

C. Drop a BRUVS

With the markers in the closed hand of the gripper, Voyager will utilize the second downward facing camera and track its own position to ensure the gripper arm is directly above the drop zone for the markers to fall in once released.

D. Return Home

Voyager will return to the start position by reverting its heading 180 degrees to repeat the use of the algorithms that surpassed the channel and start gate.

II. Design Strategy

A. System Level Design

The development of the AUV was structured around three core components: hardware, software, and electronics. This approach provided a clear framework to ensure the AUV met essential design criteria, including full autonomy, submergibility, and secure housing for all operational electronics.

(1) AUV Assembly

Considering the RoboSub 2025 Vehicle Requirements, the AUV must fit within the dimensions of 3ft × 3ft × 6ft and remain less than 125 lbs. Our vehicle has dimensions of 2.5ft x 1ft x 1.5ft and is weighted at approximately 30 lbs. The frame of the AUV was designed to have a vertical orientation of the two enclosures containing our electronics while keeping the vectorized modular configuration for the 6 thrusters. Four thrusters are mounted on the corners at 45° from forward, and two additional thrusters on the sides are oriented vertically for up and down motion. This orientation of thrusters enables the AUV to potentially have 5 degrees of freedom. Figure 1 is a picture of the fully assembled AUV taken underwater at Widener University's swimming pool.

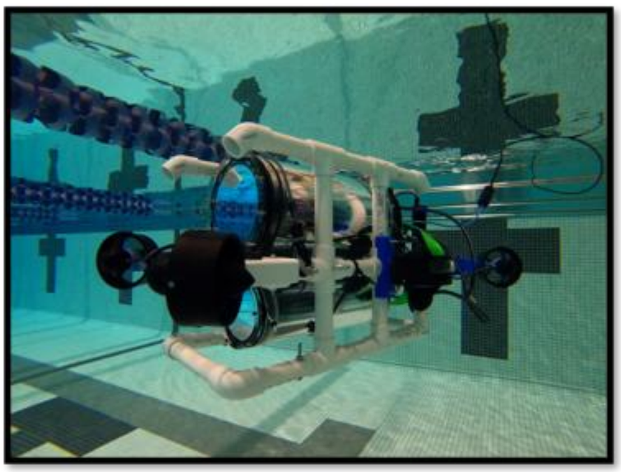

Figure 1. Fully assembled AUV

(2) Hardware

The AUV uses a PVC frame to mount the thrusters, the two acrylic enclosure cylinders, the cameras, and the gripper, as shown in Figure 2. Four thrusters are aligned at 45 degrees to control planar translation and orientation while the two middle thrusters control depth. With the enclosures, held by our two housing mounts, the six-inch cylinder on top houses the AUV's onboard microprocessors and sensors along with their interconnected wiring while the four-inch cylinder at the bottom contains the battery and the magnetic kill switch contact.

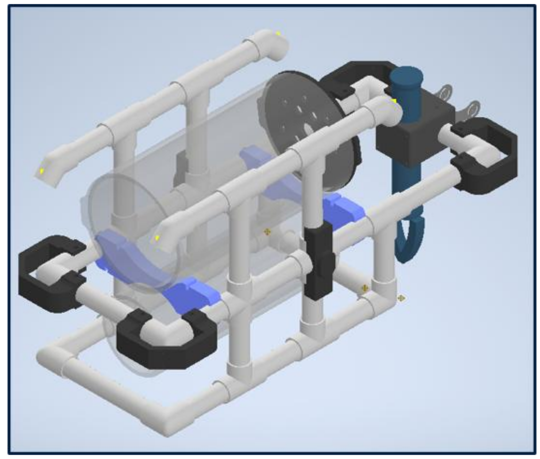

Figure 2. CAD design of the AUV body

The electronic housing unit, which is shown in Figure 3, holds all significant electronics in the six-inch enclosure, including the onboard microprocessors, front camera, and other accessory circuitry. The smaller four-inch enclosure underneath contains the two lithium polymer batteries and has a similar design to the electronic housing as it has a platform in the middle of the enclosure to hold the batteries and the anti-spark switch.

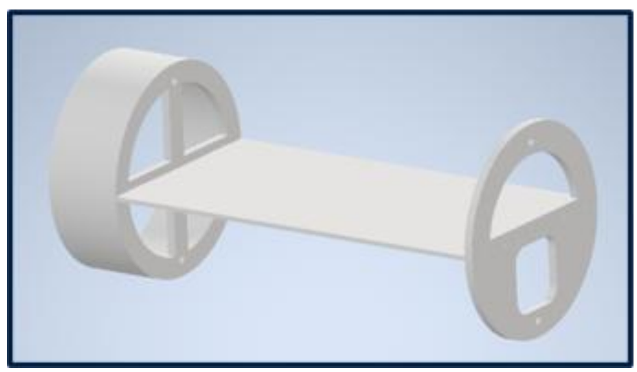

Figure 3. CAD design of electronic housing

All wires channel through the back of the housing units and out of the enclosure caps through these cable glands shown in Figure 4.

Figure 4. Cable glands

(3) Electronics

The AUV is controlled by two Raspberry Pi 4's, as shown in Figure 5. These microprocessors, adopted from the previous team's design, are used to process all sensor data, make decisions, and send control signals to the electric speed controllers (ESCs) shown in Figure 6. The BLHeli_S ESCs utilize pulse width modulation (PWM) signals to control both the speed and direction of the Thrusters. In this project, six Blue Robotics T200 thrusters (Figure 7) are used to provide thrust to maneuver the AUV. The dual microprocessor setup enables efficient sensor data steaming and real-time onboard processing, where one manages all I^2C device, inertial measurement unit (IMU), hydrophone, depth sensor, and ESCs, while the other receives and processes visual data acquired from the two vision sensors.

Figure 5. Raspberry Pi 4 onboard microprocessor

Figure 6. Electric speed controller (ESC)

Figure 7. Blue Robotics T200 Thruster

The network router shown in Figure 8 establishes a local network for the two onboard microprocessors to communicate via ROS2 data messaging.

Figure 8. Onboard router

Two vision sensors are used to detect and identify underwater objects and colors patterns.

As shown in Figure 9, the front camera is mounted within the housing unit at the end of the six-inch enclosure, oriented toward the front of the AUV. The rear camera, depicted in Figure 10, is positioned alongside the gripper at the back of the AUV to provide visual feedback for object collection.

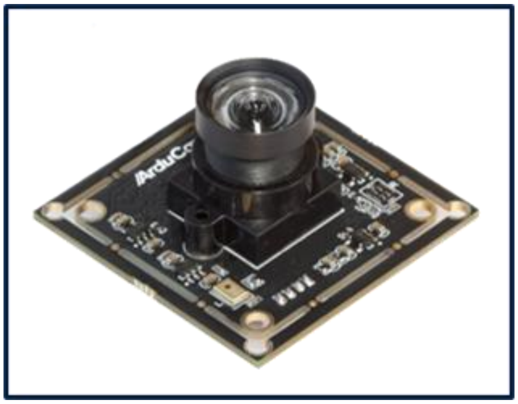

Figure 9. Front vision sensor

Figure 10. Rear vision sensor

Figure 11 shows ICM20649, a 6-DOF IMU sensor capable of measuring linear acceleration and angular velocity. It is used to determine the current heading direction of the AUV.

The Blue Robotics depth sensor (Figure 12) measures current depth in meters based on sea pressure. It is used with the IMU sensor to provide motion and position

Figure 11. IMU sensor

Figure 12. Depth sensor

The Aquarian Hydrophone H2C is a submersible microphone, purposed for detecting sonar pings for competition. Associated with the hydrophone is an analog to digital converter (ADC) that converts the original hydrophone raw signal into digital signal that can be processed by the microprocessor. It was decided that the hydrophone won't be utilized for this year's competition, as the AUV is unable to participate in the ocean cleanup task, which requires the integration of two or more hydrophones. This configuration is not implementable due to the current budget constraints.

Two lithium polymers rechargeable batteries (Figure 14) are placed in the four-inch cylinder to provide power to the six thrusters. A third power bank is used to supply power to the two onboard microprocessors and all connected sensors. This power bank was chosen because of its high capacity and compatibility with the required port types.

Figure 14. Onboard rechargeable battery

(4) Software

The software is developed in Python and operates on the Robot Operating System 2 (ROS2) middleware, deployed on each Raspberry Pi. Both microprocessors run ROS2 on the latest Ubuntu Linux OS to ensure compatibility with the newest ROS features. The processing of sensor data, such as depth, IMU, and cameras, is implemented in ROS nodes, which publish the processing results to the motion control and navigation node, which determines the AUV's movement.

All non-vision sensors are connected to a dedicated microprocessor, referred to as the "Driver," via the I^2C communication protocol. The two cameras interface with the second microprocessor, named the "Navigator," using USB connections. These microprocessors are linked through an Ethernet connection and communicate using ROS2 nodes to publish information data to each other. The Navigator is responsible for image processing, while the Driver handles decision-making based on sensor inputs and image processing results. The Driver also generates appropriate movement commands to control the six thrusters via ESC.

III. Testing Strategy

The AUV was tested at the swimming pool of the Widener University Athletic Center. The test evaluated both the structural integrity and underwater performance of the hardware design, as well as the reliability of data communication between the two onboard microprocessors and sensors. These efforts were essential to ensure that the electronic system and thrusters function effectively for the selected competition tasks.

A. Waterproofing

One of the primary challenges in developing the AUV is ensuring effective waterproofing for the onboard electronics and batteries. This design utilizes acrylic waterproof enclosures, with all wiring routed through one end of each tube using IP68-rated cable glands to maintain a watertight seal. Silicone grease is applied at the interface between the cable glands and the tubes for additional protection. The AUV's frame is constructed from PVC pipe, designed to securely support both acrylic enclosures and six thrusters. Drainage holes are deliberately incorporated into the PVC frame to allow water to flow freely in and out, preventing unwanted water retention and simplifying buoyancy management.

B. Buoyancy

The AUV's design incorporates two sealed acrylic waterproof tubes filled primarily with air, along with a lightweight PVC pipe frame, resulting in high overall buoyancy. To achieve near-neutral buoyancy and maintain stability, approximately 7 pounds of segmented steel weights were added within the PVC frame. Additionally, the larger six-inch acrylic tube is mounted above the smaller four-inch tube. This configuration leverages the greater buoyancy of the upper tube to lower the center of mass and prevent the AUV from tipping, thereby enhancing its overall stability in the water.

C. Sensor Integration and Fusion

Since all sensor inputs are integrated within the ROS2 environment, the AUV's capability to acquire and process sensor data was evaluated under both stationary and dynamic conditions. The AUV utilizes depth and IMU sensors to stabilize and correct its movement, enabling it to either hold a fixed position or maintain a set trajectory. A desired depth is achieved by comparing the current depth to a target value, allowing the motion control and navigation node to calculate the appropriate thrust duration and power for the two vertical thrusters. The IMU provides real-time heading information, with zero degrees calibrated to the initial orientation along the Z-axis, defined as the vertical axis perpendicular to the forward-facing direction of the AUV. These measures are updated and processed in real-time under the ROS2 environment. During the swimming pool test, the AUV can maintain stability when in motion.

Both vision sensors can detect object colors and generate control messages for thruster response. OpenCV functions are employed to identify object dimensions and colors, enabling reliable recognition of rectangular gates and PVC pipes modeled after competition task elements. Upon successful identification of target objects, Navigator communicates with Driver to direct the thrusters and maneuver the AUV accordingly to navigate or avoid the approaching obstacle.

D. Thruster Control

The AUV is equipped with a total of six thrusters for maneuvering. The two centrally located thrusters are responsible for changing or maintaining the depth, while the remaining four thrusters are positioned at each corner of the AUV, angled inward at 45 degrees, and purposed for horizontal motion control. This configuration enables translational movement with three degrees of freedom and rotation about one axis. By dynamically adjusting depth, heading, throttle speed, and thruster direction, the AUV is able to maneuver effectively in response to task requirements.

During the swimming pool tests, the AUV successfully navigated around obstacles by adjusting its depth, advancing forward, and altering its heading. Additionally, a self-correction feature was implemented, enabling the thrusters to autonomously stabilize the vehicle and compensate for external disturbances during operation.

IV. Conclusion

Team Pride from Widener University has successfully designed and constructed an autonomous underwater vehicle (AUV), named Voyager, for participation in the RoboSub 2025 competition. This marks the team's second entry into the competition, following four years of dedicated development. Voyager is equipped with a vectorized thruster configuration, multiple onboard sensors, and microprocessors, enabling it to execute fundamental navigation and object recognition tasks.

Testing at Widener University's swimming pool has successfully validated the AUV's watertight integrity, electronic system performance, and thruster control. Additionally, the trials revealed opportunities for future enhancements, including the integration of torpedo-launching capabilities and the addition of two hydrophones to expand AUV's functionality.

Acknowledgements

We would like to thank the US Naval Surface Warfare Center Philadelphia Division STEM program, Widener University School of Engineering, Christopher Hallahan, Mark Yankovich, Aaron Selnick, Salient Makia Nkongho Enoh, Brayden Akins, and Widener Robotics Club for supporting this project.