Take Two: RoboSub 2025: Technical Design Report

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***Abstract*—In preparation for the RoboSub 2025 competition: Protect the Deep, the Georgia Tech Marine Robotics Group constructed the *Take Two* Autonomous Underwater Vehicle platform, which will make its debut at RoboSub 2025. This year, the primary design goal was to create a platform that is simultaneously competitive at RoboSub 2025 and enables ease of future development. *Take Two* features a cast acrylic hull surrounded by eight polycarbonate guide rods on which various subsystems and sensors can be mounted, including the powertrain and various sensors. The interior of the hull features a drawer-like system to allow for easy access and maintenance of the vehicle's electrical components which include a PCB, fuses, buck converters, and more. Major effort was taken to enable parallel mechanical and software development through a medium-fidelity simulation utilizing Gazebo.**

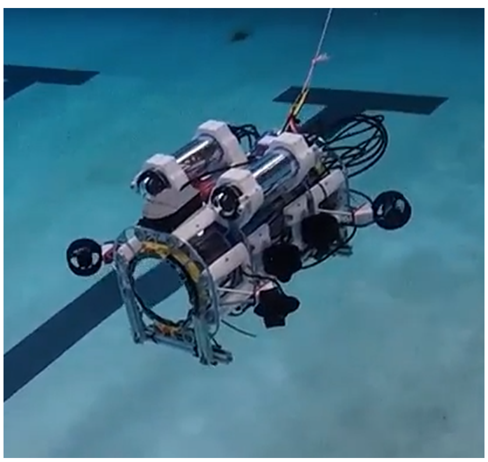

Fig. 1: *Take Two* below the surface

I. Technical Strategy

GT Marine Robotics Group's (GT MRG) approach for RoboSub 2025 was to construct the *Take Two* platform, building in high levels of modularity to enhance future expansion while still creating a stable, robust, and competitive platform for RoboSub 2025. In practice, this meant building from the ground up iteratively, relying on the team's experience creating Autonomous Surface Vehicles (ASV) as a base and adapting said knowledge into a new modality, namely Autonomous Underwater Vehicles (AUV). To accomplish this, the team divided the competition up into three categories of tasks, each of which would require different subsystems and therefore different levels of work from its three main subteams: mechanical, software, and electrical. The major task categories identified by the team are as follows: navigation (encompassing Tasks 1, 2, and 6), launching torpedoes (covering Task 4), and object manipulation (involving Tasks 3 and 5). For this year, the team decided to design mechanisms for every task; however, tasks under navigation remain the highest priority and therefore are the main tasks the team will be attempting at RoboSub 2025.

II. Competition Strategy

A. Navigation Tasks

Navigation tasks typically involve navigating through gates (Collecting Data, Return Home, and Ocean Cleanup surfacing), around obstacles (Navigate the Channel), and between tasks (Coin Flip). To effectively complete the navigation tasks at RoboSub 2025, *Take Two* utilizes its various low-light cameras, passing the video streams through YOLOv11 models to identify and localize relevant targets. Once the position of a target has been determined, the autonomous system plots 3D waypoints to complete the task while continuously updating these waypoints as new sensor data comes in. The waypoint controller then determines the necessary body velocity commands and, therefore, the individual motor commands needed to follow the defined path. This strategy is effective for navigation given the target position has been identified, but it does not assist the AUV in searching for a new target between tasks. To identify the path marker located after tasks 1 and 2, the system utilizes its angled low-light camera to provide a floor view to identify the heading of the path marker. Once above the path marker, the AUV utilizes its down-facing camera to correctly orient itself in the direction of the path marker. In cases where the AUV fails to find a task or path marker, the AUV will execute a simple search pattern to scan until a YOLO model returns a detection. To accomplish these strategies effectively, *Take Two* was redesigned to feature an X-drive horizontal thruster configuration, enabling the AUV to move simply and efficiently in the sway direction which has proved extremely useful in terms of maintaining a lock on targets with the forward facing cameras and making small adjustments to compensate for external factors while maneuvering.

B. Launching Torpedoes Task

The Tagging task would be accomplished by the AUV first identifying the target using one of its visual processing techniques running on its low-light cameras, namely stereo mapping and YOLO detections. Once the target has been identified, the AUV would use its local navigation to reach a decent firing distance (between 1 and 2 feet away) and use computer vision techniques to roughly aim at the target. From there, the AUV would release one of its two autonomous torpedoes, as seen in Figure 2, each of which can autonomously track, aim, and maneuver to the target using feedback from its camera to guide its two miniature thrusters. Once fired, the AUV would reposition to be roughly in line with the second target and fire the second torpedo. While the autonomous torpedo itself has been prototyped and tested, the release system proved too complicated for the team's compressed timeline. Thus, the autonomous torpedo will not be launched from *Take Two* at RoboSub 2025, though it will be present to collect data and test its efficacy in a new environment.

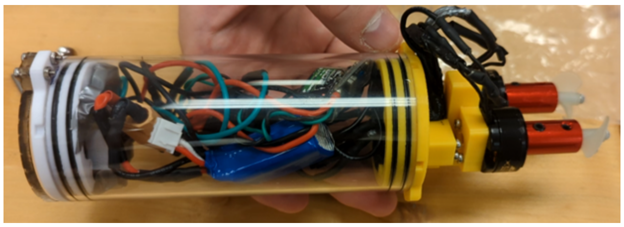

Fig. 2: Autonomous Torpedo out of water

C. Object Manipulation Tasks

The Object Manipulation task category encompasses the Drop a BRUVS and Ocean Cleanup tasks. The team identified that these two tasks could be accomplished by the same mechanism, and therefore, in the interest of keeping a small profile on the AUV, attempted to design a mechanism to accomplish both tasks. The mechanism would consist of a cascading elevator to extend an end effector made up of a rotary gripper using compliant stars [1]. The gripper would be effective at picking up items of varying size and shape because the compliant star wheels are able to deform to accommodate objects of varying shapes. The system would be mounted on the bottom of the AUV and would be preloaded with two markers to satisfy the Drop a BRUVS task efficiently. The targeting for this system would be accomplished by the down-facing low-light camera running YOLO object detection to detect the two sides of the bin as well as the two types of trash. Due to integration complexity, the team decided to postpone integrating the prototype manipulator for this year due to the additional mechanical complexity it would add while the autonomy wasn't ready.

D. Managing Complexity

Given this is the team's first year returning to RoboSub since 2020, the team decided to maintain simplicity in system design to ensure smooth integration in following seasons. To accomplish this, the team created a priority list, considering the various tasks as well as the potential mechanisms needed to complete these tasks. As a result, the decision was made to prototype mechanisms for all tasks but only finalize and install those that demonstrated a high degree of consistency and maintainability. To this end, the team's software subsystems feature a variety of distinct algorithms for accomplishing simpler behaviors identified as key components of the larger tasks such as identifying gates and navigating to goals. To prevent any single point of failure within the software system, the team created parameter files that allow for easy tuning of existing algorithms or swapping algorithms out for others. This redundancy will enable higher performance during competition as backup algorithms can be deployed while theoretically better ones can be debugged later. Additionally, the mechanical design prioritized consistency of mechanisms over potential for scoring, employing a simple thruster configuration capable of six axes of motion and a modular design for easy maintenance and the ability to quickly add, remove, or rearrange any subsystem or sensor.

III. Design Strategy

A. Mechanical Design

Take Two was designed to feature a minimum number of points of failure; each component has multiple sources of structural stability to ensure that no components are lost during a run. *Take Two* is more maneuverable than prior vehicles developed by GT MRG due to a more versatile thruster configuration and static stability in roll, pitch, and yaw. Robust protection of the electronics enclosure was also prioritized. Finally, *Take Two* was also designed with modularity in mind: every component is able to mount anywhere on the exterior of the AUV, enabling simultaneous development due to universal mounting solutions.

1) Platform: The driving concept behind the overall design of *Take Two* is modularity where various subsystems and sensors can all plug and play in an easily reconfigurable environment. To this end, the team created a symmetrical base structure consisting of a 24" long cast acrylic tube with four square-shaped 1/4"-thick aluminum plates secured along its length. These plates have been water-jetted to include large lightening holes, enhancing the AUV's hydrodynamic efficiency while also reducing its weight. These plates are connected to the main body of the AUV utilizing multiple 3D-printed clamps with chloroprene rubber lining which provide a strong friction fit to prevent potential slipping or rotating. Connecting these plates are the eight impact-resistant, stiff polycarbonate tubes referenced hereafter as guide rods, seen in Figure 3 as the light yellow rods spanning the length of the AUV.

These guide rods are the core component of the modularity of *Take Two* as they provide rigid, standardized mounting surfaces for all subsystems and sensors. Given their even distribution around the AUV, as seen in Figure 3, the AUV maintains its symmetry which allows various subsystems, including those yet to be developed, to be freely mounted around the perimeter of the vehicle. This design theory also enables optimizations for sensor placement to get the most accurate data while also maintaining weight balance. Beyond modularity, the aluminum plates and guide rods also serve a protective function for the electronics enclosure, ensuring the integrity and watertightness of critical systems during operation.

2) Powertrain: The team opted for an 8-thruster X-drive configuration, as shown in Figure 3, featuring 4 vertical and 4 horizontal thrusters. The 4 vertical thrusters allow for simultaneous roll and pitch correction while the 4 horizontal thrusters maneuver the AUV for the various tasks. The X-drive configuration allows for increased mobility with 6 axes of freedom, adding the important ability to translate sideways, a beneficial feature especially when the AUV is tracking a target such that continuous position updates can be made, ensuring the most accurate and up to date track. Testing has demonstrated that this configuration enables high performance, hydrodynamic, and stable maneuvering, along with efficient omnidirectional motion, allowing tasks to be completed in minimal time.

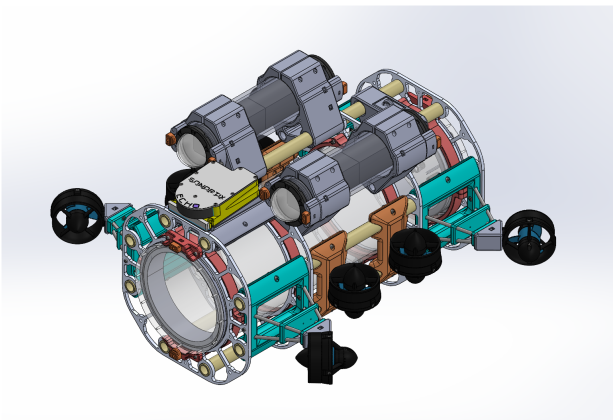

Fig. 3: CAD model of external assembly of the sub

3) Internal Retractable Electronics Housing: Take Two's internal electronics housing, shown in Figure 4, was designed to accommodate future changes and grant easy access to the internal electronics. The retractable electronic bay design was created utilizing retractable drawer rails to provide easy access to the electronics bay from the back of the AUV. This year, the team began an internal redesign aimed that improving the organization of the components and the computing efficiency by properly heat sinking the electronics. The redesign includes mounting ESCs and other components to an aluminum plate that is connected to the back plate by a heat strap. The Jetson would also be connected to the aluminum plate by a heat strap. This would allow more computation without overheating. The internal redesign is not yet complete, and the team targets its completion at the 2026 RoboSub competition.

B. Software Design

Take Two uses a newly created ROS 2 (Robot Operating System) software stack called Pontus which provides various packages for autonomy, localization, perception, mapping, and control. Pontus is heavily inspired by the GT MRG's RoboBoat software stack, Virtuoso [2], but is heavily re-designed to better suit the three-dimensional underwater environment of RoboSub.

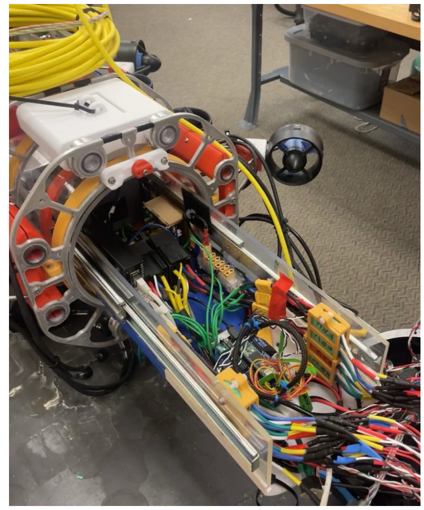

Fig. 4: Internal retractable electronic drawer of the sub

1) Autonomy: The autonomy package provides simple inheritable classes to allow for quick creation of new behaviors or modification of existing ones. Each competition task the AUV will attempt is implemented as an extension of the `BaseTask` ROS node which provides limited default functionality, namely for generating a Task future and default publishing of debug and status information. The system is built such that any architecture that can trigger the `complete` function is a valid implementation with Pontus primarily utilizing state machines. From there, different types of Runs (Qualification, Semi-Final, Final, etc.) can be implemented by extending the `BaseRun` ROS node which provides functionality for generating and running new Task nodes to completion while monitoring their status. This enables flexibility when creating Runs of varying levels of complexity. For example, the Prequalification Run simply runs the Gate Task and Vertical Marker Tasks sequentially while the Finals Run can implement a more complicated state machine with various fallbacks and contingencies. The autonomy logic follows the Sense, Think, Act paradigm. First, the autonomy nodes will receive information gathered from the perception nodes about the location of certain tasks within the pool. Within these messages sent to the autonomy nodes is the estimated position of the task, which is then used by the autonomy nodes to concurrently update the desired waypoint path for the task. Then these desired waypoint paths are sent to the controller to be followed.

2) Localization: Currently, the localization package is entirely odometry based, which is accomplished by fusing velocity data from the Doppler Velocity Logger (DVL) and acceleration data from the Inertial Motion Unit (IMU) using the Extended Kalman Filter provided by the open-source Robot Localization package. In the future, the team intends to add Simultaneous Localization And Mapping (SLAM) based on data from the camera and sonars to supplement the DVL and IMU sensor tracks.

3) Perception: The perception package relies on detecting objects with a YOLOv11 model trained with collected data from water tests. This YOLO model is run on the camera feed from the low light cameras, which compared to other cameras, provides superior color stability and accuracy underwater. A custom forward facing stereo setup is then able to calculate the relative position of the YOLO detection, allowing the perception nodes to assign both a 3D pose and id to tasks underwater. Though the AUV is equipped with a Sonoptix Echo Multibeam Imaging Sonar [3], difficulties with the sonar driver have prevented the team from utilizing the senor. The team aims to fully debug this and integrate the sensor within our perception stack for future competitions.

4) Control: The control package provides a simple cascaded PID controller. First, a position PID controller is used to generate body velocity commands which are then used as the input to a velocity PID controller. This controller utilizes a feed-forward input to estimate and counteract the effects of drag to output body acceleration commands to the thruster controller. The thruster controller uses a Jacobian matrix with the thruster locations and an inertial matrix provided by the robot's URDF file to calculate individual thruster commands. To avoid thruster saturation, the thruster controller also separately rescales the vertical and horizontal thruster commands relative to the highest thrust value in each respective set.

5) Firmware: The firmware links the autonomy to the physical motors on the AUV. Firmware running on the Teensy 4.1 microcontroller takes in motor commands for moving the AUV from the autonomy stack and converts them into Pulse Width Modulated signals. The firmware utilizes the micro-ROS library to interact with the autonomy stack through a mix of publisher and subscriber topics. The firmware also provides valuable debug information to the team on land when the AUV runs untethered through a variety of LED lights placed throughout the AUV. Additionally, the firmware enables remote emergency stopping the AUV when connected via a tether which has proved useful during tests.

C. Electrical Design

The AUV's electrical system is divided into two electrically isolated circuits: the thruster power system and the computation power system. The thruster power system powers the vehicle's thrusters, external motors, and low-level sensors via LiPo batteries. The computation power system powers the vehicle's main computer and other delicate sensors.

1) Thruster Power System: The Thruster Power system consumes around 800 Watts to power the eight Blue Robotics T200 thrusters on the vehicle, as well as any other motors. It is supplied by two 14.8V LiPo batteries. The most important functionality in the Thruster Power system is the E-Stop. The main portion of the E-Stop is implemented in a set of four automotive relays, with each relay controlling the power to two motors. Other external motors are controlled through additional automotive relays. These relays are opened and closed via a magnetic reed switch that interfaces with a mechanical pull tab on the exterior of the vehicle. Once disconnected, the thrusters and all other motors are completely isolated from the battery supply.

2) Computation Power System: The Computation Power system consumes around 50 Watts to power the Jetson Orin Nano and any associated sensor on the vehicle, such as the Blue Robotics Low-Light USB Cameras and Water-Linked A50 DVL. It is supplied by identical 14.8V LiPo Batteries to the Thruster Power System. The same battery configuration is used to preserve equal weight distribution on the sub.

3) 2025 Development Cycle: The key focuses of the 2025 development cycle have been to improve power system robustness and modularity. To achieve this, design advancements were made to the battery configuration, voltage protection systems, motor control PCB design, and internal layout. Core functionality from the 2024 development cycle was maintained, most notably in the automotive relay and ESC infrastructure. The most prominent change is featured in a new external battery configuration that improves modularity, field-test flow, and internal organization.

4) External Battery Housing: Due to heat concerns in the main tube and problems with shipping the previous batteries as they were over the 100 Watt hour limit for flying, alongside issues with down time to switch batteries during vehicle operation, the team worked to move the batteries to external tubes. The redesign features two removable external acrylic battery tubes, placed symmetrically above the AUV's midline with each containing two 14.8V LiPo batteries. The new batteries were chosen to be just under the 100 Watt hour limit while still maintaining overall similar operation time through slightly higher Amp hours. Each battery tube is designed to not need to be opened after being sealed by having all relevant wires (power + ground and balance leads) exit the rear of each battery tube through Cobalt penetrators. For normal use, each of the four penetrators on the back of each battery tube is connected into the main tube with two cables supplying power and ground while the other two feed the balance leads into the Battery Monitoring System. Inside the main enclosure, each battery tube's power and ground cables are connected together with a Y-connector such that the two batteries are run in parallel, doubling the available Amp hours while being flight legal. For charging, each of the four penetrators are hooked up to spare cables that convert the penetrators back to standard connectors to connect to the chargers. The move towards external battery tubes also posed an additional challenge in terms of the added buoyancy which was compensated for by changing the infill patterns of all external 3D prints such that they take on water far easier, decreasing buoyancy while not increasing air weight.

5) Interior Redesign:

a) Restructuring Overview: Particular efforts were made to improve the internal organization of the vehicle following the transition from internal to external battery housing. The design plan optimizes the increased available interior space by developing alternative component mounting solutions, harness management, and cable strain relief techniques. The automotive relay block featured in the Thruster Power system's E-

Stop was reconfigured to improve access to the Motor Control Board for maintenance. Progress was made toward developing a mechanical interface with the aluminum backplate for a passive heat sinking solution. To manage complexity and ensure effective integration, implementation of this feature was postponed to Fall 2025.

b) Motor Control Unit PCB Design: The largest component of the interior redesign was focused on upgrading the motor control PCB to not only provide more feedback information such as battery levels and current draw, but also improve overall control and safety of the vehicle through improved reverse polarity protection. This was accomplished through the addition of several new fail safe components ensuring sensors do not have power supplied and the AUV is E-Stopped while the firmware hasn't initialized. Additionally, the new motor control PCB and its breakout boards centralized as many components as possible onto PCBs so as to minimize extraneous wiring, thus improving maintainability, cleanliness, and reducing points of failure from wire strain and more. The board is fully assembled and is undergoing thorough testing for a projected implementation in Fall 2025.

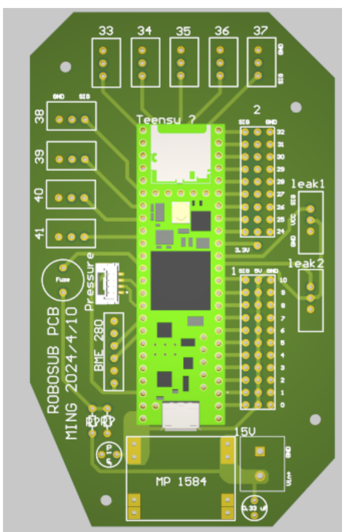

Fig. 5: V2 of the motor control board

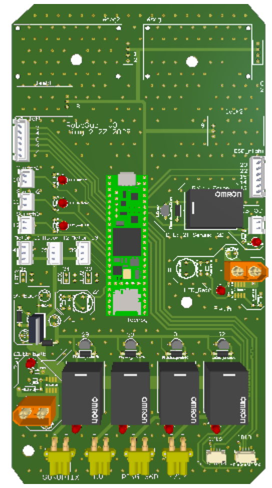

Fig. 6: V3 of the motor control board

6) Specific Design Notes from 2024:

a) Incident Response: Jetson Orin Nano Failure: On April 10, 2025, the Computation Power System computer experienced a catastrophic failure during a dry test, rendering the unit inoperable. A incident investigation was promptly conducted with the intention to learn from the event to the greatest extent possible and implement changes to safeguard against future incidents. These sessions identified the likely cause to be an unreliable buck-boost converter delivering excessive voltage during system startup, resulting in progressive component degradation and ultimate failure. Seven procedural and hardware updates were proposed to enhance system safety such as implementing voltage protection at buck-boost converter outputs, incorporating soft-start mechanisms for converters used in sensitive subsystems, isolating high-current devices from the onboard computer power supply, and requiring the use of an emergency stop (E-Stop) during power-up sequences. A PCB with relay functionality was developed in-house to prevent powering live-configured systems, which previously showed risk of computer and battery damage over time. Additional recommendations included the use of desiccant packs to reduce moisture in the AUV and keeping the vehicle sealed when maintenance is not being conducted to prevent the possible entry of conductive particles.

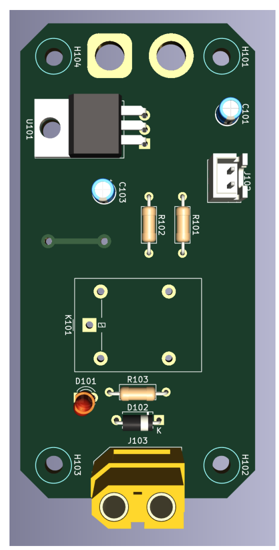

Fig. 7: Board to prevent start-up in live configuration: one of three in-house developed circuit protection boards

b) Fuses: Failure point analysis was conducted to revise fuse implementation within the power system. The existing 200 Amp ANL Fuse within the Thruster Power System was down-scaled to 125 Amps. 30 Amp blade fuses were spec'd and sourced for future implementation within the Computation Power System and for each ESC, in case of overdraw.

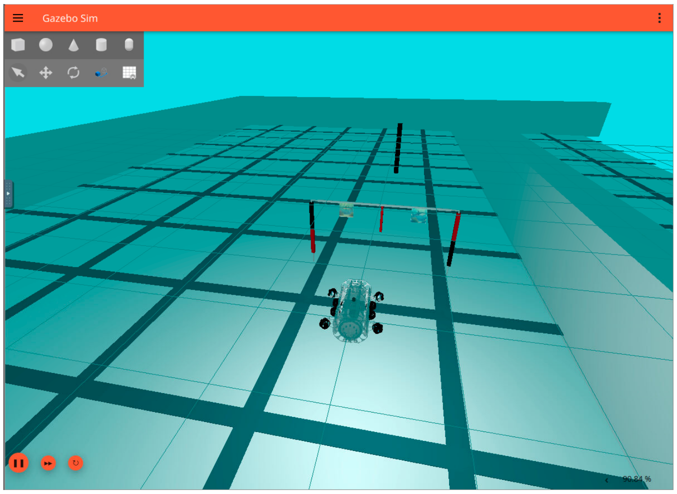

Fig. 8: Simulation environment showing pre-qualification run

IV. Testing Goals

A. Simulation

As a new team, the ability to test code while the vehicle isn't prepared for water testing has been extremely valuable. This is accomplished via Gazebo Simulation and its built-in hydrodynamics plugin. Simulating cameras and the IMU/DVL was accomplished using existing sensors in the simulation while the sonars were modeled using LIDARs configured with similar parameters as the sonars on *Take Two* (number of beams, update rate, range, etc.). Through the simulation, the team was able to access immediate feedback from all sensors and autonomous systems, enabling debugging in a more controlled environment, and saving precious time during water tests. The team is working on improving the simulation of sensor noise and better modeling the hydrodynamics of the AUV in simulation as compared to real life.

B. Dry Testing

Dry tests take place a few days before water tests, focusing on four main goals: the hardware is secured properly (including waterproof testing), the electrical system is functioning properly, the software system and relevant sensors are working, and the communication layer between the software and electrical system is functional. Ensuring the hardware is secured properly involves testing the waterproof seal for the electronics drawer, ensuring none of the subsystem mounts are loose, and all components are secured down in preparation for more extreme maneuvers such as rolling or pitching. Testing the electrical system focuses primarily on checking that the physical and remote emergency stops are functioning properly, all components are outputting the desired data, and no connections are exposed. On the software side, the main concern is that the code compiles and runs out of water along with seeing and receiving data from its relevant sensors. Finally, the communication layer tests ensure that the autonomous system can communicate to the firmware and the firmware is connected properly to all of its respective components.

With new high-end sensors, the team introduced standardized procedures for both dry testing and field testing to define step by step how to safely start up the AUV and prepare it to go underwater. This also includes checklists of safety checks such as E-Stop functionality and waterproof seal.

C. Field Testing

Field tests were conducted to test full system integration in competition-like environments. The tests were carried out in Georgia Tech's main competition pool. Firstly, the PID controller for the AUV was tuned during pool tests to ensure safe yet responsive handling by the powertrain. Secondly, basic operations, like vertical auto-stabilization, were verified such that the AUV is able to maintain its depth in spite of external motion. Thirdly, large amounts of camera data were collected while underwater to train vision models and verify performance of the perception stack. Finally, individual tasks were attempted.

V. Acknowledgements

A. Sponsors

The Marine Robotics Group thanks all of our sponsoring organizations that have contributed to the team, whether financially, through hardware, or any other form of support demonstrated. Our corporate sponsors and supporters include Altium, Firefly Automatix, Theia Technologies, Dassault Systems, TDK Lambda, VectorNav Technologies, WaterLinked Technologies, and Blue Trail Engineering. Our academic supporters include the AquaBots Vertically Integrated Project, the Georgia Tech Student Government Association, the Georgia Tech Student Organization Finance Office, the Georgia Tech Student Foundation, the Aerospace Systems and Design Laboratory, and the School of Aerospace Engineering Student Advisory Council. We also would like to thank the Campus Recreation Center for providing access to their facilities for testing.

B. Mentors

The team thanks Carl Johnson for taking over as the primary advisor on the project, Dr. Michael West for his help as an advisor to the team, Tanya Ard-Smith for her help with competition logistics, and Professor Dimitri Mavris for providing for the team at large.

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[3] Blue Robotics. *Sonoptix Echo Imaging Sonar*. 2024. URL: https://bluerobotics.com/store/sonars/imaging-sonars/sonoptix-echo/.

Appendix A
Component List

Component	Vendor	Model/Type	Specs	Custom/Purchased	Cost	Year of Purchase
Buoyancy Control	—	—	—	—	—	—
Frame	In-house	Custom Waterjet	—	Custom	—	—
Waterproof Housing	Blue Robotics	Cylindrical Non-Locking Series 8” ID	8” ID, 8.5” OD, 26” Length Cast Acrylic Tube	Purchased	$220	2024
Waterproof Connectors	BlueTrail	Assorted Cobalt Connectors	3 Pin Power, 8 Pin, BlueROV Battery Cables, 6 Pin	Purchased	$50 ea	2025
Thrusters	Blue Robotics	T200	—	Purchased	$245 ea	2024
Motor Control	PJRC	Teensy 4.1	—	Purchased	$32	2024
High Level Control	NVIDIA	Jetson Orin Nano	—	Purchased	$250	2024
Battery	Socokin	4S Lipo Battery	6600mAh 14.8V, 2 sets of 2 LiPos wired in parallel	Purchased	$50	2025
Regulator	DROK	Boost Buck Converter	DC 5.5-30V to 0.5-30V	Purchased	$17 ea	2024
Internal Comm Network	In-House	USB / Ethernet	USB3 / 1Gbps	Custom	—	—
External Comm Interface	BlueTrail	Ethernet Tether	1 Gbps	Custom	—	2025
Inertial Measurement Unit (IMU)	LORD MicroStrain	3DM-GX3-25	—	Purchased	$2640	2017
Doppler Velocity Log (DVL)	WaterLinked	A50	—	Purchased	$7890	2024
Algorithms	Open-source	—	Color-thresholding, YOLO, Extended Kalman Filter, State Machine	Custom	—	—
Vision	Blue Robotics	Low-Light HD USB Camera	—	Purchased	$110	2024
Acoustics	Sonoptix	Echo Multibeam Imaging Sonar	—	Purchased	$8950	2024
Localization and Mapping	Open-Source	—	Extended Kalman Filter	Custom	—	—
Autonomy	Open-Source	—	State Machine	Custom	—	—
Open Source Software	Open-Source	—	ROS2, OpenCV, Gazebo	Custom	—	—
Programming Language(s)	Open-Source	—	Python, Arduino, C++	Custom	—	—

APPENDIX B
CAD OF THE AUV

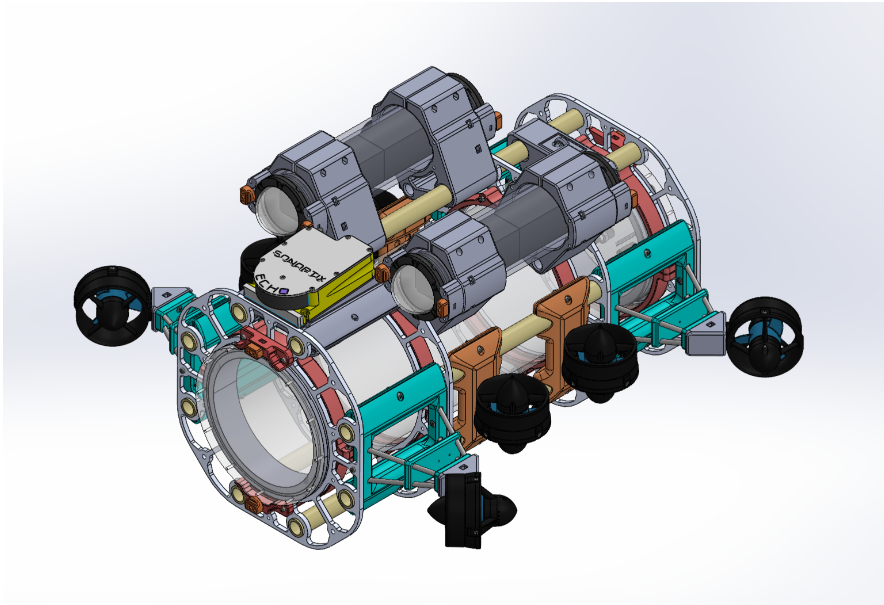

Fig. 9: 3D isometric view of the AUV's external components

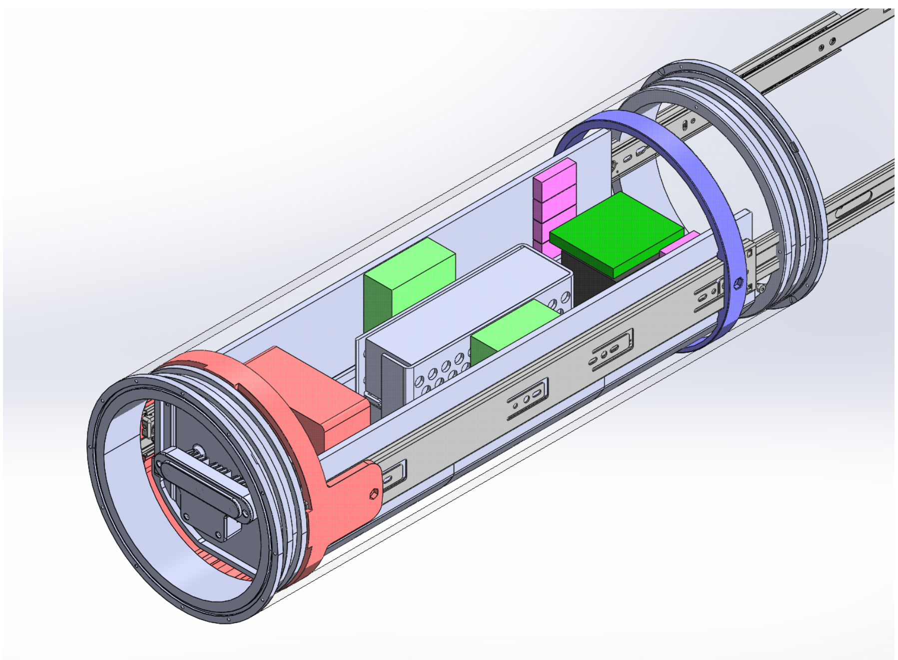

Fig. 10: 3D isometric view of the AUV's internal components

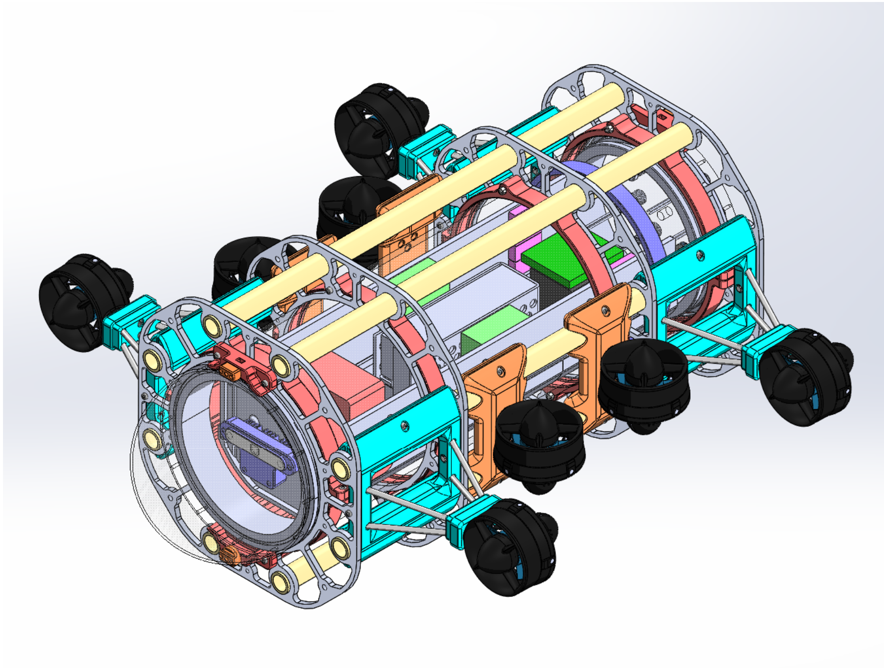

Fig. 11: 3D isometric view of the fully assembled AUV

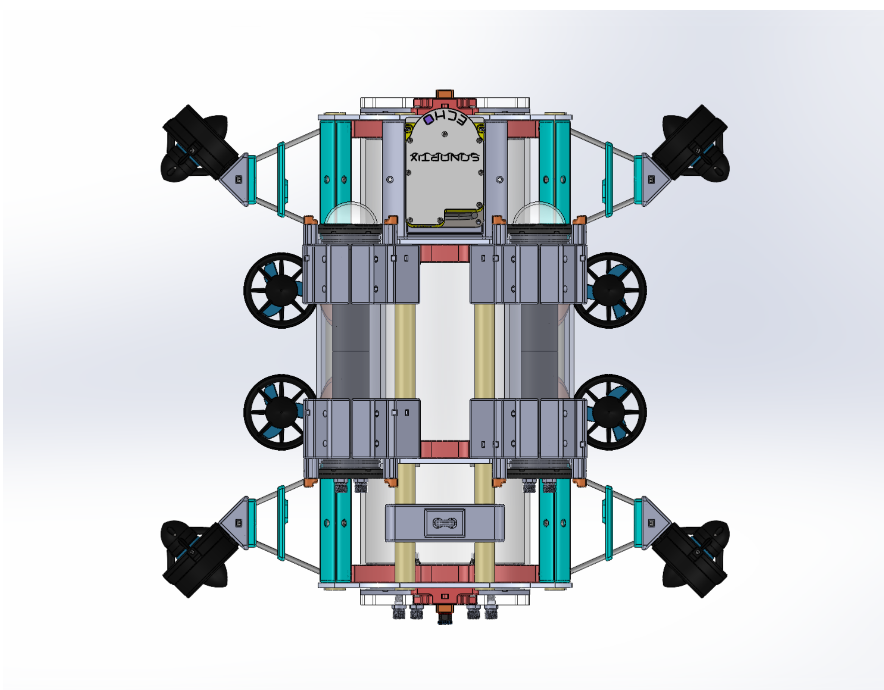

Fig. 12: Top view of the fully assembled AUV

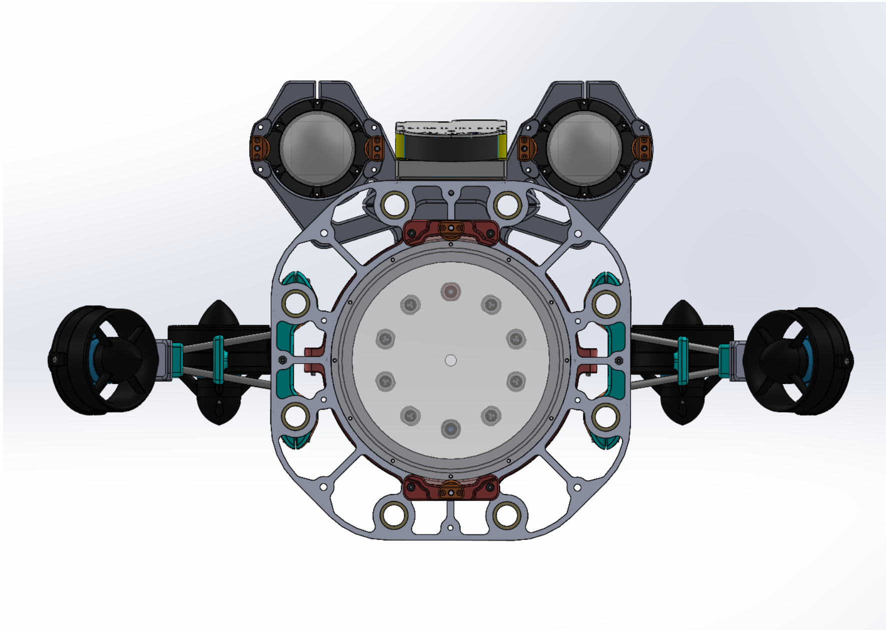

Fig. 13: Front view of the fully assembled AUV

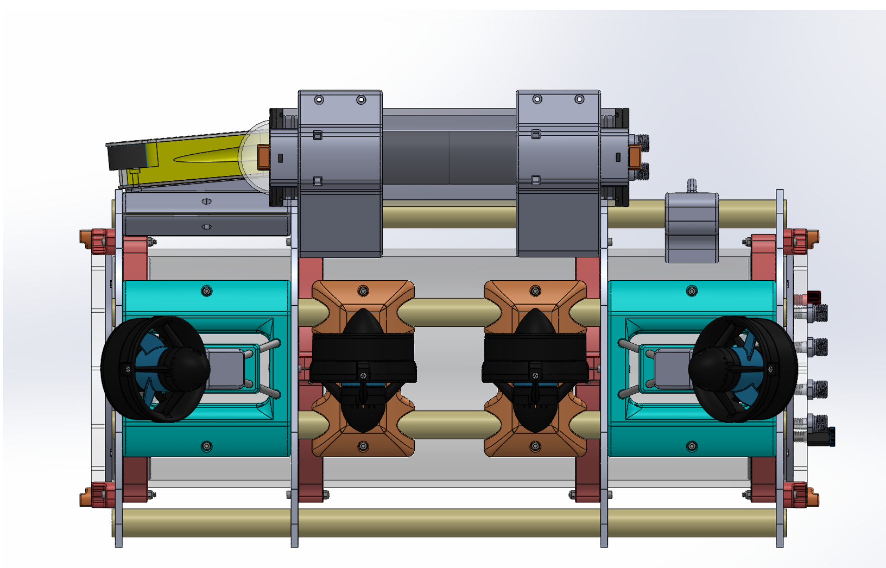

Fig. 14: Side view of the fully assembled AUV