Texas A&M University Women in Robotics, Engineering, and Development (WIRED) Autonomous Underwater Vehicle Team

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***Abstract*—Throughout the season, our Autonomous Underwater Vehicle (AUV) team focused on maximizing stability and reliable functionality for our vehicle, Swim Shady. This year's design features a prototype internal shelving system, quick-release endcaps, custom-made PCBs and 3D printed holders, and an optimized programming system.**

Through 15 hours of pool testing, Swim Shady achieved 90% success in Gate navigation and consistently maintained depth stability within 0.1 meters by using the integrated Doppler Velocity Log (DVL) sensor along with the Proportional Integral Derivative (PID) control loops. This report outlines our engineering process, from explicit competition constraints to our verified vehicle testing performance.

Keywords*— *Autonomous Underwater vehicle, object detection, underwater navigation, modular design

I. COMPETITION STRATEGY

A. General Strategy

This year, the team focused on implementing a Doppler Velocity Log. The integration of this complicated sensor involves building on the navigational code system that has been developed in previous years. Combining DVL and camera model data allows the AUV to navigate between key targets with improved accuracy and reliability. A ZED mini camera, equipped with depth and motion sensing capabilities, is used to grab video feed for the camera model. With those goals in mind, the team's strategy was developed: attempt tasks based on navigational requirements to reduce extra hardware, while maximizing total earnable points.

B. Coin Flip

The first task the team plans to complete is the coin flip. The AUV's camera runs a machine learning model trained to detect the gate, prompting the sub to spin right until the model detects it, before moving in that direction.

C. Gate Task

The team will then complete the gate task. The camera will detect the gate using the camera model mentioned, and the AUV will activate thrusters to move toward its right side.

D. Slalom

In accordance with the side of the gate the AUV passes through, the camera will guide the sub through the right side of the slalom.

E. Octagon Task

The only portion of the Octagon Task that the AUV will attempt is surfacing. For this, the camera's image recognition and the DVL's mapping will help orient the submersible. Once the robot's position has been checked against the bottom section of the octagon, the code will give the surfacing command.

F. Vision of Success

Our strategy for the 2026 competition is centered on maximizing point-to-minute efficiency through a reliability-first model. To achieve completion of the Gate, Slalom, and Octagon maneuvers within a 15-minute window, we prioritize high-probability tasks based on a weighted success-to-time ratio, supported by design benchmarks such as depth stability within 0.1 meters and heading accuracy within 2 degrees. By aligning every technical requirement with these specific performance metrics, we ensure the vehicle executes the competition field with maximum precision and minimal mission latency.

II. DESIGN CREATIVITY

A. Mechanical Creative Aspect

1) *Modular Internal Frame & Shelving*

To address previous years' issues on electrical accessibility, this year, the mechanical team transitioned from static shelving to an active modular slide rail design. The core frame is still built from aluminum T-slot bars. These bars serve a dual purpose: they provide an adjustable backbone for easy component bracket mounting as well as providing a light, structurally reliable frame, as shown in Appendix D Figure 1.

A major structural upgrade for the shelves is integrating drawer rails directly into the internal frame. The electronics are mounted to these slider tracks, allowing the entire electrical stack to slide smoothly out of the acrylic hull like a drawer. This eliminates the risk of wire bending during maintenance and provides smoother debugging and visibility of internal components.

To maximize the structural packaging and stability requirements, the center of mass (CM) and center of buoyancy (CB) were calculated along the vehicle's x-axis [6].

$$x_{cm} = \frac{\Sigma(m_i \cdot x_i)}{M_{total}}$$

We optimized our design using lightweight T-slot rails and aluminum metal components. We successfully maintained the vehicles' CB directly above the CM to guarantee passive hydrostatic stability.

2) Component Placement & Wiring Optimization

The electrical trays are split into a dual-layer shelving system optimized explicitly for visibility, accessibility, and clear wiring, as shown in Appendix D Figure 2.

- Top shelving layer: All components are mounted on the top side of the top tray, facing upwards.
- Bottom shelving layer: Components are mounted to the bottom side of the lower tray, facing downwards

This layout allows for the active electronics to face outward against the transparent acrylic hull, allowing for the team to conduct rapid visual diagnostic checks (e.g., monitoring status LEDs or checking for loose physical connections) while the vehicle is fully sealed and pressurized.

3) Latch Sealing Endcaps

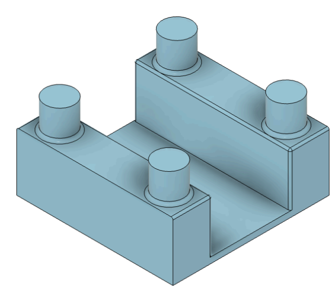
We did a complete redesign of the end caps due to water-tight issues faced last year. We worked towards designing better tolerances on the updated design [5]. The primary connection this year utilized a latch mechanism, as shown in Appendix D Figure 3. This clamps the end caps directly to the hull, compressing the o-rings instantly without requiring any hand tools.

Recognizing that a latch failure throughout testing could compromise the entire hull, the cap also features backup bolt holes. If a latch sustains damage, it can be replaced; however, if the surface sustains damage, standard marine-grade bolts can be instantly threaded through the backup holes to securely lock down the end cap.

B. Electrical Creative Aspect

1) ESC Holders

New ESC holders were designed and implemented to improve the organization and accessibility of the electronic speed controllers



(ESCs).

Figure 2: CAD model of ESC Holder

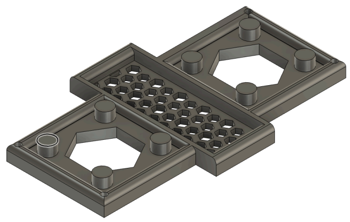


Figure 3: CAD model of ESC Holder Base Plate

Instead of using a dedicated ESC PCB, the current AUV uses a vertically stacked holder. This design allowed the ESCs to be mounted in a compact arrangement, reducing the amount of wire strain and horizontal space required on the electrical tray. The holders were fabricated using 3D printing, which allowed the holders to remain lightweight and custom-fit based on available hull space. Additionally, WAGO connectors were used for the thruster side signal wires connected to the ESCs, while keeping the existing terminal connector system for the power wires. In previous designs, the thruster signal wires were permanently soldered, making end cap removal and overall maintenance difficult. By implementing WAGO connectors, the ESCs could be quickly disconnected and reconnected whenever the end cap is removed, reducing the risk of damaging wires and simplifying debugging and repairs. Overall, the new design and connectors increased modularity and reduced the complexity of the electrical layout compared to a full ESC PCB.

2) *Reed Switches*

To improve waterproofing and long term reliability, the push button switches from last year's design were replaced with magnetic reed switches mounted inside custom 3D printed holders. The assembly consisted of an internal holder with the reed switch, mounted inside the AUV hull and an external magnetic component mounted on the outside of the hull. These components were aligned using side magnets embedded in both parts of the holder, while a central magnet is used to control the system, by actuating the reed switch.

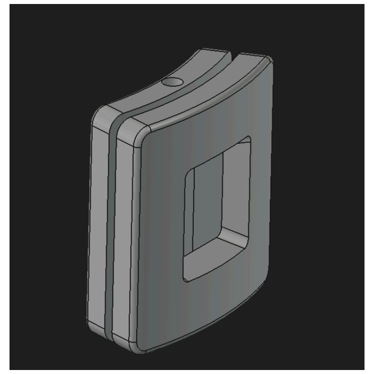


Figure 4: CAD model of Reed Switch Holder

Unlike traditional mechanical push buttons, reed switches use a magnetic field to operate, removing the need for physical switch penetrations, which eliminates a common source of water intrusion. The fully sealed magnetic switching system allowed for an improvement to the AUV's waterproof integrity and the durability of the electrical system.

3) *Power Control Switching System*

The switch systems were designed to improve the AUV's reliability, waterproofing, and power control. On the Jetson side, the switch system functions as the main power control for the Jetson Nano and the mission control electronics. MOSFETs were implemented on the Jetson side of the electrical system, allowing the MOSFET to connect directly to the battery and provide power to the Jetson Nano when no voltage is applied to the gate. MOSFETs were selected over other types of transistors due to their ability to provide safer high-current switching which allows the battery voltage itself to be used most efficiently within the circuit. On the thruster side, a solid state relay that's controlled by a 3.3 V signal provided by the Jetson is used to disconnect power to the thrusters when the kill switch is activated. The separate switch systems were implemented for both the Jetson and thruster side battery systems in order to improve subsystem isolation and overall electrical safety of the AUV.

4) Mission Switch

The mission switch is designed with an active-low configuration and acts as a manual trigger to start the thruster code. The thrusters are connected to a battery, but remain still until the mission switch is activated. By default, the circuit is open, and no signal is sent, but when the mission switch is activated, the circuit closes and connects to ground through a resistor, which creates a voltage drop that the Jetson reads. This voltage drop signals the Jetson to begin executing the thruster control code.

C. Programming Creative Aspect

1) ROS Code Structure

ROS 2 (Galactic) is used as the communication framework between the vehicle's components. By developing publishers for each sensor, such as the DVL, camera, and mission switch, ROS allows for a user-friendly code breakdown. These publishers transmit relevant data, like camera detections or distance measurements, to a centralized subscriber. This configuration simplifies sensor integration and data flow, facilitating scaling and debugging. Sensor inputs can be synchronized in real-time to regulate thruster behavior and autonomy logic during underwater operation by constructing these publishers and linking them via a single subscriber. Additionally, Figure 8 below, shows how various parts/sensors work together as a single AUV system.

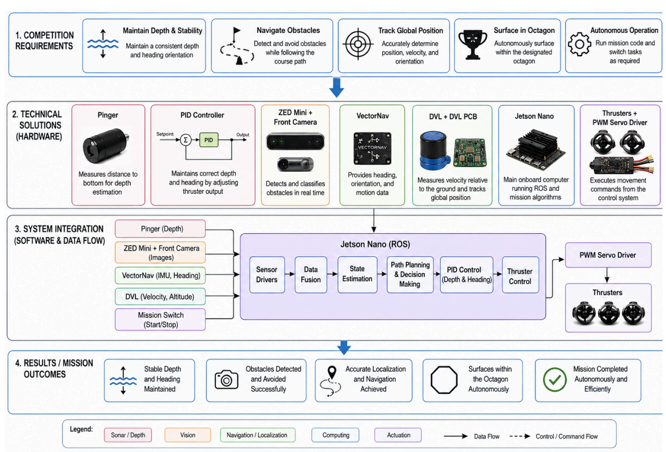


Figure 5: Single AUV System

2) Front Camera

The front camera system uses a custom object detection model to identify competition obstacles and guide navigation decisions. This year, the programming subteam collected image data and trained machine learning (ML) models using Roboflow, Kaggle, and YOLO. Roboflow was used to organize and label image data sets, while YOLO-based training allowed the team to create a model capable of detecting objects in the camera frame. These detections are used to determine the relative position of the objects so the AUV can adjust its movements during autonomous operation. Without the camera model, the vehicle would not be able to reliably identify targets.

3) DVL

The Doppler Velocity Log (DVL) enables underwater navigation without GPS. By measuring velocity relative to the seafloor, the DVL allows the AUV to estimate its position over time and construct a global map of its environment. This helps the vehicle remember its path and navigate efficiently during long missions. Integrating the DVL with other onboard sensors enables innovative path planning and autonomous decision making [4].

4) Pinger Integration

The pinger was connected and integrated with the rest of the robot's programming system to provide additional distance feedback during underwater operation. The programming subteam troubleshooted communication issues and verified that the pinger produced usable sensor data. The pinger data is also useful for the PID control system because it provides real-time measurements that can be compared against desired values.

5) PID

This year, the programming subteam began implementing a PID controller to improve the AUV's stability and navigation accuracy. During pool testing, accuracy issues in movement and positioning showed the need for a feedback-based control system. The PID controller uses sensor data to calculate error between the desired and actual position or orientation, and then adjusts thruster output to reduce that error over time. This allows the robot to make continuous corrections instead of relying only on fixed motor commands.

6) *VectorNav*

The VectorNav sensor was tested and integrated to improve the robot's ability to record orientation data during operation. It was verified that the sensor output changed correctly as the robot's orientation changed, ensuring that the AUV could accurately track heading information. This data is important for maintaining directional awareness during autonomous navigation and can be used with other sensor feedback to improve stability and control. Successfully connecting and testing the VectorNav also improved the team's ability to troubleshoot sensor communication and validate navigation data.

III. EXPERIMENTAL RESULTS

A. Mechanical

1)Testing approach and strategy

To ensure the structural integrity and operational safety, the team tested a verification cycle to separate physical structural testing from the full payload validation. The primary focus of the initial phase was water safety testing. This is meant to verify the empty mechanical chassis and hull integrity to guarantee that everything is sealed properly without risking water leaks.

Once the hull was verified as completely watertight, the internal frame and electrical systems were added so that the team could accurately gauge and calibrate the vehicle's buoyancy [6]. The vehicle is typically iteratively weighed down with physical counterweights along the T-slot rails. This process was continued till the vehicle achieved a slightly positive buoyancy profile.

2) Performance results and feedback loops

The initial testing revealed a critical failure. During early submersion trials, water leaked past the end caps into the main hull. We discovered that the O-rings were smaller than required, causing a lack of compression to create a seal on the end cap [7]. To resolve this problem, we switched out our orings to thicker orings. Due to the time constraint, we engineered custom-sized seals from the O-ring cord to match the exact required dimensions.

Further testing showed that the factory on/off/kill switches rated as watertight were not watertight. It allowed water into our hull, flooding the bottom. We resolved this issue by sealing the original switch holes with specialized sealing screws. In their place, we engineered a completely new, non-penetrating switch technique by designing and 3D printing a custom magnetic switch that mounts directly to the outside of the hull, preserving the structural waterproofing and maintaining full operational control. Following these modifications, the vehicle achieved a 100% waterproof success rate across 15 hours of cumulative pool testing.

B. Electrical

The electrical sub-team developed a power distribution system that meets the needs of each component. The system is powered by two 14 V batteries routed through two boost converters, which step up the voltage before it reaches the Jetson Nano and the fuse board. The first boost converter steps up the voltage to 16 V for the Jetson Nano and wires the mission switch to allow a direct connection between the Mission Switch and the Jetson Nano. A MOSFET was newly implemented to supply power to the Jetson when there is no voltage through the gate. The second boost converter receives input from the solid-state relay connected to the Kill Switch and outputs a stepped-up voltage of 18 V to the Fuse Board. The solid-state relay allows the circuit to switch to an open circuit when the kill switch is triggered, removing all power from the rest of the components. The Fuse Board connects to the new ESC holders, allowing easy control of the thrusters through the PWM servo driver connected to the Jetson Nano.

The PID controller system was integrated into the Pinger and VectorNav sensor in order to improve stability, orientation control, and accuracy regarding navigation. The PID controller processes sensor feedback in real time, allowing the robot to make continuous adjustments to maintain an accurate position underwater. The PID system communicates with the thrusters through the PWM servo driver connected to the Jetson Nano. The robot's sensors are also seamlessly integrated into the electrical schematic, with the ZED Mini camera and the VectorNav navigation sensor connected directly to the Jetson Nano. The newly added DVL is connected using a DVL PCB, allowing for parallel connection of the battery to the DVL and to the Jetson Nano.

Troubleshooting was done by cross-checking component specifications and using a multimeter to ensure the correct voltage was supplied to each component. To test new components such as the DVL, a power supply was used to slowly increase and decrease the voltage to ensure that the power supplied to the DVL was correct. The team put in an extensive amount of effort to make sure that the schematic was as efficient as possible. Safety measures were taken during high-voltage settings, and troubleshooting frequently took place. Dismantling the schematic, making the team rewire everything from a clean slate, allowed each member to familiarize themselves with the schematic and identify issues by starting at the very beginning. This was also helpful in case multiple issues were encountered.

C. Programming

The 2025 competition exposed a critical gap in the vehicle's sensor pipeline: none of the onboard sensors were functioning during the competition run**.** The team had to rely on hardcoding every task in the absence of real-time sensor data. This approach was both inefficient and difficult to adapt as these tasks rely on dynamic feedback and cannot be reliably completed with static commands.

During the 2025-2026 year, we worked on several upgrades. First, the team integrated an acoustic pinger system, enabling the vehicle to detect and look out for underwater targets. A dedicated PID controller was developed for pinger-based navigation, allowing the vehicle to autonomously track a pinger signal and adjust its heading and position in real time. This eliminates the need to hardcode tasks and substantially improves the vehicle's ability to locate and interact with underwater targets. Additionally, a VectorNav IMU was integrated to provide reliable 3-dimensional heading data. A PID controller was also implemented for VectorNav, giving the vehicle continuous control over its orientation. Together with the pinger PID, this provides the vehicle with a layered, sensor-driven navigation, which is a huge shift from the hardcoded approach used during the 2025 competition. In terms of the camera model, the team collected and labeled underwater images relevant to competition tasks and trained a custom machine learning model. We used tools like Roboflow, Kaggle, and YOLO for training the models. This model is tailored to the specific visual targets the vehicle needs to detect and is deployable offline via the local inference server solution established during the 2024 cycle. The ultimate product is a camera system that is both independent from the internet and specific to the task at hand.

IV. ACKNOWLEDGEMENTS

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V. REFERENCES

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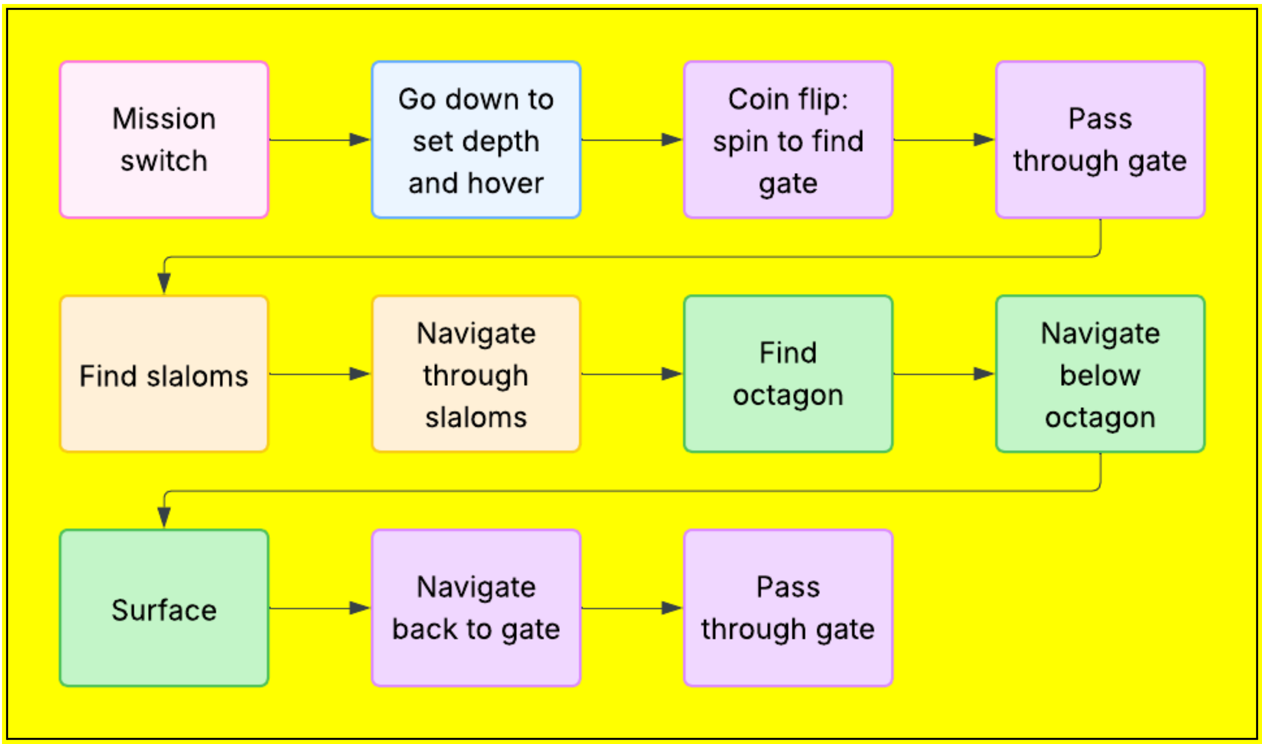
Appendix A: Component Specifications

Component	Vendor	Model/Type	Specs	Custom/ Purchased	Cost	Year of Purchase
Frame	Team Storage	6061 Aluminum Plate	Additional manufacturing and drilling of the previous model	Custom	-	2023
Hull: Tube	McMaster-Carr	Polycarbonate Tube	ID: 11 3/4”, OD: 12”, L: 14”	Purchased	$185.05	2018
Caps	Speedy Metals	6061 Aluminum Plate	Size: 2"x10"x10"	Purchased	$235	2024
Waterproof Connectors	Subconn & Blue Robotics	Blue Robotics Cable Penetrators	Circular Series 12-pin	Purchased	$600	2022
Propulsion	Blue Trail Engineering	Blue Robotics T200 Thruster	T200	Purchased	$1,960	2023
Servo	Blue Trail Engineering	SER-2020	+/- 230 deg, used for manipulator	Purchased	$495	2023
Motor Controls	Blue Robotics	R3	7-26 volts, 30 amps, Spade terminals, Tinned Wire Ends, L 1.38’, W .67’	Purchased	$200	2020

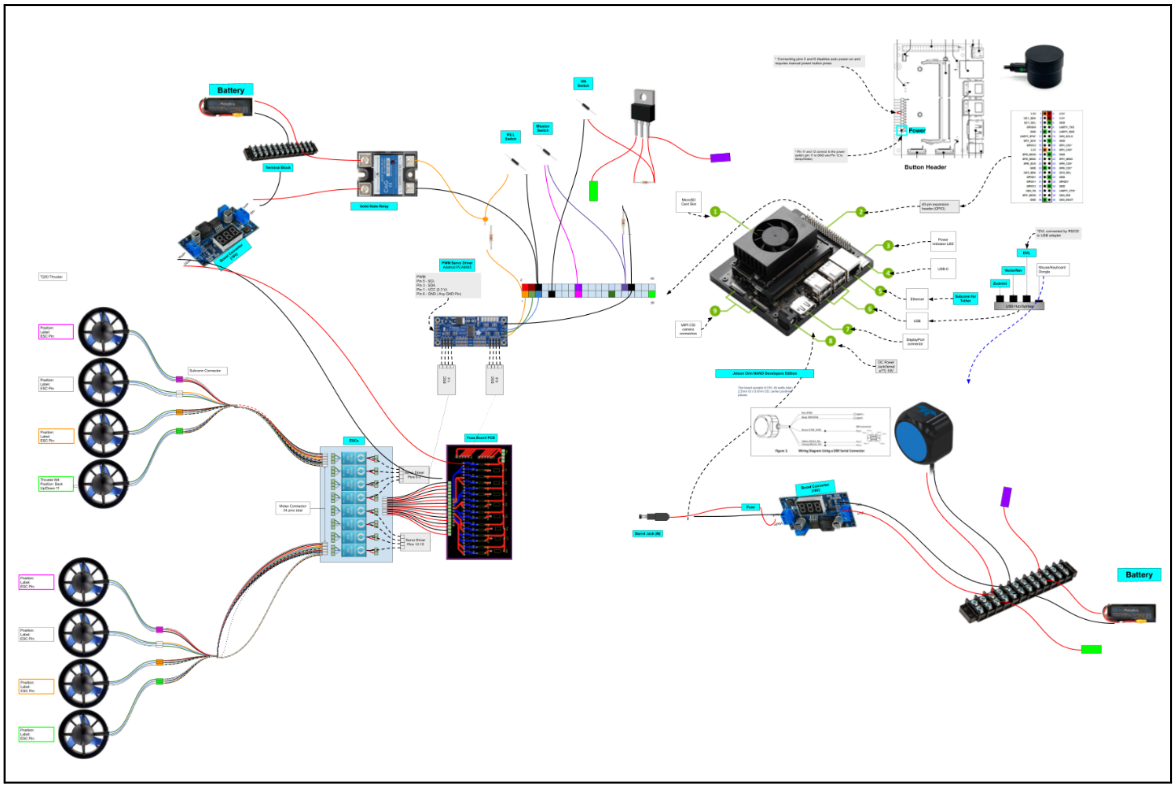
CPU	NVIDIA	Jetson Nano	4 GB, 25.6 GB/s of memory bandwidth	Purchased	$148.95	2023
Inertial Measurement Unit	VectorNav	VN-100 IMU/AHRS	3-axis gyros	Team Storage	-	2016
Doppler Velocity Log	Teledyne Marine	Wayfinder DVL	600 kHz Bottom Tracking, Long Term Accuracy ±1.15%	Purchased	$4,959	2023
Top Camera	ZED	ZED Mini	100 Hz FPS, 0.1 - 15 m depth range	Purchased	$399	2023
Bottom Camera	Blue Robotics	Low-Light HD USB Camera	Sony Exmor IMX322 / IMX323 1920(H) x 1080(V)	Purchased	$117.54	2018
Algorithm: Vision	Roboflow	Inference	Object detection model	-	-	-
Vision	OpenCV	-	Runs camera	-	-	-
Pressure Sensor	Blue Robotics	Bar30 High-Resolution	300m depth, 2mm depth resolution	Purchased	$91.50	2023
Pinger	Blue Robotics	Ping2 Sonar Altimeter and Echosounder	25-degree beam width, 300-meter depth rating	Purchased	$435	2022
Programming Language	Python	Python 3	Installed on Jetson	-	-	-
Boost Converter	Digikey	20W Adjustable DC-DC Boost Converter With Digital Display	32×34×20 [mm]	Purchased	$15.00 (2x$7.50)	2025
Solid State Relay	CGELE	DC to DC Input 3-32VDC To Output 5-240VDC 25A Single Phase	58 x 45 x 32 [mm] 2.3 x 1.8 x 1.26 [in]	Purchased	$9.90	2018
Lipo Batteries	Blue Robotics	BATTERY-LP-4S-10AH-R1 Lithium-polymer 14.8V/10Ah/148wh	168 x 44 x 59.4[mm]	Purchased	$510.00 (2x$255.00)	2025
Reed Switches	Generic	Magnetic Normally Closed Reed Switches	16 x 2.4 x 2.4 [mm]	Purchased	$10.50 (3x$3.50)	2026
Fuseboard	Electronics Salon	Panel Mount 10 Position Power Distribution Fuse Module Board	150 [mm] x 72.5 [mm] x 29 [mm]	Purchased	$28.00	2018
PWM Servo	Adafruit	Adafruit 16-Channel	"62.5 x 25.4 x 3 [mm]	Purchased	$14.95	2023

Driver		12-bit PWM/Servo Driver - I2C interface - PCA9685	2.5 x 1 x 0.1 [in]."			
Electronic Speed Controller	Blue Robotics	Basic ESC	17.1 [mm] x 32 [mm]-	Purchased	$304 (8x$38)	2023

Appendix B: Proposed Mission Plan



Appendix C: Electrical Schematic



Appendix D: Mechanical CAD Models

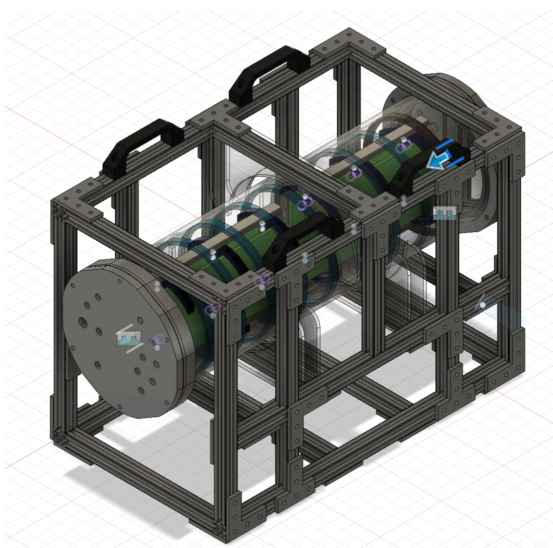


Figure 1: Autonomous Vehicle Assembly CAD

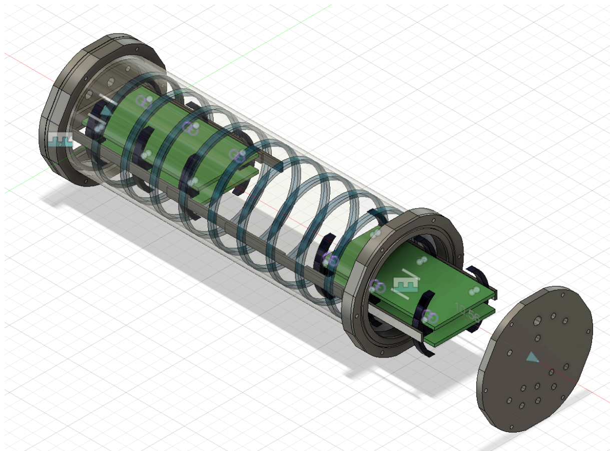


Figure 2: Simplified Internal Frame CAD

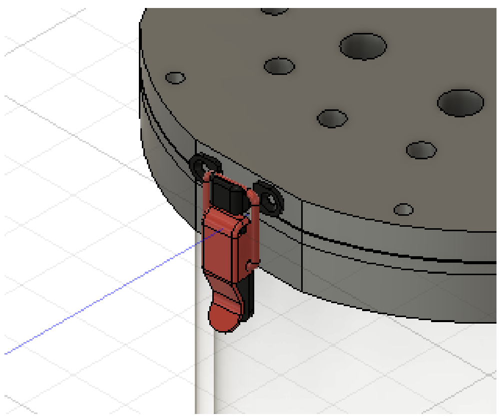


Figure 3: CAD model of latch sealing end caps