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

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***Abstract*—Throughout the 2024 - 2025 competition season, our Autonomous Underwater Vehicle (AUV) team focused on building a vehicle capable of both stability and reliable functionality while maintaining modularity. This year's design features a prototype internal hull, custom-made PCBs, and a restructured programming system to further increase the accessibility of internal components as well as the complexity of the robot's overall design. Navigational tools such as the Doppler Velocity Logger (DVL), ZED Mini Camera, and Pinger combine with machine learning techniques to guide our AUV, affectionately nicknamed "Swim Shady," through the tasks presented on the competition field. Because this design is new, the tasks focused on were the Gate, Slalom, Surface in the Octagon, and Return Home. The team also aims to complete the coin flip at the beginning of the run.**

***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 Logger. 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.

II. DESIGN CREATIVITY

A. Mechanical Creative Aspect

1) *New Modular Design*

This year's submersible features an entirely new design, created with hydrodynamics and the evolving electrical system in mind. Design considerations included rough calculations to balance the AUV's center of mass and center of buoyancy, as well as identifying where drag could be reduced and where it could not.

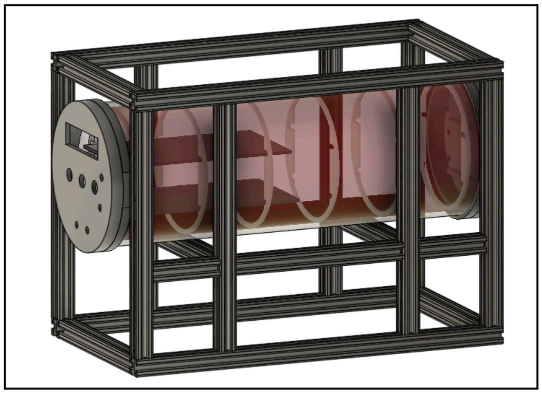

Figure 1: Autonomous Vehicle Assembly

This led to the usage of thin T-slot rails, which allows for easy, secure assembly while still maintaining a lightweight, unobtrusive form. The rails on these bars allow for mounting brackets for sensors like the DVL and Pinger to be made and attached while remaining secure. Another integral part of this new assembly was the redesign of the previous year's end caps. Each cap is designed to attach directly to the internal frame for an accessible interface that can be changed easily. The caps themselves primarily feature the necessary cable penetrator and wire connections alongside the camera window; the primary addition to these standard functions is the tabs, which allow the caps to adhere to the internal frame.

2) *Internal Frame*

To accommodate the shape of our cylindrical hull and the space required for our internal electrical components, our internal frame consists of several circular rings, which act as shelves. On top of this sit two layers of trays with holes strategically drilled to allow some of the thicker wires to easily travel from the higher shelf to the lower one. These trays attach to the end-caps on either side of the hull, but are not connected, allowing the trays to slide out like drawers for easy electrical access.

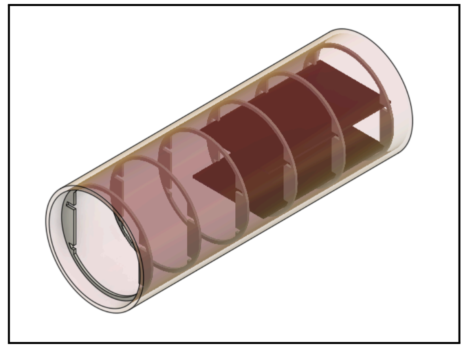

Figure 2: Simplified Internal Frame CAD Drawing

By separating the shelving system of the internal frame, the electrical systems are now more linear; each internal component is organized based on the systems it connects to, with problem areas being the easiest to access. This organizational structure results in significantly cleaner and more manageable wiring. The current internal frame is a prototype version of a more complex design that will be implemented next season. Lightweight, flexible alternatives to the final design were used to allow for testing without wasting any budget.

B. Electrical Creative Aspect

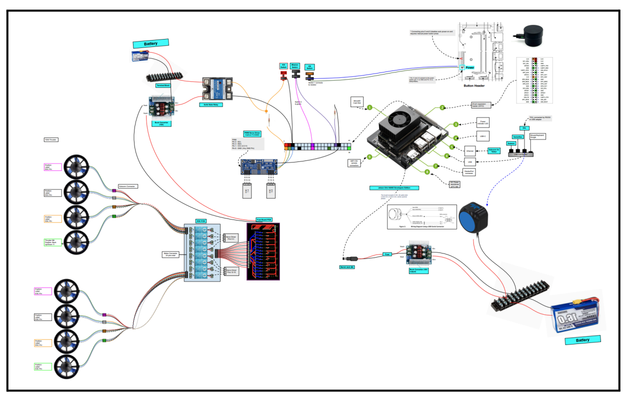

Figure 3: Full Electrical Schematic

1) Kill Switch PCB

The kill switch was designed to have an active low configuration with a path for the SSR, having the thrusters connect to the battery unless the switch is pressed. This allows the voltage to take another path with a resistor connected to ground. This path has the least resistance; the resistor accounts for the voltage drop and kills the thrusters. The kill switch is connected to ground on the solid-state relay and gets 3.3V from the Jetson. When the kill switch is pressed, the solid-state relay disconnects the power from the battery's thrusters and creates an open circuit.

2) *Mission Switch PCB*

The mission switch is designed with an active high 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 pressed. By default, the circuit is open, and no signal is sent, but when the mission switch is pressed, 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.

3) On Switch

The power switch is configured to control the startup of the Jetson by disabling the default auto-on feature. Pins 1 and 2 on the Jetson were connected using a momentary button to power the Jetson back on. Pin 1 is the power button, whereas Pin 2 is ground. Turning off the Jetson can be done through the monitor or disconnecting the batteries.

4) *Fuse Board PCB*

The Fuse Board PCB in Swim Shady integrates multiple fuse holders to protect the ESCs and thrusters from overcurrent. Each fuse holder is rated for specific current loads, ensuring optimal protection for connected subsystems. The board features connectors that maintain electrical connections as the AUV moves, with a clearly labeled layout, facilitating accurate and efficient installation. The decision to include a centralized fuse board PCB reduces the volume of wiring within the electrical system, preventing clutter and potential wiring errors. Compared to last year’s design, where fuses were scattered throughout the electrical system, the centralized Fuse Board design significantly improves accessibility and maintenance efficiency.

5) ESC PCB

In previous years, the eight electronic speed controllers (ESCs) on the autonomous underwater vehicle were distributed haphazardly across the bottom of the robot, leading to significant challenges in wire management and system maintenance. The resulting tangle of wires made debugging extremely difficult and increased the risk of mechanical failure. Due to the fragile nature of ESC wire terminals, wires were often inadvertently disconnected or damaged when the system was accessed or moved.

To address these issues, the team designed and integrated a custom ESC PCB this year. This centralized board allows all ESCs to be neatly arranged in a single row, with clearly labeled and secure connections for both power and signal lines. Organizing the ESCs in a fixed order corresponding to specific thrusters has streamlined the debugging process and made system diagnostics far more efficient. The new layout also reduces mechanical strain on connections and improves overall reliability during operation and transport.

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, as seen in Figure 4.

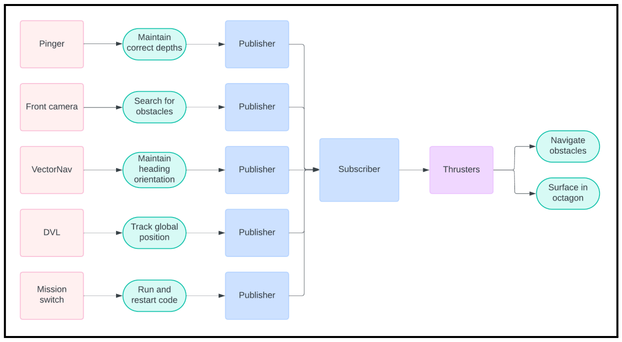

Figure 4: Code structure for competition

2) Front Camera

The front camera utilizes a custom object detection model trained with Roboflow's AutoML to determine and navigate to the position of the competition obstacles. Without the camera, the vehicle would be blindly swimming in the pool, playing the biggest role in successfully completing the tasks.

3) DVL

The Doppler Velocity Logger (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) PID

This is the first year that the team has had the time to include a PID controller, as no members had previous knowledge in the past years. The DVL will measure the actual distance to calculate the error from the desired traveled distance.

III. EXPERIMENTAL RESULTS

A. Mechanical

Testing each of the submersible's systems individually is an integral part of ensuring overall functionality. This began with water-safety testing, which verified the empty mechanical systems and ensured that everything sealed properly without leaks. There was a minor issue ensuring that the look-out window for the camera was properly water-tight, but the problem was fixed easily enough by applying additional marine epoxy. After all leaks were avoided, the electrical systems were added so that the team can gauge the buoyancy. As is standard, the submersible had to be weighed down to the point that it was only slightly positively buoyant. Recorded video feed also showed that the camera window showed a significantly clearer image.

B. Electrical

The electrical sub-team developed a power distribution system that meets the needs of each component. The system is powered by two 24 V batteries routed through two buck converters, which step down the voltage before it reaches the Jetson Nano and the fuse board. The first buck converter steps down 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. The second buck converter receives input from the solid-state relay connected to the Kill Switch and outputs a stepped-down voltage of 16 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 PCB, allowing easy control of 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 took place often. 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

During the 2024 competition, the camera model was a frequent issue. Specifically, the Roboflow AutoML camera model required a WiFi connection to run inference, which made object detection difficult underwater. This year, the programming sub-team worked to create a replacement camera model.

After further attempts to create a custom object detection model in another format, a legacy document on Roboflow's website was discovered. It discussed a "deployment option" for "situations where you need to run your model without a reliable Internet connection" [2]. It was designed for a Raspberry Pi, but all the commands appeared to be universal for other devices. Success was found by running Roboflow's local inference server through Docker. The "result" variable object that is updated after each detection is an odd collection of definitions and lists. Several attempts at switching indexing methods ultimately resulted in a program that can output all objects and their positions in the camera's frame.

Additionally, the programming sub-team ran into several issues while trying to use the ZED Mini depth sensing camera on the robot. Although the system sometimes recognized the camera, the depth data stream was often very inaccurate. A major problem seemed to stem from driver conflicts—specifically, the ZED SDK wasn't compatible with the version of JetPack and L4T running on the Jetson. Even after reinstalling the SDK and ensuring the correct USB connection and power supply, frequent errors remained during initialization, and the distances the camera read were inaccurate. The team struggled with labelling the object the camera was detecting without the proper drivers installed, making debugging harder. These problems made relying on the ZED Mini for real-time depth sensing difficult, so alternative solutions were found.

Although the team utilizes a pinger to detect the depth from the bottom of the pool, a pressure sensor would allow the vehicle to confirm its position using both directions. Running the program for the old pressure sensor resulted in a remote I/O error, and the sensor could not be connected. The electrical connections were confirmed to the Jetson using a multimeter, and both Jetsons were tested to ensure it wasn't an issue specific to the board. Running the I2C dump and detect showed that the pressure sensor was not detected on any of the buses. Ultimately, it was marked as a low-priority sensor and was not used. Last summer, the team faced some mechanical issues due to the heat the vehicle was subjected to on its trip to California. The current theory is that the car exceeded the maximum storage temperature the sensor is rated for on its datasheet [1].

This year, a mission switch was added to the vehicle. The status of the button is read through a GPIO pin. In the past, there had been GPIO conflicts with the switch and the PWM board, but this was solved by cleaning up the GPIO board at the start of the code before setting up the switch. The code was written to begin with an infinite loop that waits for the button to be activated. Once this occurs, the main loop of the program begins. A second, smaller loop inside allows for the program to be stopped with one press and restarted after a second press. This allows the vehicle to restart its run without having to reconnect to the computer and manually restart the code.

The team found example programs written for the Teledyne Wayfinder DVL. These were used to write the programs the team required. Through pool testing, it was determined what data values were necessary to navigate through the water. By reading the distance traveled from the DVL, the vehicle can begin to build a global map. This will aid the team in returning to the gate to end the run. The distance will also be implemented in the new PID controller.

The programming subteam spent this past year learning how to use the Robot Operating System (ROS) to significantly improve the codebase and functionality of the autonomous underwater vehicle. Transitioning to ROS 2 presented a steep learning curve, particularly in understanding its modular architecture and communication structure. Previously, the team had not taken full advantage of ROS packages, which made development more difficult and less scalable. The tutorials ROS provided greatly helped the team learn about workspaces, packages, and the new formats for publishers and subscribers [3]. This year, integrating and testing ROS packages became a priority, leading to more efficient code organization and better system performance. Adopting ROS ultimately empowered the team to build a more flexible, robust, and maintainable robotic system.

As previously mentioned, the team had no previous experience with PID controllers. This, with the team's timeline, made it challenging to implement a controller. This year, several members learned about PID in their courses, and more time was designated to teach the rest of the members about it. Over the summer, the PID program was created, using the distance data from the DVL to find the error. The appropriate gain values were determined through pool testing to produce the results the team desired.

IV. ACKNOWLEDGEMENTS

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V. REFERENCES

[1] Blue Robotics, "Bar30 High-Resolution 290m Depth/Pressure Sensor" Accessed: March 27, 2025. [Online.] Available: https://bluerobotics.com/store/sensors-cameras/sensors/bar30-sensor-r1/

[2] Roboflow Docs, "Raspberry Pi Legacy" Accessed: May 31, 2025. [Online.] Available: https://docs.roboflow.com/deploy/legacy-documentation/raspberry-pi

[3] ROS, "Tutorials - ROS 2 Galactic documentation" Accessed June 14, 2025. [Online.] Available: https://docs.ros.org/en/galactic/Tutorials.html

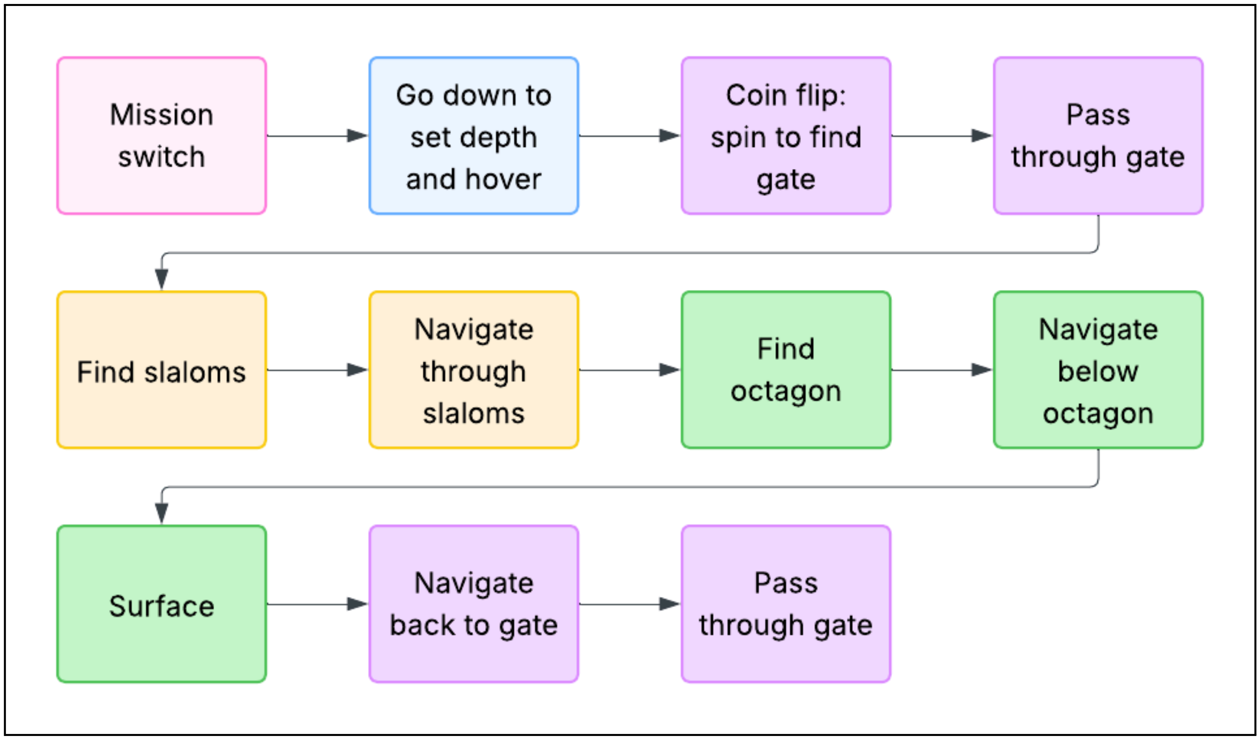
[4] Teledyne Marine, "Wayfinder DVL Guide" Accessed: June 28, 2025. [Online.] Available: https://www.teledynemarine.com/en-us/products/SiteAssets/RD%20Instruments/Wayfinder_DVL_Guide.pdf

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
Top Cap	Midwest Steel Supply	6061 Aluminum Rod	Size: 14in Length: 1in	Purchased	$225	2023
Bottom Cap	Midwest Steel Supply	6061 Aluminum Rod	Size: 14in Length: 1.75in	Purchased	$179.82	2023
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 Logger	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	Blue Robotics	Bar30	300m depth, 2mm depth	Purchased	$91.50	2023

Sensor		High-Resolution	resolution			
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	-	-	-
Buck Converter	ANMBest	DC 6-40V to 1.2-36V 20A 300W Buck Converter	60×53×27 [mm] 2.36×2.08×1.06 [in]	Purchased	$19.99	2022
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	Turnigy	Turnigy High Capacity 16000mAh 6S 12C Lipo Pack w/XT90	183 x 77 x 70[mm]	Purchased	$163.83	2018
LED Switches	Generic	22mm Waterproof Push Button 12V 24V 110V 220V IP68 Momentary Latching	22 [mm]	Purchased	$27.99	2022
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 Driver	Adafruit	Adafruit 16-Channel 12-bit PWM/Servo Driver - I2C interface - PCA9685	"62.5 x 25.4 x 3 [mm] 2.5 x 1 x 0.1 [in]."	Purchased	$14.95	2023
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