TEAM SIMPLEXITY 2025 - *High Tide*

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***Abstract* -- Team Simplexity is a continuing private team composed of 10 passionate students from 5 high schools in San Diego, California. This season, we continued to improve our *High Tide* vehicle from last year, iterating upon our state-of-the-art software, electronics, and mechanical systems. Our main AUV, *High Tide* incorporate the Navigator Flight Controller to process aspects of the sensors and thrusters and the *Jetson* Nano and *ZED* Box Mini to process vision. With a focus on modularity and efficiency, *High Tide* has been built to perform a multitude of tasks and provide a robust foundation for future development. While *HydroX 2.0* continues to be a reliable testing platform for mechanical and software systems. This year our mechanical efforts have centered around our new sub design, while electrical work has focused on designing and testing a new PCB for our killswitch, and software has revolved around creating a robust computer vision pipeline for the sub.**

Competition Strategy

Design of our High Tide Vehicle

High Tide is designed to be a highly modular and expandable AUV platform. The main structure of the frame is composed of 4 hollow steel tubes to allow easy component mounting and reconfigurability of electronics, sensors, and attachments, as well as the vehicle dynamics such as centers of gravity, buoyancy, and thrust vectors. Unlike traditional AUV frame construction with a fixed size and geometry, our steel tube construction enables rapid iterations as the main structure of the frame does not need to be modified to make design changes; only the 3D printed clamping components need to be replaced or shifted when a design is updated.

We had two goals for reducing hydrodynamic drag on the High Tide vehicle. Number one: reduce the frontal area, and number two: reduce the drag coefficient. With the components mounted in line with each other, the frontal area of the vehicle is minimized, and the hydrodynamic drag is reduced.

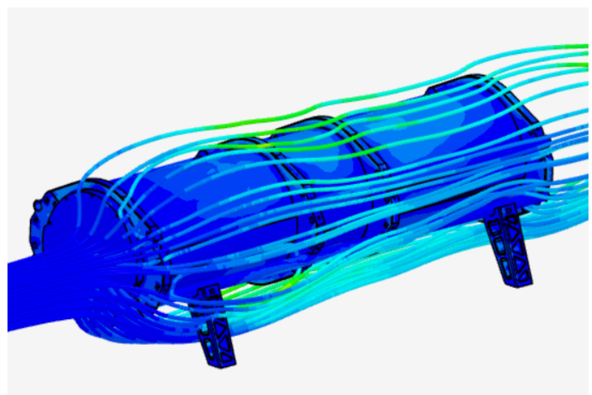


Figure 1: Computational Fluid Dynamics (CFD) simulation on the High Tide Vehicle in Simscale

Using Computational Fluid Dynamics (CFD) simulations, we optimized and validated our vehicle model. Through multiple iterations of the design, we were able to minimize the flow separation at the bottom of the vehicle induced by the landing legs and the enclosure mount. Thus, reducing drag caused by pressure difference and significantly improving drag coefficient. Our final version of the *High Tide* vehicle has a drag coefficient (C_D) of 1.1 and a frontal area of only 0.051 m^2. A significant improvement in comparison to *HydroX 2.0*, which has a higher C_D of 1.4 and a frontal area of 0.094 m^2. To put into perspective, under the same forward velocity, *High Tide* experiences only 43% of the drag compared to *HydroX 2.0*

Additionally, while thinking of ways to further optimize the efficiency, we realized that the majority of the AUV's movement will be forward and backward; strafing side to side is only required when aligning with certain tasks. Thus, mounting the thrusters at the standard 45° angle is nonoptimal for efficiency. We opted for a thruster angle at 25°; through our calculations, we found that this thruster angle increases the forward-backward efficiency by 28.2% while still leaving plenty of power for precise horizontal movements.

We are building upon last year's *HydroX* 2.0 vehicle to further develop the software, as it has proven to be a reliable, water-tight, and flexible platform for us to add custom electronics and attachments. Our goal with the *HydroX 2.0* was simply to submerge, orient in the correct direction, and navigate through the gate. This year, with the new *High Tide* Vehicle, we are hoping to complete additional challenges, including launching the torpedos, dropping objects, contacting the buoy, and surfacing the octagon.

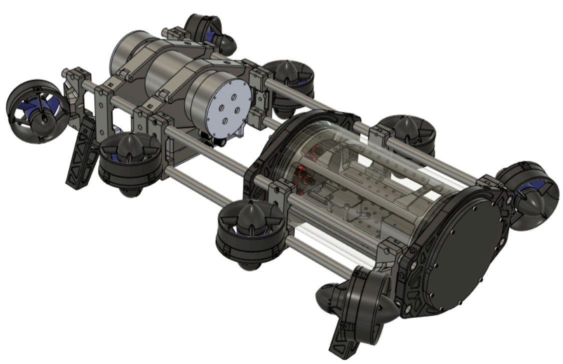


Figure 3: CAD model of our completed High Tide AUV

Design Creativity

Mechanical and CAD

High Tide utilizes a waterproof 6-inch cylindrical acrylic enclosure from Blue Robotics with an acrylic lid on one side and an aluminum plate with feed-throughs on the other. Two pressed-fit o-rings make a watertight seal with the cylinder. To maximize the space that was available for our electronics, we prototyped several methods of mounting our electronics using 3D-printed parts to achieve a highly modular and stable structure. To create the foundation of our enclosure, we designed a cylindrical piece that ran the length of the enclosure. The enclosure structure is directly bolted to the connector lid so that we can pull out all of the electronics inside the main enclosure as a single unit without any hassle. The structure of the electronics is 3D-printed with acrylonitrile butadiene styrene (ABS) to be able to withstand high temperatures without losing rigidity. We optimally positioned our hardware inside the enclosure for ease of use when plugging in Ethernet, power, or other connectors. Figure 2 displays the CAD model of the 3D-printed structure of the enclosure.

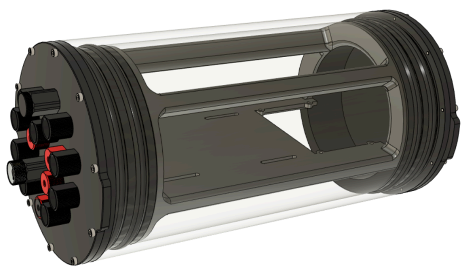


Figure 4: CAD model of the High Tide Vehicle's main enclosure

During experimental testing, we experienced thermal heating as a direct result of the battery and ESC being in the main enclosure. Therefore, we designed and built our own custom T6-6061 aluminum alloy enclosure for the ESCs to maximize thermal conductivity, allowing us to keep the ESCs cool even at high loads. We also designed and custom built our battery enclosure out of PVC pipe and custom-machined aluminum end caps to ensure maximum modularity by designing the battery enclosure to be easily swappable; simply loosening two screws allows the mount to be folded up to allow for rapid replacement of the battery.

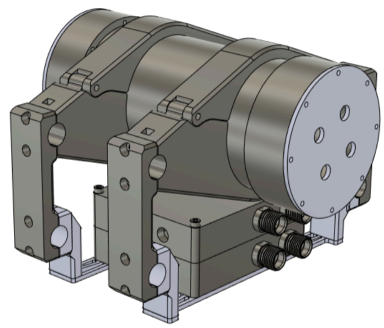


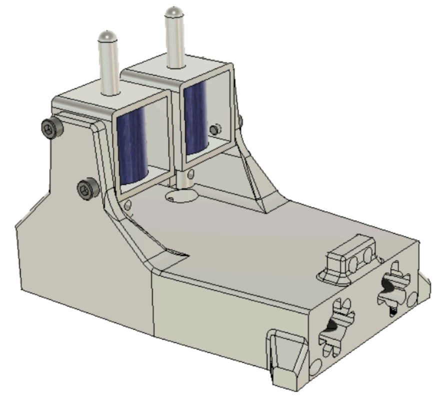
Figure 5: CAD of our custom battery and ESC mounting system. Top: Battery Enclosure, Bottom: ESC enclosure.

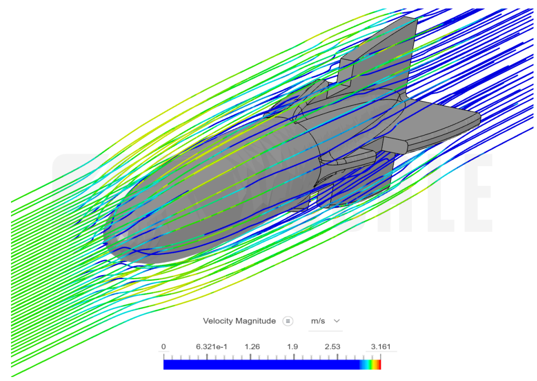
Solenoid Usage

While most other teams use servos to power their various mechanisms, we opted for solenoids for our torpedo launcher, dropper, and claw mechanisms. For some tasks, servos are preferred since they offer precise, variable positioning. However, solenoids are incredibly reliable for tasks which require only an on/off or open/closed state. Additionally, solenoids are highly reliable, cost-effective, and more resistant to water leaks.

Torpedo Launcher

Our torpedo launcher uses a bungee-loaded design with a solenoid-actuated release. The entire release module and dual torpedoes are 3D-printed out of 100% infill ABS for improved underwater performance compared to PLA and to ensure the torpedo is slightly positively buoyant. The torpedo itself has 4 fins with a minimized circular cross-section to reduce unnecessary hydrodynamic drag. Small cutouts in the fins were also added to hold each torpedo individually using the solenoid, preventing them from firing prematurely. Both our torpedo and launcher went through several iterations. For instance, by using computational fluid dynamics testing and physical testing, we improved the reliability of the torpedo and found that it travels straighter for a longer distance than past designs. We reduced the impact of the frontal surface area of the torpedo by smoothing out connections from the fins to the body of the torpedo, making it more hydrodynamic.





Through testing and iterating, we improved our torpedo from launching 3 feet with an 8° deviation to only a <5° deviation from the initial trajectory. To carry out these tests, we secured the torpedo launcher to the pool stair and placed a phone camera underwater to record 300 total launches.

Dropper Mechanism

Our new dropper mechanism has a much smaller footprint compared to last year, which minimizes drag and allows for the attachment of more peripheral devices to the sub. The dropper uses solenoids to pull back plates, releasing the two weights with 100% reliability over 500+ underwater trials. Additionally, due to the spring on the solenoid shaft, reloading is extremely convenient.

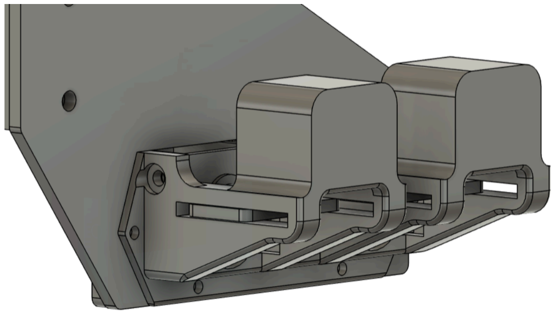
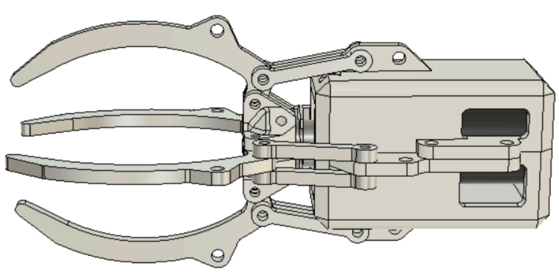


Figure 6: The dropper design. The two modules are mounted onto a plate connected to the sub’s main body.

Claw Mechanism

This year, we completely redesigned our claw mechanism using linear solenoid actuators rather than servos. As the claw only requires two states, open and close, the precise angle controlled by the servo is unnecessary. Similar to our torpedo and dropper mechanisms, solenoids enabled lower manufacturing costs and improved robustness. With our custom-designed linkage mechanism, we achieved a 15:1 drive ratio in a compact package. This enables faster actuation speed compared to servos while maintaining sufficient force to grip objects from the bottom of the pool.



Communication

We custom-designed a tether box to house the *RAKwireless LX200V30* communication adapter. This module allows us to communicate with the AUV through a two-conductor tether, providing more freedom of movement while at the same time extending our maximum operating range to 300 meters. We manufactured the heatsink and frame of the tether box with 6061 aluminum alloy on our custom-designed CNC gantry mill and leveraged 3D printing to create the battery housing and the snap-on cover.

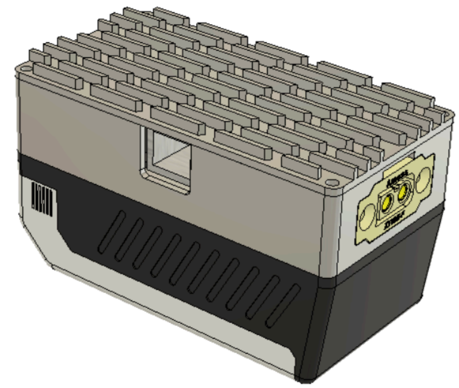


Figure 7: CAD model of the Tether Enclosure V2.0

Magnetic Kill Switch Design

According to section 4.3.1 of the RoboSub handbook, titled "AUV Requirements," it is a requirement for all participating vehicles to incorporate a distinctly marked kill switch that can be easily activated by a diver. The kill switch should effectively disconnect the batteries from all propulsion components and devices on the AUV. We use a kill switch that disconnects the PWM signals from the Navigator to the ESCs. The switch is made up of a board connected to the PWM signals from the flight controller to the ESCs and the reed switch connected to the board. The reed switch forms a closed connection when an external magnet is affixed outside the AUV; this allows for the kill switch to activate by pulling off the magnet.

Solenoid Control Board

Since this year we modified the torpedo launcher, the dropper and the claw mechanism to use solenoids, we made a custom board that can provide current to each solenoid individually based on I^2C signals sent from the flight controller.

Power comes from two XT30 connectors designed for two different voltages. The board allows selection between the two voltages on each solenoid using pin headers and a jumper. The board uses P-MOSFETs to control whether current can flow to the solenoid or not. The gates of the P-MOSFETs are connected to a I²C to GPIO board which is then connected to a JST-GH 4-pin connector to receive signal from the flight-controller. Power to the solenoids is then delivered via MOLEX connectors. Green and orange LEDs are also mounted on the board to indicate the state of each solenoid (is ready to receive power and is currently receiving power).

The custom boards were designed using KiCad software, manufactured, and subsequently assembled by JLC PCB.

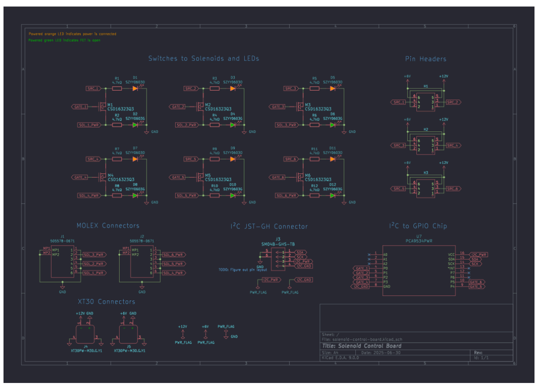


Figure 8: Solenoid Control Board Schematic

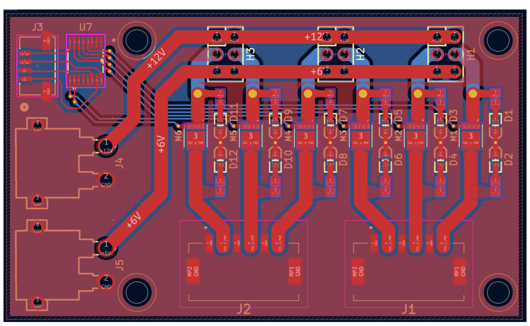


Figure 9: Solenoid Control Board PCB layout

On our HydroX 2.0 vehicle, we angled 4 thrusters towards the centerline instead of straight forward to allow the robot to move in the x-y plane (using strafing) without physically rotating. Due limited battery capacity, we decided to implement this change so we can input less current into the thrusters to move the UAV forward because less force is being wasted pushing against the motor across, creating no net force.

Electronics

The *Blue Robotics* T200 thrusters propelling the Robosub are a three-phase brushless motor optimized for underwater navigation. At 16V, it can provide a maximum of 5.25 kg of force (~51.45 N) and draws 24A (390W) at full throttle. All 8 thrusters are controlled by two *Hobbywing* 4-in-1 ESCs which support 60A of current on each channel at up to 20V.

The Navigator controls all the ESCs and the thrusters for autonomous movement. The Navigator communicates with the ESCs using the DSHOT protocol which unlike traditional PWM protocol allows motor telemetry data to be received from the ESCs as well. The message then travels from the main enclosure to the ESC enclosure via CANBUS, a protocol used in cars that allows signals to be sent and received between multiple devices all connected to only 4 wires.

The Navigator is equipped with the *Sony* IMX577-AACK Sensor Module and *OMNIVISION*'s OV9282 used for image processing. The Navigator is connected to a MS5837 depth sensor which is able to measure up to at most 30 bar (300m depth); the Navigator Nano is also connected to an RM3100 magnetometer and Invensense's 6-axis IMU to obtain the Robosub's heading, acceleration and velocity.

All of the sub's telemetry is able to be communicated using Ethernet via a wired tether to a computer outside the submarine in real time for testing. Because the tether is over 300 ft. long, two *RAKWireless* PLC LX200V30 on each side are needed in order to send data using the Homelink protocol. The maximum transmission rate is 500 Mbps.

All the electronics onboard are powered by a 10Ah, 4S *Lumenier* LiPo battery. The *Lumenier* LiPo battery operates at 16.8V at full charge and 14.8V when mostly discharged. The AUV draws an average current of 30A, so with its 10Ah capacity, the LiPo battery is able to power the sub for 20 minutes or two rounds between each charge.

Software

This year with our new ZED Box Mini our software underwent a major rehaul. We first upgraded our current Ubuntu version from 20.04 to 22.04 Jammy Jellyfish and our ROS Version to Humble Hawksbill. This enables our software codebase improved stability, better performance, and more support for the packages we need compared to the previous ROS version, Foxy Fitzroy.

In addition, we also changed our ground station controller from QGroundControl to BlueOS's Cockpit control station running on our own Raspberry Pi, which served as our flight controller. The figure below shows our overall software stack and the corresponding hardware components.

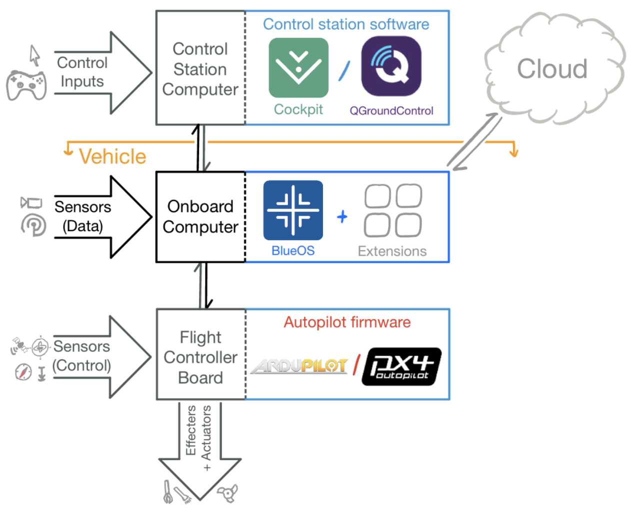


Figure 10: Visual overview of software stack.

For our main competition routine we used a finite state machine to control submarine functionality. The use of the finite state machine enables us to define certain state transitions for the robot to operate in a controlled manner while also allowing for easy debugging. For instance, our gate routine has a move forward state, spin state, and end state.

Throughout each movement, we used the flight controller's existing control algorithms and PIDs to maintain heading, and X, Y, Z position.
On the vision side, our new ZED Box mini enabled far more computer vision capabilities than before. This includes 3D perception, underwater visual-inertial localization, and object detection. To test our vision processing pipelines within a realistic environment without requiring the use of the physical sub, we sought to explore simulations. By utilizing Gazebo, an open-source 3D robotics simulator, we were able to gain a better understanding of the physics properties associated with the underwater vehicle. Gazebo's realistic underwater simulations also enabled us to experiment between a six-thruster configuration, as was utilized in 2021, and an eight-thruster configuration. The Unity simulation with the Transdec environment also enabled us to import the computer-aided design (CAD) model of our sub. The simulation utilized was composed of one client representing the flight controller and another client as the computer processor. The two clients received sensor data and controller input from the server and translated this to thruster commands allowing for sub movement.

On the localization side, the ZED Box Mini coupled with the ZED X mini stereo camera enables us to create real time maps of the subs environment. From there a predefined path is followed while a PID running on the robots heading and X, Y, Z position accounts for deviations and errors. This enables precise navigation even if the sub is perturbed. At the same time, a YOLO object detection model looks for visual markers and tasks to align the sub with the task. This enables a consistent autonomous routine across a wide variety of conditions.

Acknowledgements

We express our deepest gratitude to the individuals, organizations, and sponsors whose unwavering support and contributions were instrumental in our RoboSub 2025 season. Their expertise, resources, and encouragement enabled our team to design, build, and test our autonomous underwater vehicles.

Our mentors played a pivotal role in guiding our team through the complexities of this project. Particularly our lead technical advisor, Bruce Meagher, and our head financial advisor, Paul Fernandez. Coach Bruce dedicated countless hours assisting us with mechanical and electrical design, as well as our autonomous navigation software. Coach Fernandez provided us with tremendous support in terms of financial organization and trip planning.

We are also immensely grateful for Qualcomm, General Atomics, Blue Trail Engineering, Blue Robotics, Motovisio, and RISE for their generous support.

Lastly, we also acknowledge the resources provided by each of our parents, enabling us access to our engineering lab and testing pool. The collaborative effort of our team members, mentors, and sponsors has been pivotal in our RoboSub 2025 season so far. We are profoundly thankful for their contribution and dedication.

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Appendix A

Components	Vendor	Model/Type	Specs	Number	Status
Frame	ePlastics	ePlastics Cut Enclosure	Acrylic	1	Installed
Waterproof Housing	Blue Robotics	6" diameter acrylic with end caps	Acrylic	1	Installed
Thruster	Blue Robotics	T200		4	Installed
Motor Control	Hobbywind	60A 4-in-1	60A / 6S/ 4 Ch	3	Installed
Propellers	Blue Robotics	T200		4	Installed
Battery	Lumenier	LiPo Battery	10000Ah 4s 25c	1	Installed
Control Computer	Blue Robotics	Navigator Flight Controller		1	
Internal Comm Network	Ethernet, I2C, SPI, RS-232, USB, CAN				Installed
External Comm Network	1Gbit Ethernet, WiFi				Installed
Ethernet Current Converter	Qualcomm	QCA7005 chip	QFN 68 pins	2 (1 on each end)	Installed
Compass / Magnetometer	Blue Robotics	MMC5983MA	±8G FSR / 18bits operation 0.4mG total RMS noise / Enables heading accuracy of 0.5º / Max output data rate of 1000Hz	1	Installed
IMU	Multiple	Included on Navigator	3-axis accelerometer w/ gyroscope	5	Installed
Vision	Qualcomm	Sony IMX577-AACK Sensor Module	4K, 30 FPS	1	Installed
AI Module	NVIDIA	NVIDIA Jetson Nano Module	128-Core NVIDIA Maxwell™ GPU	1	Installed

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Thruster	Blue Robotics	T200		4	Installed
Motor Control	Hobbywind	60A 4-in-1	60A / 6S/ 4 Ch	3	Installed
			Quad-Core ARM® A57 CPU 4 GB 64-Bit LPDDR4 10/100/1000BASE-T Ethernet		
Algorithms: Vision	OpenCV				In Use
Algorithms: Localization and Mapping	SLAM				In Use
Algorithms: Autonomy	PX4, ROS2 OpenCV				In use
Open Source Software	Yocto, Ubuntu, C++, Python, JavaScriptC, ROS2				All programs Used throughout the season
Schematic/Fritzing Software	Fritzing, EasyEDA Pro, LTspice				All programs Used throughout season
CAD software	Solidworks, Fusion 360, KiCAD				All programs Used throughout season
Expertise Ratio	5 Mechanical 1 Electrical 4 Software				In use
Team Size	10				In use
Underwater Testing	Gazebo				Used Throughout Season

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Thruster	Blue Robotics	T200		4	Installed
Motor Control	Hobbywind	60A 4-in-1	60A / 6S/ 4 Ch	3	Installed
Simulation					
Water Test Time	Backyard Pool; Long Course Pool	6ft; 12ft	Started:	50 hrs	N/A