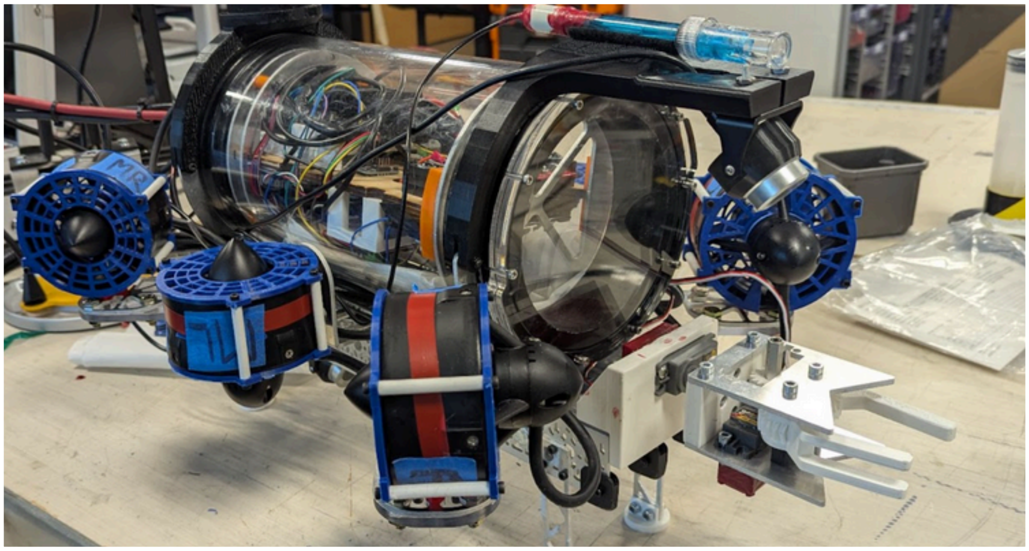

2025

LEVIATHAN ROBOTICS

North Carolina School of Science and Math
Underwater Robotics Company Morganton, NC, USA

Employees	Roles
Larry Zhao	CEO, Lead Programmer, Electrical Engineer, Tech Writer
Stephen Zhou	Lead Electrical Engineer, Safety Officer, Tech Writer
Julian Monzavifar	Lead Mechanical Engineer, Tech Writer
Eric Li	Financial Officer, Float Engineer, Programmer, Electrical Engineer, Tech Writer
Sebastian Gonzalez	Lead Float Engineer, Mechanical Engineer, Electrical Engineer
Noah Senzon	Mechanical Engineer, Electrical Engineer
Riya Reddy	Mechanical Engineer, Electrical Engineer, Tech Writer
Sam Day	Mechanical Engineer, Electrical Engineer, Tech Writer
Stella Friedman	Mechanical Engineer, Electrical Engineer, Tech Writer
Henry Chen	Mechanical Engineer, Electrical Engineer, Tech Writer
Bao Truong	Mechanical Engineer, Programmer
Brecken O'Leary	Mechanical Engineer, Programmer
Ishaan Joshy	Programmer
Mentors: Matthew Hilton, Brian Sea, and Dustin Hand	

ABSTRACT

The 2024-2025 season is Leviathan Robotics's third season competing in the MATE Ranger class competition. This season's activities have included team-building, leadership training, honing technical ability, advanced original software design, fabrication, safety culture promotion, and peer mentorship to develop an underwater ROV. We are proud to present NEMO 2 (Nautically Engineered Mechanical Object 2nd generation), an ROV designed to complete the 2025 mission tasks that simulate documenting the effects of climate change and invasive species on aquatic environments, producing renewable energy, and monitoring the health of the world's oceans.

Using lessons from last year, we designed NEMO 1's successor to be more nimble, reliable, safe, and efficient. This was done by reducing its size to allow for less drag underwater, implementing additional safety features, and simplifying various mechanical and software systems without sacrificing functionality. These refinements demonstrate our company's commitment to striving for excellence and producing the best possible product in terms of dependability, robustness, and functionality.

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PROJECT MANAGEMENT

Company Organization

This year, our company was broadly divided into four teams, the Mechanical, Electrical, Programming, and Float teams, each headed by the most experienced member in that field. Members were encouraged to explore multiple fields to deepen their understanding of each and aid their decision in which one they would like to specialize in. This provided many opportunities for teams of multiple fields to collaborate, promoting more diverse perspectives while problem-solving and understanding how different fields come together to create a working product. We also hosted meetings twice a week to allow for different teams to communicate and coordinate with each other, making it easier for different components to be integrated. Google Chat was our primary method of communication because it was easily accessible for all employees and allowed employees to have threads that branched off main conversations. Events such as meetings and field tests were kept track of through Google Calendar.

Build Schedule

In order to track the project's progress and make sure tasks were completed on time, we developed a Google Sheet that organized tasks by discipline, tentative deadline, and completion status. The benefit of using this was that it was extremely easy for all employees to understand and contribute to, while also allowing for everyone to remain informed about the progress of each team.

Category	Task	Complete By	Current Progress	Team Members Assigned	Notes
Mechanical	Waterproof Servos	1/22/2025	In Progress	Julian, + Stella	
Mechanical	Screw in thrusters	TBD	Completed	Julian, +	
Mechanical	Assemble thruster baseplate		In Progress	Julian	
Mechanical	Install electrical housing clamps	2/22/2025	Not Started	Julian, Stella,	
Mechanical	Install thruster guards	2/1/2025	In Progress	Srihan, Sam, +	
Mechanical	Prototype Claw	3/1/2025	Not Started	Julian, Noah, Sam, +	
Mechanical	Build Props		In Progress	Noah, Sebastian, Ryia, +	Worked on props and made a list of what props would be neccesary for practice and testing
General	Take Pictures for Documentation		In Progress	Everyone	
Electrical	Wire PWM breakout board	1/18/2025	Completed	Stephen, Sebastian, Brecken	Need to be wired to the new Jetson and calibrated
Electrical	Wire electronic speed controllers	1/18/2025	Completed	Stephen, Stella	Resoldered and wired escs; need testing
Electrical	Complete basic circuit diagram	2/1/2025	Completed	Stephen, Sam	Basic diagram including everything but claw servos completed
Electrical	Wire thrusters	1/18/2025	Completed	Stephen, Stella	Thrusters wired, should be no issues
Electrical	Complete onboard electronics diagram	2/16/2025	Not Started	Stephen	
Electrical	Install electronics into the electrical housing	2/16/2025	Not Started	Stephen, +	
Electrical	Wire claw (waterproof servos)	TBD	Not Started	Stephen, Sebastian	
Electrical	Wire cameras	1/25/2025	Completed	Stephen, Sam	Cameras have been tested, should be no issues
Electrical	Wire sensors	TBD	Not Started	Stephen, Stella	
Electrical	Complete final circuit diagram	TBD	Not Started	Stephen, +	
Programming	Check if Jetson Flashed properly	1/15/2025	Completed	Larry, +	Jetson has not been flashed properly, flashing a new SD Card didn't work. Now Checking if the firmware is the problem.
Programming	Calibrate PWM board	2/8/2025	Completed	Stephen, Brecken	1340 min pulse, 1870 max pulse
Programming	Send Request for Static IP for Jetson	1/15/2025	Completed	Larry, +	Sent an IT ticket to request for a Static IP of 10.50.2.103
Programming	Install ROS2 Humble on Jetson	2/12/2025	Completed	Larry, +	
Programming	Set up Docker	2/13/2025	Not Started	Larry, +	
Programming	Test Previous Year's Code	2/14/2025	Not Started	Larry, +	
Programming	Create new Git Repo for this year	2/15/2025	Not Started	Larry, +	
Programming	Set up workspaces	2/19/2025	Not Started	Larry, +	
Programming	Research Computer Vision	3/8/2025	Not Started	Larry, +	
Float	Find a way for Arduino to send data to laptop	1/14/2025	Completed	Eric Li, +	Hosted a flask server, then had arduino send messages to flask server using http requests.
Float	Read values from depth sensor	1/16/2025	Completed	Eric Li, Sebastian	
Float	send data from depth sensor to laptop	1/18/2025	Completed	Eric Li, +	
Float	Use values from depth sensor to control syringes to hover	1/22/2025	In Progress	Eric Li, +	
Float	Create way to start + stop the float	1/24/2025	In Progress	Eric Li, Sebastian	
Float	Finish Code	1/28/2025	Not Started	Eric Li, +	
Float	Assemble Float	1/29/2025	Not Started	Eric Li, Sebastian	
Float	Test Waterproofing + Functionalities	1/31/2025	Not Started	Eric Li, Sebastian	

Figure 1: Spreadsheet used to track project progress

DESIGN PROCESS

Approach to Innovation and Problem Solving

At Leviathan, we believe that effective problem-solving involves rapid communication and diverse perspectives. When confronted with an issue or a specific challenge we need to address, the proper employees are notified during meetings as soon as possible and then the entire company is notified by a message in Google Chat that outlines the problem. This allows all employees to be aware of the situation and propose their solutions. Because many of our employees are involved in multiple disciplines, this also allows us to better consider how features and solutions we decide to implement will affect various aspects of the robot as a whole. If employees propose multiple conflicting solutions, those proposing a solution explain the benefits and drawbacks–such as ease of implementation, cost, reliability, and functionality–of their idea to other employees involved in brainstorming to vote on the idea that best fits the company's collective vision for the ROV.

Once a solution is agreed upon by the majority , we evaluate whether or not we should build the needed components ourselves or buy them. If the decision is made to purchase the items, an employee is assigned to search online for the best component for sale that meets the necessary specifications. Their selection is evaluated by the heads of the involved team, and once confirmed, it is added to a Google Sheet for items that need to be ordered.

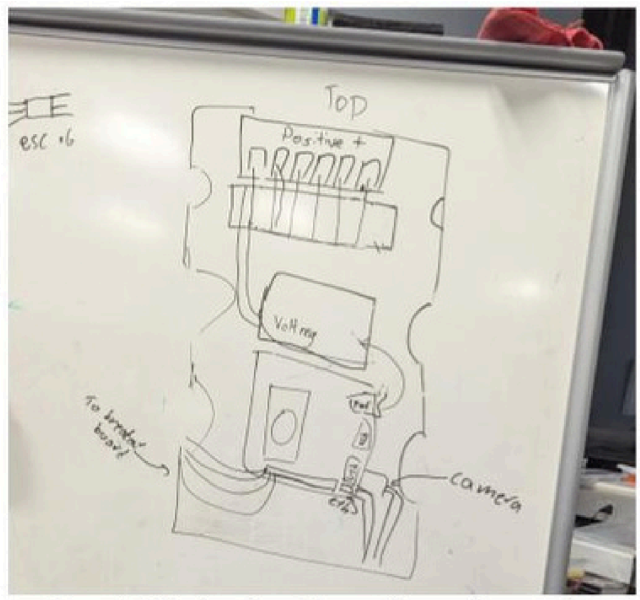

Figure 2: Whiteboard used by members to illustrate their ideas to others during brainstorming

Build vs. Buy, New vs. Reused

Due to our access to high-precision CNC fabrication machinery and our employees' being well-versed in fabrication techniques like CAD, we tend to prefer to produce whatever parts we can ourselves to reduce the cost of a solution. Often, these parts performed better than those for sale because we could produce them to fit our unique specifications and goals. For components that we already had and were working properly, we would decide whether they needed to be replaced with a new alternative or could continue being used. For each of these decisions, we would evaluate the cost of production, cost to purchase, time to implement, and how necessary new changes were. The following are examples of when we chose to build, reuse, and buy new parts:

Waterproof Servos (Build)

As a company, we have struggled with servos for manipulators being damaged from prolonged exposure to water. Both pre-waterproofed and self-waterproofed servos had the same result of becoming waterlogged and eventually becoming unusable. So, instead of purchasing waterproofed servos this year, we have developed a new waterproofing method of our own.

In past years, we simply coated the outside of servos with liquid electrical tape to prevent water from getting inside the servo housing. This year, we have expanded our method. We first disassemble the housing of the servo, then fill the insides with a non-conductive fluid, in our case mineral oil, replace the screws, placing O-rings on the head of every screw as well as on the servo horn, and then fully coating the outside with liquid electrical tape. The non-conductive fluid prevents water that might get between cracks in the servo housing from getting to the electronics and shorting the circuit. This method has yet to fail us, with our testing showing that leaving a servo fully submerged for over a month still working at 100% capacity.

Voltage Regulator with Switch (New)

The voltage regulator from last year for the Jetson was working just fine, however, we decided to purchase a new one and replace it. The price of this voltage regulator was actually cheaper than the original, and it featured two Ground and VOut terminals instead of only one of each. In addition, it had a switch that could turn the voltage regulator on and off, which made troubleshooting issues with the electrical system easier because we could quickly disconnect and reconnect the Jetson to the main terminal blocks.

T-200 Thrusters (Reused)

Blue Robotics T-200 thrusters are the thruster of choice for many robotics teams competing in underwater robotics competitions and for underwater drones used to inspect underwater infrastructure, ships, and shipwrecks. Although they are costly at $200 each, they are worth the price tag as they are known for their versatility, reliability, and ease of use. Through testing, we confirmed that the thrusters that were used last year were working perfectly fine and were still able to output a similar speed underwater, and thus decided that reusing them would not hinder our final product.

Testing and Troubleshooting

After the relevant component is either produced or purchased, we put it to the test to evaluate how well it meets the requirements we originally intended. For example, after waterproofing all of our cable penetrators, we tested the canister's ability to maintain air pressure using a vacuum pump with a gauge. This was a much-needed improvement over last year, when we tested water tightness within a bucket of water because the bucket was not deep enough to adequately simulate the higher pressure environments that the ROV would have to operate in during the competition.

We also extensively prototyped parts that we created ourselves. For our Jetson mount, we had to go through several iterations before reaching an acceptable product. We tested various mechanisms to hold the Jetson in place and also experimented with reducing the amount of PLA used to make the mount to reduce the weight and shrink the size of the mount. Our final version exhibited a good balance between small size and the ability to securely clamp the Jetson to the electronics board.

When calculating the limits of the electrical system, we tested the amount of power used by our T-200 thrusters. According to Blue Robotics, each thruster pushed to full throttle uses 17 amps at 12 volts, but this was not consistent with our results from testing. We determined that each thruster used only about 3 amps at full throttle when submerged and 2 amps when above water. This indicates that we are not maximizing the full potential of the thrusters, but this is most likely due to the MATE-compliant power supply not being able to output enough power to support the thrusters.

When testing the ROV, we take many precautions to prevent and quickly catch any malfunctions before serious complications can occur. We achieve this by performing a preliminary water tightness test where two employees submerge the vehicle in shallow water for a minute before allowing it to resurface and checking for water within the main canister. In addition, whenever the ROV is released in the pool, a minimum of two employees will be in the pool to recover the vehicle in case of a system failure. We test buoyancy by driving the ROV to a depth of 1.25 meters within a 2.5-meter pool and timing how long it takes to resurface or sink to the bottom on its own. Additional tests also include camera visibility in water, maximum vehicle speed, and manipulator precision when grabbing props. We constructed a wide variety of these props to determine how versatile NEMO 2 is at manipulating various objects.

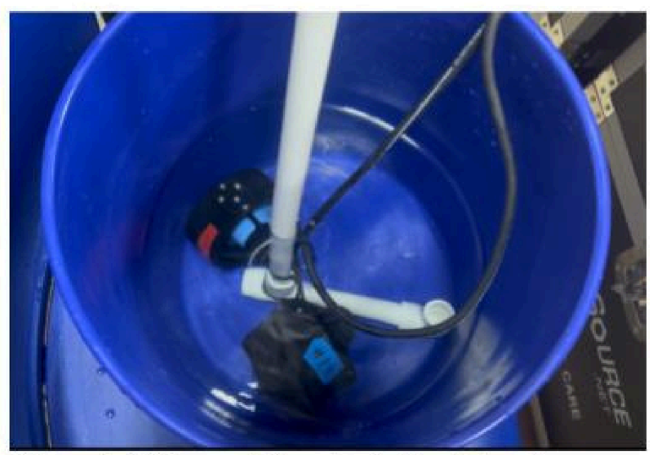

Figure 3: Submerged thruster test to determine power usage

SYSTEMS APPROACH

While designing our ROV, we took an approach that emphasized integration and collaboration across all subsystems. We recognized that no component is ever purely mechanical, electrical, or software-based; instead, each part requires teamwork and communication between all disciplines. For example, when developing our wooden internal electronics board, all of our teams worked closely to coordinate the placement of holes and openings. As a result, after the board was cut, we had an easy time mounting and connecting all of our electronics while also including the various sensors our software team needed. With the combination of our two cameras, depth sensor, and IMU, our ROV can provide our driver with a clear vision of the ROV's surroundings and automatically hover in the water. In addition to inter-team coordination, we also made sure to consider the impact of each component on the rest of the ROV. When developing our claw, we accounted for the fact that its weight would influence the balance of the ROV as a whole and redistributed our weights to the opposite side of the robot to act as a counterbalance. By always thinking beyond our individual responsibilities and considering how each part fits into the broader system, our approach makes sure we create a cohesive, well-functioning ROV and avoid unexpected issues during integration.

DESIGN RATIONALE

When designing NEMO 2, we envisioned it to be more reliable, nimble, and easier to modify than the original NEMO. Our innovations and improvements in mechanical, electrical, and software systems exemplify this. NEMO 2 is 55 cm long, 40 cm wide, 22 cm tall, and omits an external frame to reduce weight, bulkiness, and drag. Since it was also made with the ability to easily make modifications in mind, it is easy to disassemble and reassemble to troubleshoot individual electrical and mechanical components.

MECHANICAL SYSTEMS

Frame

For the 2025 ROV frame, we utilized ¼’’ polycarbonate due to its low weight, high rigidity, and our in-house manufacturing ability with the use of our ShopBot CNC router. The main body of the frame is 33 cm long and 18 cm wide, with the thruster sections extending out slightly further. Compared to the 2024 season, we significantly compacted both the length and the width, improving the overall packaging of the ROV for increased maneuverability. Two 48 cm long U-channels of aluminum (REV Robotics, REV-41-1750) are mounted underneath the polycarbonate sheet for reinforcement and tool mounting locations, specifically for the ROV claw and passive hook mechanisms. The U channel is hole-patterned and allows us to design parts that can be easily adjusted positionally on the U channel.

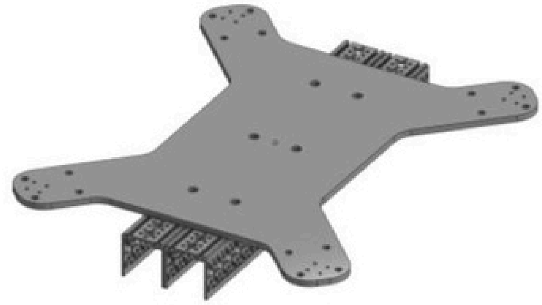

Figure 4: ROV Frame

Thruster Mounts

Our forward and reverse thrusters are mounted to the ROV frame by a custom laser-cut ⅛'' aluminum gusset pocketed for weight reduction. The gusset is mounted to the polycarb plate by ¼-20 fasteners, and the thrusters are then secured through the polycarbonate plate by their mounting screws. The ¼-20 fasteners ensure that the thruster mounts are extremely rigid and secure due to the high torque placed on them from the T-200 thrusters.

The vertical thrusters are mounted to the ROV frame by the same aluminum material and ¼-20 fasteners but utilize a 90° bend to provide the proper orientation for the thrusters.

Figure 5: Forward/Reverse Thruster Mount

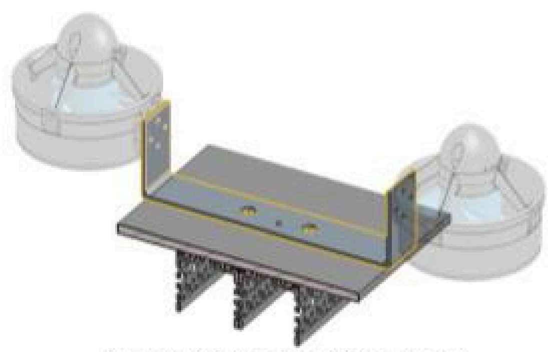

Figure 6: Vertical thrusters

Internal Architecture

Due to its low cost and weight, last year's ROV electronics for N.E.M.O were mounted on a 3D-printed PLA board. However, we experienced difficulties with drilling through the PLA board to mount the electronic components, and a new printed iteration could take up to 20 hours to print. Additionally, the supports on the board that kept it in place within the canister were flimsy and prone to breakage.

We fixed this problem for the 2025 ROV by switching to a thin chipboard material for the electronics board, as it has similar benefits of low cost and weight with the added benefit of quick, in-house manufacturing with our Glowforge laser cutter. The chipboard is then slid into two slotted custom-laser cut aluminum pieces that are mounted to the inside of the canister lid. This allows for easy access to electronics because the entire tray can be removed in one piece while also allowing the wooden electronics board to be easily swapped for new board iterations. The aluminum pieces are also much more stable and sturdy than the PLA supports attached to the board from last year.

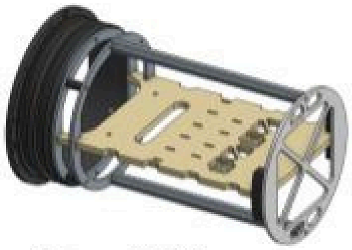

Figure 7: Electronics Housing

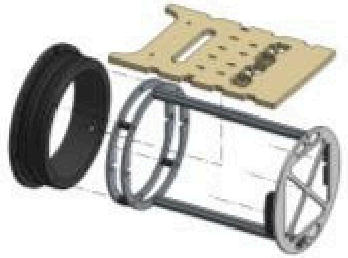

Figure 8: Exploded View of Electronics Housing

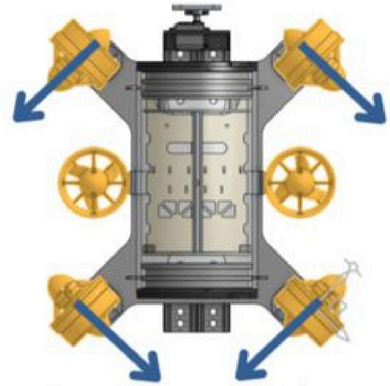

Figure 9: Thruster output when in forward mode

Propulsion

NEMO 2 uses six T-200 Blue Robotics thrusters to propel itself through the water. The decision to continue using T-200 thrusters was influenced by the thrusters' reputation as reliable and efficient for usage in both underwater robotics competitions and real-world applications. Two thrusters are mounted facing up on the sides to control the vertical axis and roll. Meanwhile, the other four are arranged in an "X" configuration, controlling movement in the horizontal axis and yaw. While this means that forward and backward motion is not as fast as it would be in an "H" like configuration, it allows for a good balance between speed and stability. As the ROV moves forward and backwards, it is extremely stable because the left and right movement from each thruster is cancelled out by another, leaving only forward and backward motion. In addition, the configuration does not hinder the yaw, so the robot can still make turns with ease.

Cable Management Prongs

To improve wire management and prevent any tangles from forming, we added prongs to the sides of our aluminum hub clamps. These prongs allow for wires to easily slide in, but not out, and we use them to hold the thruster, camera, and sensor wires in place and away from the thrusters.

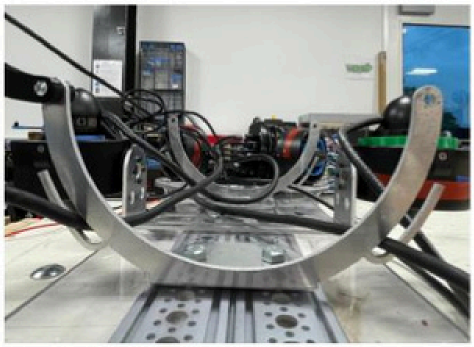

Figure 10: Hub clamps with cable management prongs on sides

Buoyancy and Ballast

In planning, our company set out to create an ROV system that was both neutrally buoyant and balanced. To achieve this, we strategically placed our two U-channels at the bottom of the ROV, where they would double as both a structural hub and a ballast. We then calculated the amount of weight we would need to add to the ballast in order to achieve our goal of neutral buoyancy in freshwater and adjusted it as needed through testing. The volume of our ROV is estimated by our CAD model to be 4.3 liters (4.3 kg) of pool water displaced, and its mass is estimated to be 10 kg. The difference of 5.7 kg is the ballast required to make the ROV neutrally buoyant in pool water. With the ROV's heaviest components concentrated at the bottom, the ROV became much more stable and stayed balanced even when moving.

Payload and Tools

Cameras

We decided to continue using the DeepWater ExploreHD waterproof cameras because they come watertight and provide a wide field of view and range of colors useful for quickly identifying objects in the ROV’s environment. One camera is mounted on the front top of the ROV, pointing slightly downward so the driver can effectively control the manipulator and drive forward. The other is attached to the U-channel at the back bottom at the same angle to scan under the vehicle and make use of the passive hook also attached to the U-channel.

9-Axis IMU

The Adafruit 9-DOF Absolute Orientation IMU Fusion Breakout 2472 is mounted on the upward-facing side of the electronics board. It provides the driver with critical information about the vehicle’s orientation, including roll, pitch, and yaw when under operation. Data from the IMU is also used for software programs that stabilize the ROV’s orientation when submerged.

Depth Sensor

The BlueRobotics Bar02 Ultra High Resolution 10m Pressure Sensor is, as its name suggests, very precise in measuring the depth of the ROV, with a resolution of 0.16 mm when submerged. It allows us to gauge the depth of the ROV, and its data, when used in conjunction with the IMU’s, supports a program that can stabilize the ROV’s vertical movement in the water to more precisely make use of the manipulator.

Manipulator

As a company, we prioritized tasks that could be completed with the fewest degrees of freedom possible for game-piece manipulation. We found that the majority of simple, yet high-scoring tasks could be performed by two degrees of freedom: a 90° articulating wrist that allows the ROV to grab PVC pipes in horizontal and vertical orientations and a “pinch” style manipulator.

The wrist is composed of a high torque servo that is mounted by a 3D printed PLA part to the U Channel on the front of the ROV. The manipulator is then attached to the servo hub on the wrist servo. The manipulator is mounted to the wrist by two screws, allowing for easy assembly and repair.

The end effector is composed of ⅛'' aluminum for the structure, a high torque servo, and 3D printed gears. The end effector's geometry is optimized for a ½'' PVC pipe and utilizes a geared servo with a .6:1 reduction to increase the torque output. Due to the high torque conditions, the end effector utilizes 3D printed double helical gears for the highest possible tensile strength of the gear. The 3D printed claw jaws are dead axles, containing a bearing inset to the print itself rather than the aluminum plate holding the claw together. This use of a dead axle was done to prevent the bearings from being pushed out of the plate, as well as to increase the overall rigidity and durability of the claw.

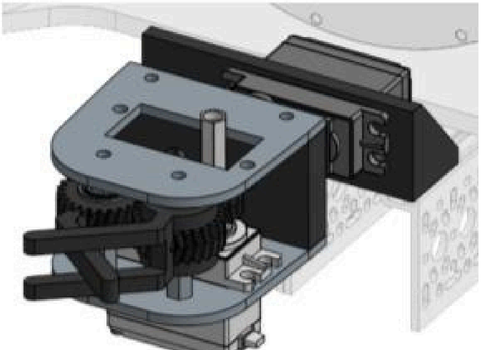

Figure 11: Full Manipulator

Figure 12: Wrist Assembly

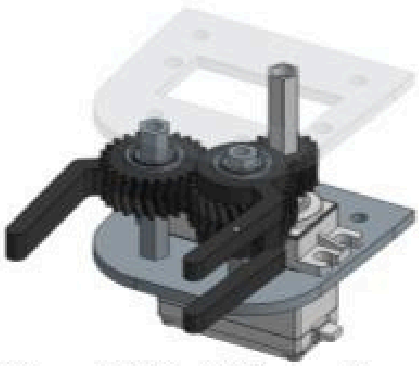

Figure 13: End Effector Assembly

ELECTRICAL SYSTEMS

Fuse and Power Calculations

Item	Current	Power
Thrusters x6	3A each * 6 = 18A	18A * 12V = 216W
Jetson Orin Nano	1A	1A * 15V = 15 W
Cameras x2	0.15A each * 2 = 0.3A	0.3A * 12V = 3.6W
Servos x2	0.45A each * 2 = 0.9A	0.9A * 15V = 13.5W
Totals	**20.2A**	**248.1 W**

For the main fuse, we calculated that ROV Full Load Amps (FLA) in water = 20.2 amps, so selecting the next higher standard fuse size would be 25 amps. Thus, Fuse size selected based upon FLA = 25 amps. Last year, the ROV suffered a short circuit, and excess current surged through the system, frying components of the Jetson. To prevent future accidents, we installed a secondary fuse between the voltage regulator and the terminal blocks to protect the regulator and the Jetson from dangerous power surges. The Jetson uses 15 watts at max power, and divided by 12 volts means that the maximum amperage the Jetson should draw is 1.25 amps. The next highest standard fuse size was 2 amps, so we used a 2 amp fuse.

The ROV is calculated to use 248.1 watts at full power. Given that the max amperage from the fuse is 25 amps and the max voltage from the MATE power supply is 12 volts, 25A * 12V = 300W, meaning we have 51.9 watts left over to account for power losses and to use for any future applications.

Control Systems

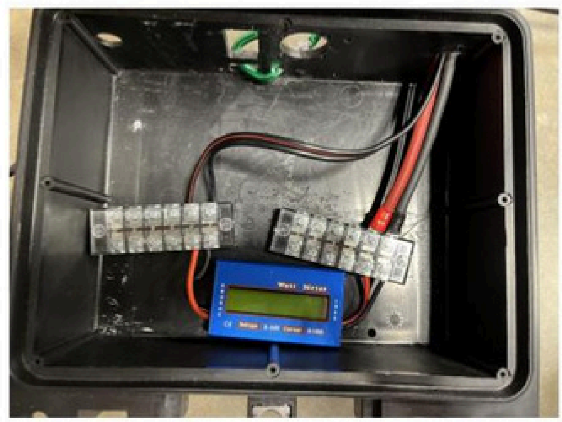

Figure 14: Wires are connected to a watt meter inside the control box

We decided to continue on from last year using the Jetson Orin Nano as our primary computational unit due to its ability to handle Linux and Robotic Operating Systems (ROS) 2. ROS 2 allows us to easily and quickly handle data from sensors and execute user inputs to thrusters and servos without much latency.

All bottom-side electronics are powered by two 8 AWG copper main power cables connected to the topside control box and the 10-position terminal blocks in the ROV. A voltage regulator is then connected between these blocks and the Jetson to maintain a constant voltage. Unlike last year, this voltage regulator has a switch, allowing it to be turned on or off, enabling us to troubleshoot issues with the electrical system. Communication between the Jetson and the driver’s laptop is maintained through a Cat 5e ethernet cable in a T568B wiring configuration. This specific cable in T568B configuration allows us to transmit data at high speeds up to 1000 Mbps, further reducing latency. The Jetson Orin Nano has 2 I2C loops: one that we used for the 9-axis IMU and the depth sensor and another used to operate an Adafruit PCA9685 PWM breakout board that was necessary to control the Blue Robotics ESCs due to the Jetson’s lack of PWM pins. The IMU provides data on the robot’s roll, pitch, and yaw, while the depth sensor provides accurate data about its vertical placement, allowing us to implement programs to stabilize the ROV’s positioning.

On the topside, we have the control box where the two main power cables are connected. Bolted inside the control box is a terminal block that connects the main cables to the wires plugged into the MATE power supply. The control box also features a watt meter that allows us to monitor the voltage, amperage, and wattage of the system. Please refer to Appendix I for details regarding the ROV’s SID.

Tether Protocol

The tether consists of the 2 main power cables and the ethernet cable wrapped in a sheath with pool noodles wrapped around it to maintain its neutral buoyancy. When the tether is to be used, we follow the protocol below:

1. Designate one employee to be the dedicated tether tender and execute the protocol.
2. Remove tether from the storage bin and place it in an easy-to-manage coil configuration.
3. Visually inspect tether for any damage to the wires.
4. Ensure tether is secured in the strain relief device.
5. Connect ethernet cable to laptop and power cables to power supply.
6. Avoid weaving around obstacles and turning 360 degrees as this could cause the tether to become entangled.
7. Never step on the tether, this could cause concrete to grind against it and damage the wiring.
8. Once operations are completed, disconnect the tether from the laptop and power supply.

After disconnection, recoil the tether and carefully place it in the storage bin without jamming it in.

SOFTWARE SYSTEMS

Software Map

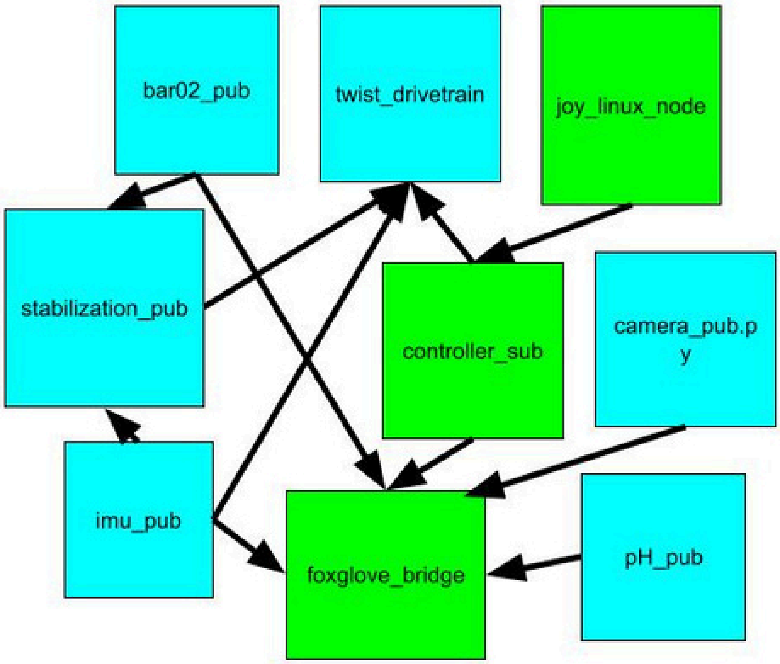

Figure 15: ROS Node Diagram. Arrows indicate the flow of data, blue nodes are run onboard on the Jetson Orin Nano, and green nodes are run topside.

ROS Node Descriptions

- joy_linux_node: A built-in joystick driver for ROS, this node publishes a joy message containing controller inputs.
- controller_sub: Subscribes to the joy messages and publishes twist and manipulator messages.
- imu_pub: Publishes data from the Adafruit bno055 IMU for use with automatic stabilization and vertical thrust alignment.
- bar02_pub: Publishes data from the BlueRobotics Bar02 pressure sensor for use in auto-stabilization.
- pH_pub: Publishes data from the pH sensor for use in certain tasks.
- stabilization_pub: Subscribes to the orientation and depth data from the IMU and depth sensor to publish a custom ROS stabilization message used to control the vertical thrusters to maintain a standard depth and roll.
- twist_drivetrain: Subscribes to the twist, manipulator, and IMU topics and sends the appropriate signals to the thrusters and manipulator servos. The IMU message is used for auto-roll correction using the vertical thrusters. In the instance that there is no immediate signal, this node defaults to using the twist message from the stabilization_pub node, which maintains neutral roll and consistent depth.
- foxglove_bridge: Uses the Foxglove WebSocket protocol to connect with Foxglove to display information about sensor, thruster, and manipulator data.
- camera_pub: Uses the ROS CVBridge library to continuously publish camera images taken from both DWE exploreHD 3.0 cameras. These images can then be easily accessed from the driver's laptop via Foxglove.

Launch Files

With last year being our first time using ROS, we had a lengthy and complicated launch process in which we had to open a new terminal window for every node we ran. This meant that we had to create 5 new terminal windows just for our robot to be able to have basic driving functionalities, resulting in an extremely slow, frustrating process that wasted valuable time starting the ROV. This year, we significantly improved our workflow by creating custom launch files. These scripts allow us to start all of our necessary nodes with just two commands: one for the topside nodes and one for the nodes running on the Jetson, streamlining the process and saving us time during deployment.

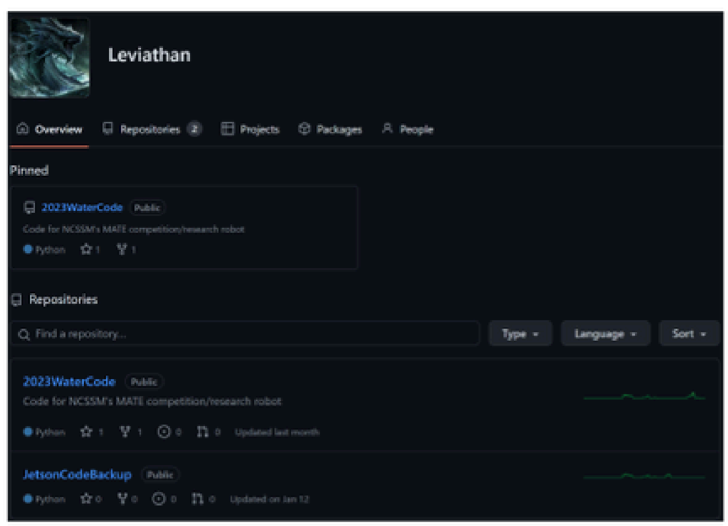

Figure 17: Leviathan's GitHub Repositories

Dashboard Display

Last year, our drive station also didn't have a dashboard display. Instead, we had various terminals cluttered across the screen, making it harder to set up and read when driving. This year, we created a dashboard using Foxglove, a purpose-built visualization tool we chose for its modular organization structure as well as its ability to view messages sent between ROS nodes and plot values from those messages over time.

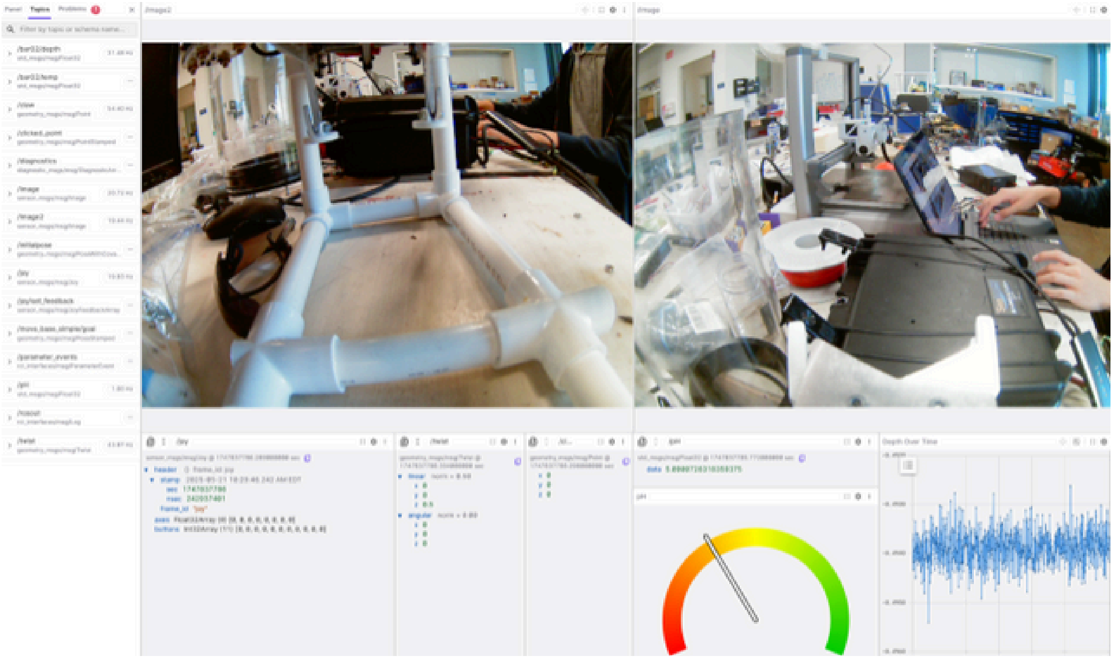

Figure 16: Early Prototype of New Dashboard

Code/Software Management and Version Control

Git

Throughout the development of our codebase, we used Git for both version control and collaboration. Git is a version control software that enables each employee to create separate branches from the main codebase, make changes independently, and later merge their updates back into the main branch. Git also allows us to quickly distribute the latest version of the code to the Jetson Orin and all employees' computers. Just as importantly, Git tracks every change along with the contributor's identity, providing both accountability and the ability to roll back to previous versions if issues arise.

Docker

We used Docker to create custom environments for running topside ROS nodes on our computers. These containerized environments automatically installed all essential software and code dependencies, ensuring that every employee had a consistent and fully equipped setup for writing and deploying programs. Due to conflicts between the controller connection and WSL2, the topside code is executed on a machine running Linux during operation.

MATE FLOAT

Figure 18: Isometric view of CAD design of the float

Last year, we attempted the float, but various technical issues prevented it from entering the water. This year, we decided to continue tackling the float, carrying on our lessons from last year. We utilized a syringe and a servo as the buoyancy engine.

Learning from last year, where we had an excessively buoyant float, we reduced the total syringe volume from a single 350mL to 4 50mL syringes, giving us a total of 200mL capacity instead of 350mL capacity. The syringes displaced water, which would affect the buoyancy of the float, allowing us to rise and fall in the water. We reused the same Blue Robotics 4’’ Acrylic Tube for the electronics housing and used similar end caps to seal the canister. The end caps were modified for a depth sensor to be used to measure the pressure and temperature of outside water, as well as a pressure relief valve to be added, preventing excessive pressure from building up. The end caps were also modified to allow for the four syringes to run through.

The syringe is connected to a lead screw, connected to a servo motor. Turning the servo motor turns the lead screw, which pushes/pulls the syringe. The servo is controlled by an Arduino MKR WiFi 1010, which controls the functions of the float. The Arduino is also connected to the depth sensor, gathering data about the outside water, including depth and temperature. The entire float is powered by AA batteries, each with a voltage of 1.5V. The Arduino is powered by 4 AA batteries in series, meaning 6V in total. This allows it to autonomously collect data, send commands to the servo, and communicate using Wi-Fi with an outside computer. The servo motor is powered by a separate set of 4 AA batteries in series. The servo motor is a component that requires more power when compared to other components and is, therefore, powered by a separate set of batteries. Both packs are fused by a 0.75A Fuse on the positive end, as well as a 1.5A Fuse on the common negative terminal. Details regarding the Float’s SID and fuse calculations can be found below. Please refer to Appendix II for more details regarding the Float’s SID and fuse calculations.

The float is controlled via HTTP. Using Wi-Fi, the float can communicate with an external computer using the HTTP protocol, which it uses to both send data and receive commands. When the command to dive is sent from the computer, the float can dive down for a specified amount of time and will continuously collect data about the surrounding water. After the specified amount of time, the float will rise back up, and once the Wi-Fi connection is reestablished, the data can be sent back to the computer.

SAFETY REVIEW

Our Safety Philosophy

At Leviathan, we believe that the safety of our employees and products are of the utmost importance. In keeping with this belief, we take a series of precautions to prevent accidents in the workplace and during field tests, where they are most likely to occur. The most important of these safety measures include keeping everyone informed of the possible dangers that can occur during the construction and operation of the ROV and the strict regulation and completion of the appropriate safety checklist (see Appendix III).

In the Workplace

Most of our work on the ROV takes place inside a fabrication lab, where we have access to power tools and CNC machinery. Before using any power tools or saws, employees must complete the necessary training for that tool with an adult expert. Before starting construction, employees must not be working alone and be wearing the appropriate PPE and no prohibited clothing items like open-toed shoes, loose or baggy clothing, and shorts. When using dangerous CNC machines like the metal cutter or electric saws, an adult must always be present.

At the Poolside

When testing, we also enforce strict safety protocols to prevent damage to the ROV or harm to handlers. These include poolside handlers having to wear closed-toed shoes with good traction and absolutely no running to minimize the risk of slipping. Before deployment, the ROV's electronics are carefully inspected for compromises, and the tether is coiled to prevent tangles. During deployment, employees are not allowed in the pool at the same time as the ROV to protect them from any danger the ROV could pose.

Built-in Safety Features

Two Fuses

NEMO 2 makes use of two fuses: one 25 amp fuse to protect the electrical system of the ROV and one 2 amp fuse to specifically protect the Jetson Orin Nano and voltage regulator.

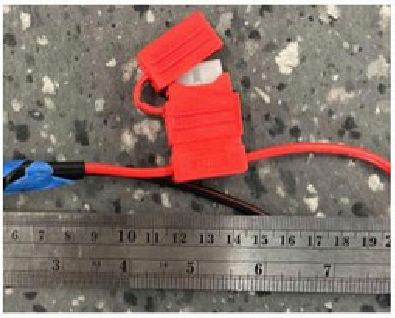

Figure 19: Main 25 amp fuse

Thruster Guards

The connection points on our thruster guards from last year were extremely thin and flimsy, making them snap off occasionally during operations. These new thruster guards remedy that issue, maintaining low drag while still effectively preventing debris from entering the thruster.

U-Channel Corner Guards and Sanded Edges

3D-printed corner guards made out of PLA are attached over all protruding corners on the U-Channel, and all sharp edges along the polycarbonate frame, aluminum thruster mounts, U-Channel, and manipulator are sanded down. This protects employees from abrasions when handling, especially during field tests when the robot is handled most often.

Tether Strain Relief

The ROV is equipped with a tether strain relief device on its frame that prevents the transfer of pulling forces to the electronics. This prevents any accidental wire disconnects and damage to waterproofing.

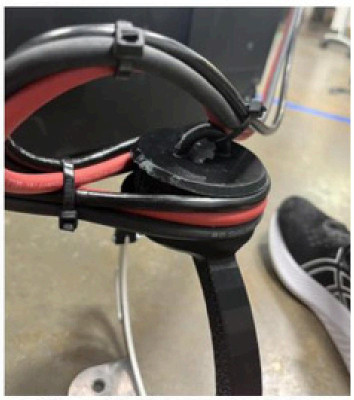

Figure 20: Tether strain relief on the frame

Figure 21: Custom-made thruster guard in orange

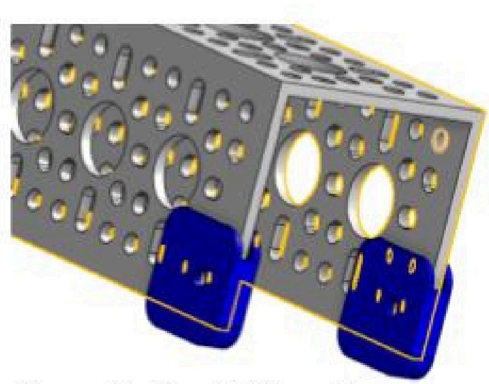

Figure 22: Blue U-Channel corner guards

BUDGETING

Team Name:		Leviathan Robotics				
Mentor		Matthew Hilton				
Income						
Source						Amount
North Carolina School of Science and Mathematics						$2,000.00
SCSSI Club Dues						$2,600.00
					Total:	$4,600.00
Expenses						
Category	Type	Examples			Projected Cost	Budgeted Value
Hardware	Purchase				$700.00	$667.20
Electronics	Purchase				$200.00	$98.80
General	Purchase				$600.00	$593.52
Travel: Regionals	Purchase	Hotel, Food, Gas			$850.00	$850.00
Travel: Worlds	Purchase	Hotel, Food, Travel			$7,000.00	$7,000.00
Club T-Shirts	Purchase	T-shirts			$370.00	$370.00
Registration	Purchase				$450.00	$450.00
			Total:		$10,170.00	$10,029.52
			Total excluding worlds travel:		$3,170.00	$3,029.52
			Excess excluding worlds		$1,430.00	$1,570.49
			Deficit including worlds		-$5,570.00	-$5,429.52
			Fundraising needed for worlds		$5,570.00	$5,429.52

Figure 23: Budget Documentation Sheet

Team Name:		Leviathan Robotics		Initial funds:	$2,000.00
Mentor		Matthew Hilton			
Funds:					
Type	Category	Expense	Notes	Amount	Running Balance
Purchased	Hardware	15mm square tubing		$41.90	$1,958.10
Purchased	Hardware	30 ml Syringe (3 Pack)		$4.99	$1,953.11
Purchased	Hardware	4" diameter O-ring end		$56.26	$1,896.85
Purchased	Hardware	4" end cap-aluminum-blank		$30.00	$1,866.85
Purchased	Hardware	zipties and adhesive mount		$9.99	$1,856.86
Purchased	Electronics	FUSE GLASS 100MA 250VAC 5X20MM (5 pack)		$4.93	$1,851.93
Purchased	General	Jetson Orin		$534.02	$1,317.91
Purchased	Hardware	192mm hex shaft		$12.18	$1,305.73
Purchased	Electronics	Fuse 100 MA (5 pack), SHR-05V-S-B Connector (10 Pack), PHR-2 Connector (10 Pack)		$12.31	$1,293.42
Purchased	Electronics	In line fuse holders and blade fuses		$14.48	$1,278.94
Purchased	Electronics	Step-down voltage regulator		$34.00	$1,244.94
Purchased	Electronics	CONN SOCKET 28-32AWG CRIMP TIN		$12.19	$1,232.76
Purchased	Hardware	PolyCarb Sheet 24x24x1/4		$43.68	$1,189.08
Purchased	Hardware	GoBilda high torque servo		$38.40	$1,150.68
Purchased	Hardware	Mineral Oil		$3.03	$1,147.65
Purchased	Electronics	analog to digital convertor		$20.89	$1,126.76
Purchased	Hardware	8.5 mm LC WetLink Penetrators		$54.50	$1,072.26
Purchased	General	Lab grade pH sensor		$59.50	$1,012.76
Purchased	Hardware	claw servos		$120.00	$892.76
Purchased	Hardware	claw servos		$60.00	$832.76
Purchased	Hardware	Pressure, Depth, Temperature sensor		$150.00	$682.76
Purchased	Hardware	PLA 2.85 (Black)		$22.99	$659.77
Purchased	Hardware	36mm stand offs		$4.39	$655.38
Purchased	Hardware	servo hub		$10.00	$645.38
Purchased	Hardware	45mm screws		$4.89	$640.49
Club Dues	Club Dues	SCSSI Dues for Worlds		-$5,600.00	$6,240.49
Purchased	General	Tax		$4.41	$6,236.08
Purchased	General	tax		$6.50	$6,229.58
Purchased	Hardware	Lidar		$77.35	$6,152.23
Purchased	Electronics	Switches		$84.50	$6,067.73
Purchased	Hardware	Leak Sensors, RGB Lights, Venting		$279.77	$5,787.96
Purchased	Hardware	Liquid Tape and Caulk Gun		$29.87	$5,758.09
Purchased	General	Poster		$154.79	$5,603.30
Purchased	General	Team Breakfast First Day		$48.03	$5,370.38
Purchased	General	Team Breakfast Second Day		$38.91	$5,331.47
Purchased	Hardware	Sponge		$3.65	$5,327.82
Purchased	Hardware	Magnets, Paracord, Worm Weights		$16.45	$5,311.37
Purchased	Hardware	Building Supplies		$47.46	$5,263.91
Purchased	Hardware	Plastic Syringe with 0.15" ID Taper Tip, Clear, 50 ml Capacity		$33.26	$5,230.65
Purchased	Hardware	4" end cap-aluminum-blank SKU: BR-102993-999		$66.10	$5,164.55
Purchased	Hardware	216mm stand off 1516-4008-2160		$27.13	$5,137.42
Purchased	Hardware	35kg waterproof servo INJS0270		$49.30	$5,088.12
Purchased	Hardware	2lb scuba shot 766114914175		$12.99	$5,075.13
Purchased	Electronics	WiFi R3 ATmega328P+ESP8266 Development Board 32mb Memory USB-TTL CH340G Dual Microcontrollers, WiFi Connectivity, Arduino Compatibility, Flexibility, Support		$14.99	$5,060.14
Purchased	Electronics	DIYmall 2.4G WiFi Antenna with U.FL to Female SMA Cable, 3DBI Gain Antenna for Arduino Wemos D1 M1 ESP8266 ESP32 ESP-07 2pcs		$9.99	$5,050.15
Purchased	General	Food Chaperones - Regionals		$126.00	$4,924.15
Purchased	Electronics	Ardunio MKR WAN with waterproof antenna		$52.85	$4,871.30
Purchased	Travel	American Airline Flight to DTW		$1,895.76	$2,975.54
Purchased	Travel	Van Rental		$1,690.00	$1,285.54
Reused	Props	Leftover PVC pipes and connectors		$150.00	...
Reused	General	xbox controller		$60.00	...
Reused	Hardware	6 T200 thrusters		$1,200.00	...
Reused	Electronics	6 Blue Robotics ESCs		$230.00	...
Reused	Hardware	Wetlink and potted cable penetrators		$160.00	...
Reused	Electronics	Terminal Blocks		$20.00	...
Reused	Hardware	Tether Materials		$130.00	...
Reused	Electronics	Terminal Crimps		$15.00	...
Reused	Hardware	Epoxy		$30.00	...
Reused	Hardware	2 explore HD cameras		$600.00	...
Reused	Hardware	Aluminum robot frame from last year		$80.00	...
Reused	Hardware	Robot watertight enclosure		$500.00	...
			Total Cost of Parts		$6,314.47
			Initial Budget		$2,000.00
			SCSSI Dues for Worlds		$5,600.00
			Total Spent		$6,314.47
			Balance Left		$1,285.54

Figure 24: Project Cost Tracker

REFERENCES

MATE Website: https://materovcompetition.org/
Depth Sensor: https://bluerobotics.com/store/sensors-cameras/sensors/bar02-sensor-r1-rp/
IMU: https://learn.adafruit.com/adafruit-bno055-absolute-orientation-sensor/overview
Cameras: https://dwe.ai/products/explorehd
Thrusters: https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/
PCA Board: https://www.adafruit.com/product/815
Jetson Orin Nano: https://developer.nvidia.com/embedded/learn/jetson-orin-nano-devkit-user-guide/index.html
ROS Documentation: https://docs.ros.org/en/foxy/index.html
Watertight Enclosure: https://bluerobotics.com/store/watertight-enclosures/wte-vp/#tube
2000 Series Dual Mode Servo (25-2, Torque): https://www.gobilda.com/2000-series-dual-mode-servo-25-2-torque/
Proton Servo (Steel Gears, 180° Rotation, Torque Ratio): https://www.gobilda.com/proton-servo-steel-gears-180-rotation-torque-ratio/
T200 Thruster: https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/

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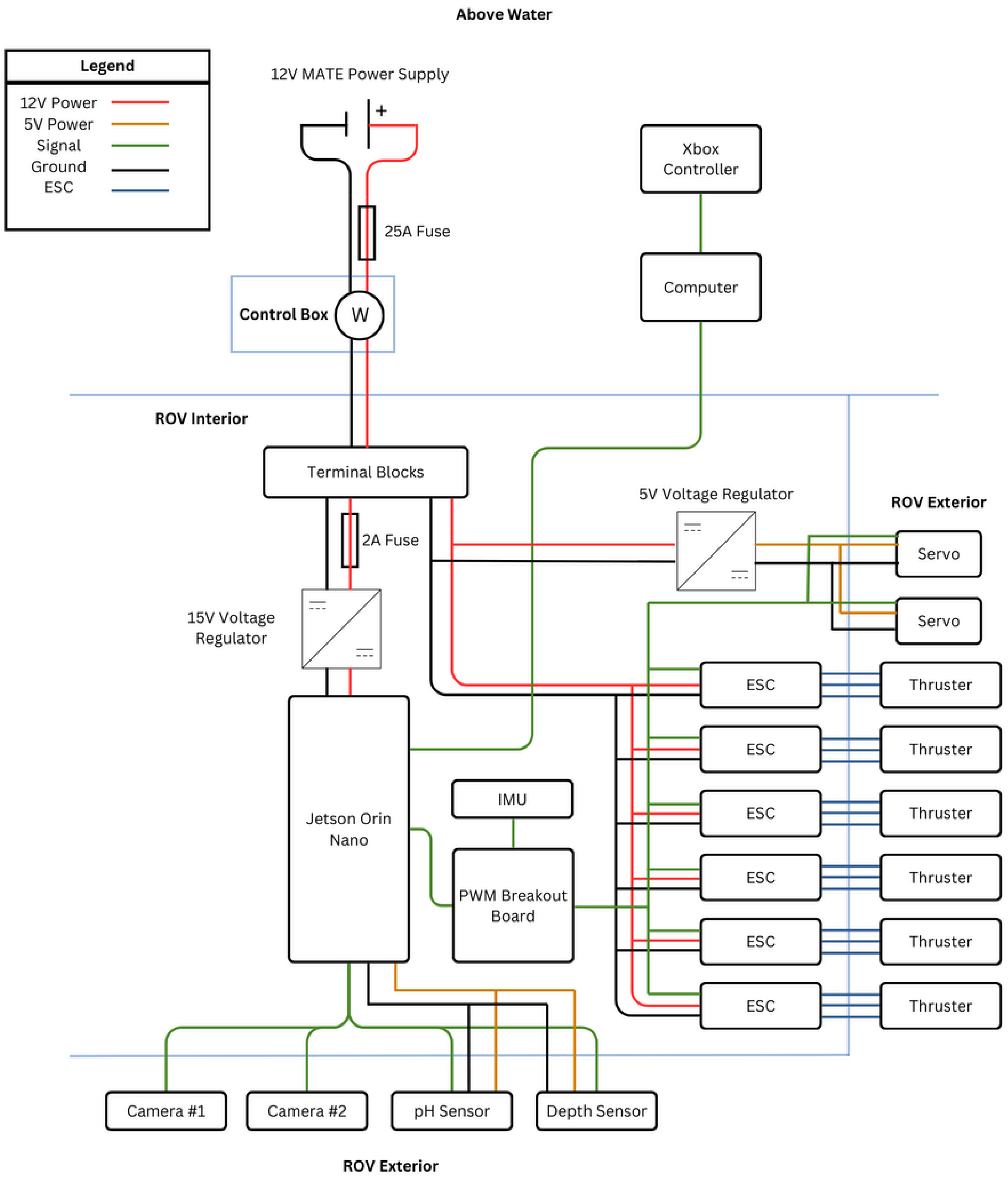
APPENDIX I

ROV Electrical System Integration Diagram



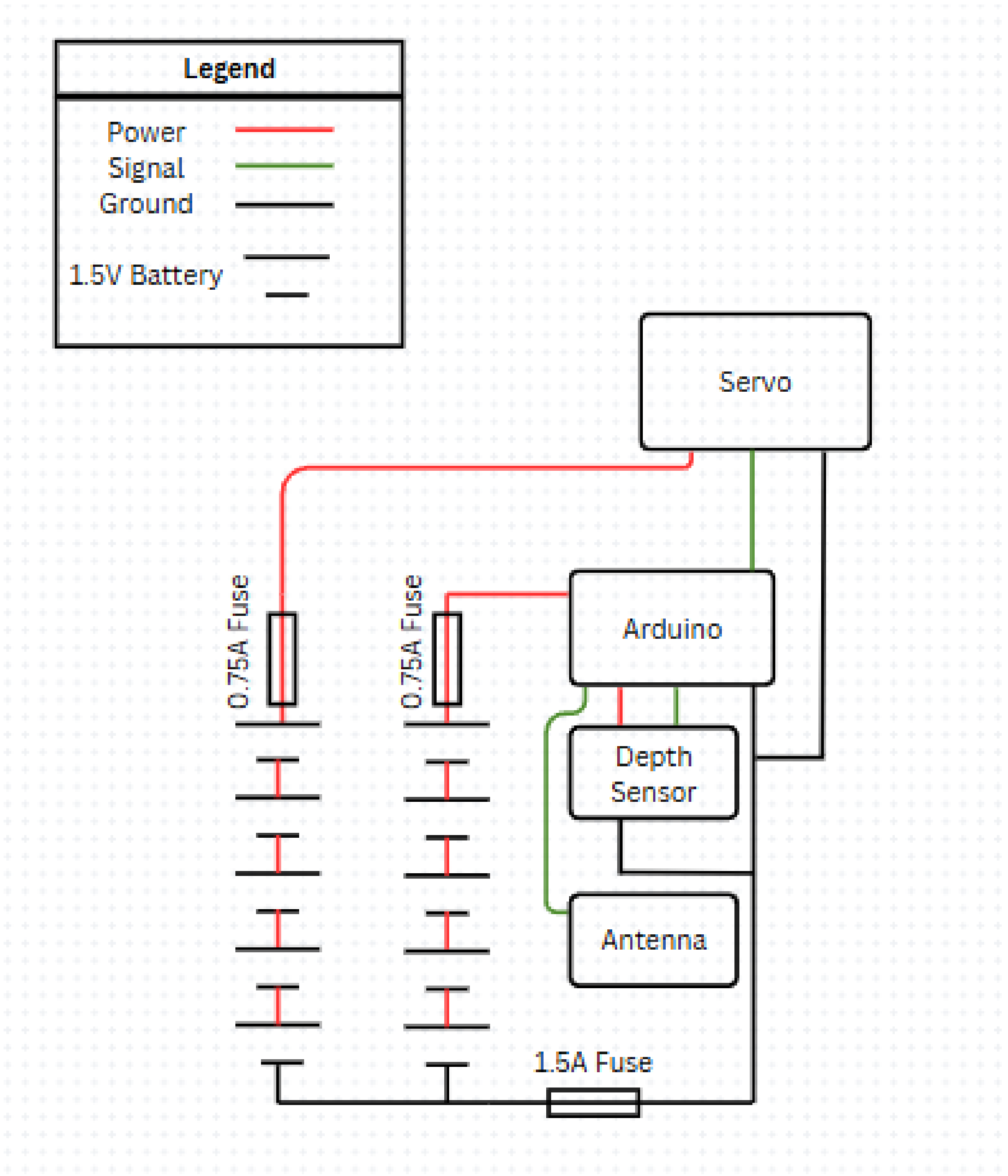
APPENDIX II

Float Electrical Systems Integration Diagram

Float Fuse Calculation

0.75A Fuse: 4 AA 1.5V batteries in series in a battery pack. As directed by the MATE ROV competition rules, the battery pack has a 0.75A fuse.

1.5A Fuse: Two packs of 4AA 1.5V batteries. As directed by the MATE ROV competition rules, a 1.5A Fuse connected in the common negative terminal of both packs



APPENDIX III

Safety Checklists

Pre-Construction Checks

Procedure	✓/X
Wearing closed-toed shoes, pants, no dangling accessories, and long hair tied up	
Received training for all applicable power tools	
One other person in the room	
Wearing eye protection and gloves to use power tools	
ROV power is off	
All wires, electronics, and fuses securely connected	
No risk of ROV falling off high places	

Pre-Pool Checks

Procedure	✓/X
All wires, electronics, and fuses securely connected	
Tether strain relief is secure	
Tether is free from knots or tangles	
Canister is watertight	
All connecters attached securely	
Two employees poolside ready to recover ROV	
Poolside clear of obstacles and hazards	
Camera feed working properly	

Post-Construction Checks

Procedure	✓/X
All power tools turned off	
Tools returned to proper storage space	
ROV power is off	
No dangerous/sharp debris in the workspace left uncleaned	

Operating Checks

Procedure	✓/X
Thrusters working properly	
Manipulator working properly	
No employees touching the ROV while the driver is touching controller	
No water in the canister	