2024

TECHNICAL DOCUMENT

Stingy 2024

Underwater Research Robot Company

Name	Grade	Company Title
Sarah Rabbideau	11	Safety Officer
Myah Rondeau	11	Project Specialist
Kylie Gagnon	11	Fabricator
Lydia Thomson	10	CEO
Gus Wirgau	10	Pilot
Lucas Thomson	10	CTO
Abbey Glover	9	CFO
James Rawlings	9	Pilot
Lizzie Rabbideau	9	Payload Specialist

Abstract

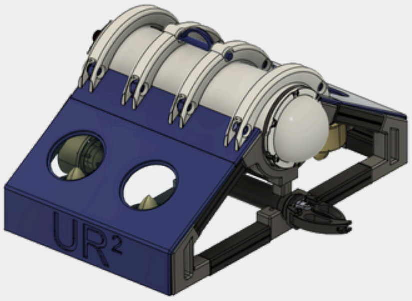

Figure 1. ROV in CAD

The Underwater Research Robot Company (UR2) is a team of nine skilled students from the ninth to eleventh grade who are dedicated to developing innovative solutions to help sustain ocean and marine ecology. Our ROV, Stingy, has a multidirectional grabber designed to accurately and safely place data collecting arrays for expanding global ocean observation systems. UR2 also designed a substrate sampler to test and verify a suitable spawn area for the endangered lake sturgeon. The ROV is equipped with three cameras, with the main camera allowing pilots to navigate safely to complete tasks while the two additional cameras provide optical sensors for photogrammetry development of 3D imagery. These cameras will collect multi-layered photos of coral reefs to provide restoration data and transport brain coral. The UR2 team's ROV is designed to thrive in multiple scenarios, and they are committed to helping the environment and waterways.

This technical document details the design process in creating our most recent ROV, Stingy. Stingy's design journey began shortly after the 2023 World Championships. Our team was inspired by all the innovative design UR2 saw at the 2023 World Championships that UR2 wanted to create something truly innovative.

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Project Management

Our Company

The Underwater Robotics Company (UR2) was created in 2010 by a scrappy bunch of fifth graders working to make an ROV that would just work. UR2 develops and creates remotely operated vehicles (ROVS) for exploration, discovery, and research. UR2 is dedicated to developing unique underwater technology that will help our community grow and inspire students to engage in STEM careers. Our company has developed relationships with many of our local community agencies and corporations to design programs that support growth. UR2 are more than a competitive engineering team. Our mission is to be a positive force in our community to promote exploration and innovation.

What We Do

1. **Protecting:** UR2 has partnered with the Thunder Bay National Marine Sanctuary and the NE Michigan Great Lakes Stewardship Initiative to support the mission of protecting and preserving our local freshwater resources.

2. **Preventing**: Working with companies like Viking Cruise Line to develop substrate samplers that can be used in the Artic to take samples that will be used to create a data base of both biotic and abiotic factors to develop heath assessment of substrate ecosystems.

3. **Preserving**: UR2 has partnered with Alcona Community Schools and the Hubbard Lake Sportsman Association to use an autonomous surface vehicle with side scan sonar to identify historically interesting targets in Hubbard Lake and use our new photogrammetry technology to create 3D images of targets to research.

Creating Real World Testing Equipment Team members from UR2 receive training on one of two submersibles onboard Viking Cruise Line Explore Class Ship, *Octanis*. Figure 2.

Brick Build Competition
UR2 promotes STEM creativity through our regional brick build competition.

Company Profile

Our company, UR2, is made up of students from grades nine to eleven (Figure 2). Although we are a young company, most of our team members have been building ROVs since fifth grade. Despite our young age, UR2 has a lot of experience. Our team consists of nine members, including a CEO, a CFO, and a CTO (Figure 2A). All of our officers have multiple responsibilities within the company. The CEO oversees all company operations and is also our lead software engineer. The CFO is responsible for overseeing company expenses, while one of our lead designers and the CTO oversee the development of all ROV hardware and subsystems. Our company may be small, but we are motivated and passionate. With just nine members, we share the load of responsibility. This is why self-reliance is one of the key traits we look for in people who want to join our company. Team members must be motivated and driven to get things done. When we bring on a new member, everyone shares the responsibility of training and bringing them up to speed. We encourage our team members to explore their passions and pursue what they love. Our company starts meeting in August for strategic planning and ROV design. We developed a design criteria outline to give us some structure for our design decisions to follow (Figure 3). We started with three main objectives: Reduce the overall size and weight of the ROV. Develop a new operating system. Build a reliable vertical profiler, "Float."

The design team starts meeting in August for strategic planning and ROV design. UR2 developed a design criteria outline to give us structure for our design decisions (Figure 3). UR2 started with three main objectives:

- Reduce the overall size and weight of the ROV.
- Develop a new operating system.
- Build a reliable vertical profiler "Float"

Figure 2 and 2A Current member of the Underwater Robotics Research Company Photo by Mr. Thomson

CEO	Lydia Thomson
CFO	Abbey Glover
CTO	Lucas Thomson
Pilot	Gus Wirgue
Co-Pilot	James Rawling
Payloader	Lizzie Rabbideau
Safey Officer	Sarah Rabbideau
Mechanic	Kylie Gagnon
Project Specialist	Myah Rondeau

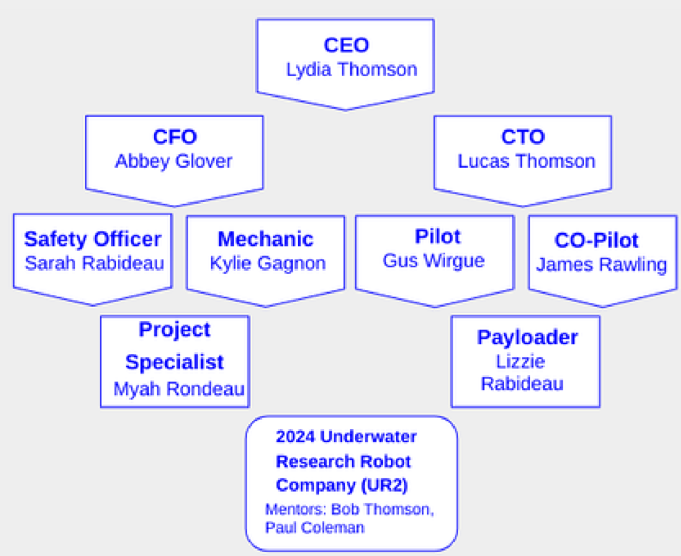


Figure 3. Company Structure Diagram Developed By Multiple Team Members.

Project Management

Our goal is always to develop a highly functional and innovative robot, but our company also needs to generate the resource to build a robot. Our company is always looking for ways to not only secure funding opportunities but develop Partnership in creating projects. Leveraging our success at the 2023 World Championship, UR2 secured to major projects working with Viking Cruise Lines and The US Naval Warfare Center at Crane. These Partnerships provide us with world class mentorships, but they also provide opportunities to fund our ROV development.

UR2 start officially meeting once a week on the second week of September. Our team creates a project plan to give us a timeline for completing components of the ROV (Figure 4.) This year UR2 focused on our three goals and divided the team based on these goals. Our partnered with Alpena STARBASE program to train team members on using the CAD programs OnShape and Fusion 360. The team worked to develop a basic frame design, research possible changes in thrusters and operation systems. The team continued to prototype ROV ideas until the official mission tasks released. Our goal is to have several options ready so that when the mission tasks are resealed, UR2 can make adjustments and start building. At the release of the mission tasks, the team starts meeting twice a week. Once January comes, we are in full ROV season and start meeting three to four times a week until the Great Lakes Regional ROV Competition.

The Underwater Research Robotics Company, has built a strong Partnership with the Thunderbay National Marine Sancturary, and we have worked together to create Makerspace for local teams to work together to grow the program. UR2 uses the Makerspace as our companies home based and use it test and develop all our products (Figure 5).

ROV Size Design Options		
Design Criteria requiring that the ROV and equipment fit through a 1 meter square opening	Reduce thruster size or number	Frame SIze and materials to reduce total weight
Option 1	Upgrade thrusters to Blue Robotic T200	Use a rigid frame design w aluminum tubing
Options 2	Find small thruster, but we may need more to maintain the same speed and lift strength	Continue to 3D print frame and do a solid frame print
Option 3	Use combination of Blue Robotics Thruster and small thrusters	Develop a combination of 3D print and tubing
New Operating System		
Create a operating system for the ROV that is not dependent on Ardusub and Blue Robotics	Surface Control	Subsurface Control
Option 1	Completely remove Ardusub	Use only a Raspberry Pie on the ROV
Option 2	Use Ardusub, but learn how to make custom changes to the software to develop our own needs	Upgrade existing system to Blue OS with Navigator System
Vertical Sample (FLOAT)		
Make one that works with reduced size in power needs and overal size	Buoyancy Control	Software Control
Option 1	Develop a better motor with a reliable battery source	Stay with same surface interface
Option 2	Create buoyancy engine	Change to a different onboard processor.
Option 3	Use the buoyancy engine	Use Raspberry pie with better motor controller software

Figure 4. Design Criteria Table Developed by the Whole Team.

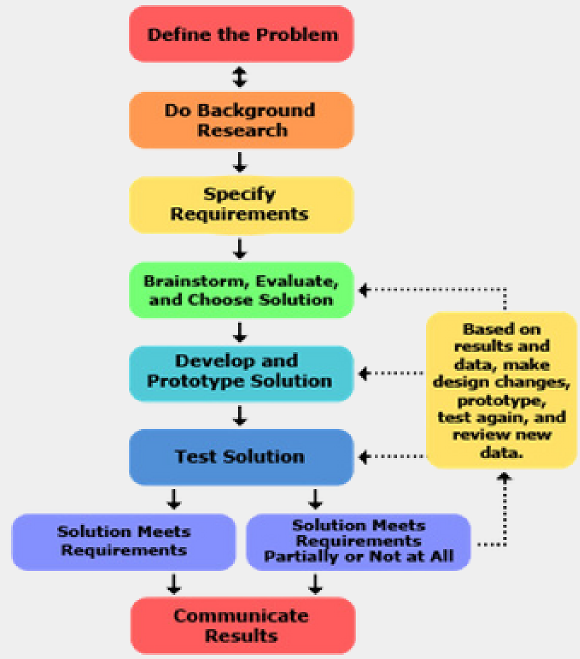


Figure 5. UR2 Design Process.

Underwater Research Robot Company

Design Rationale

Design Decisions

Our company allocated nearly six thousand dollars for our design and test budget. This allocation included building a functional prototype ROV with new thrusters and a control system. When maximizing our budget, we always consider the factors involved in building an ROV from the ground up. This includes deciding which parts to buy, which parts to attempt to build, and what we can reuse. Our goal is to create an ROV that exceeds last year's performance. The limitations of funding must meet the needs of the design. To make these decisions, we started by choosing a thruster.

Task	Time To Complete	Date Started	Date Finished
Float Software Prototype	8 hours	7/1/23	8/5/23
Float Machanical Design	12 hours	7/15/23	11/8/23
Float Body Prototype	5 hours	7/5/23	9/10/23
ROV Design	2 hours	9/10/23	10/5/23
Frame Design	2 hours	9/15/23	9/15/23
ROV Softwear Prototype	6 hours	9/20/23	10/25/23
CAD Design	3 hours on the first design 1 hour for the final design. Total 4 hours	9/25/23	10/20/23
ROV Prototype	8 hours	10/2/23	2/1/23
Building ROV Sytem	3 Hours	11/3/23	11/26/23
Building ROV Structure	5 hours	1/2/24	1/12/23
Wiring	1 hour in wiring camera and 1 hour wiring	1/25/24	1/25/24
Testing Float in the pool and adjusting the boyancy	30 minutes	2/12/24	2/12/24
Testing the ROV in the pool	2 hour	2/23/24	2/23/24

Figure 6. Company Design Schedule.

Thrusters

The team has been designing our ROVs with the Blue Robotics T100s for the past five years, and using the T100s remains an option, but we would need to rebuild or replace them. Upgrading to the Blue Robotics T200s would be expensive and require some power modifications in the software to limit the amount of current the thrusters pull. Switching to T200s would require the ROV to upgrade to a Raspberry Pi 4 with the companion Navigator board. Using four thrusters would require us to restrict the current to each thruster by 50% or more. The total cost is a thousand dollars. Reaching our primary goal of reducing our overall size and weight would still be limited by the size of the Blue Robotics Thrusters. Our team located another option using the Aplisqueen U2 mini thruster, costing fifty-six dollars a thruster. We outline the cost versus benefit of both thrusters to help make a cost-effective design that was beneficial to the ROV design in Figure 6. The team chose the U2 thrusters for cost and size. The size of the thruster gave more options for our frame design.

Thruster Comparison		
Factors	Blue Robotics T200	Apisqueen U2
Power	12V, 17A	12V, 8A
Thrust	8 lbf	1.3 kg
Direct Comparison in lift	35.6 N	12.8 N
Power Need	Need to limit to 50%	Run full power
SIze	102 mm	72 mm

Figure 7. Thruster Comparison Table

Reaching a Decision

The T200 thruster provide over twice as much thrust as the U2 mini thrusters, but UR2 would need to run the thrusters at 50% of their max power to make sure we are not pulling more than 25 Amps. Our biggest concern is the lift ability of the ROV and to come close to the lift capacity of two T200 thruster we would need to have four U2 mini thruster to provide vertical left strength.

Design Rationale

ROV Frame System

The design process for our ROV, named Stingy, initially drew inspiration from the shape of a stingray. However, when considering size requirements and materials, UR2 encountered a design challenge. This year, we aimed to reduce the size and weight of the ROV. To achieve the stingray-like shape UR2 desired, we planned to create an 80% 3D printed frame. UR2 intended to use secondary structure materials to support the 3D-printed parts. To counterbalance the displacement caused by the 3D print components, we opted for a solid material with a negative buoyancy value. Figure 8 shows a middle support that has four connection points to join the plastic tubing. In recent years, we have exclusively used 3D printing for the entire frame of our ROVs, necessitating the addition of extra ballast to manage buoyancy. This increased weight compromised the ROV's lifting capacity.

UR2 selected one-inch plastic tubing commonly found in Vex robot construction for the frame material. Using Fusion 360, UR2 designed connecting parts. These parts, connecting the tubes, were printed using carbon-nylon filament (see Figure 9). To secure the connections, UR2 utilized a two-part marine epoxy.

To assess the strength of the connections, we constructed a small prototype using the same tubing and carbon-fiber 3D-printed connectors. Our fabrication team attached two thrusters intended for the competitive ROV to the prototype. The prototype had navigation issues, but the parts connected well and help up under normal operational conditions.

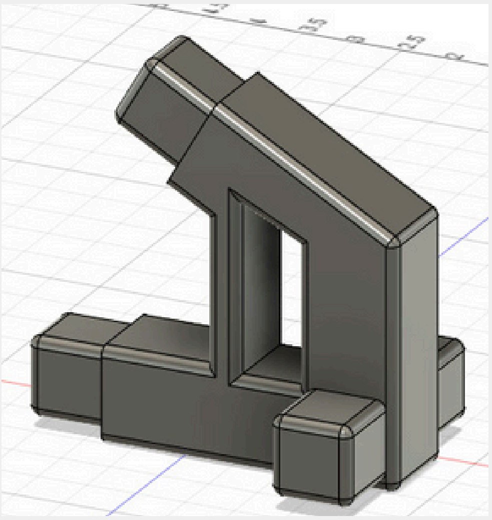


Figure 8. Middle Frame Section and Below Is the Frame Sections Connect to the Plastic Tubing.

In Figure 9, our calculations for determining the frame displacement weight are presented, which is essential for calculating the total ROV displacement. The complete assembly of our ROV weighs 4.5 kg.

Total Frame Displacement	
Plastic Tubing	450.2 Grams
Carbon Fiber Connections	1,372 Grams
Total Frame Displacement	1.8 Kg

Image 9a. Image taken by Gus W.

Design Rationale

Sub Surface Electrical System

The Blue Robotics acrylic enclosure guarantees Stingy's underwater safety and efficiency due to its sturdy and watertight design. It proves versatile for a variety of underwater tasks with dimensions of 100mm by 1000mm and a depth rating of up to 100m. Stingy, with all its electronics securely housed inside, is primed for dependable performance in aquatic environments. Its compact yet robust design enables effortless maneuvering underwater, boasting a total displacement of 7.8 liters or a weight of 7.8 kg.

Within the enclosure, Stingy features six electronic speed controllers (ESCs) connected to six U2 brushless thrusters, ensuring precise control and movement. These ESCs receive their Pulse Width Modulation (PWM) signal from the Blue Robotics Navigation board, guaranteeing seamless integration and operation. The Navigation Board interfaces with a Raspberry Pi 4 processor running the Blue Operating System, offering advanced functionality and control for Stingy's underwater tasks.

Stingy is equipped with an HD camera with a 170-degree view, mounted on a single servo to regulate the camera's vertical scanning. This feature allows the pilot to adjust the camera position downwards or upwards by an additional thirty degrees of view.

Stingy’s enclosure also houses leak detection sensors that are placed throughout the enclosure to make sure all enteral electronics stay the same.

Surface Electrical System

Stingy's surface operations and command control utilize the HP EliteDesk 800 G3 Mini Business Desktop, which runs on a Linux-based system. This compact topside computer, small enough to be held in one hand, perfectly suits Stingy's operational needs. Its portable command-and-control system can easily fit in your pocket, offering convenience. The HP Elite Mini can be powered by a standard AC outlet or a 12v DC supply, ensuring seamless transitions for remote operations.

Stingy uses the Arusub operations program to connect with the Raspberry Pi 4 situated in Stingy's enclosure. Additionally, Stingy can stream all operational data via Blue OS. Both systems are open source, enabling us to modify Stingy's operational performance by adjusting the code to align with the mission's requirements.

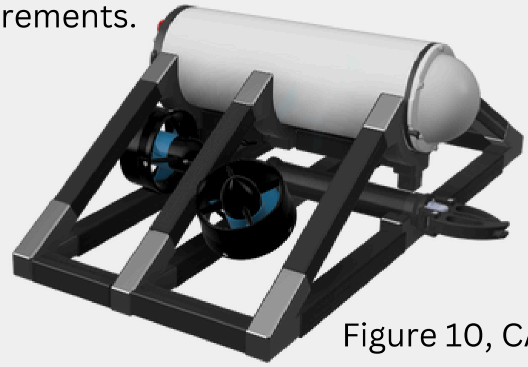
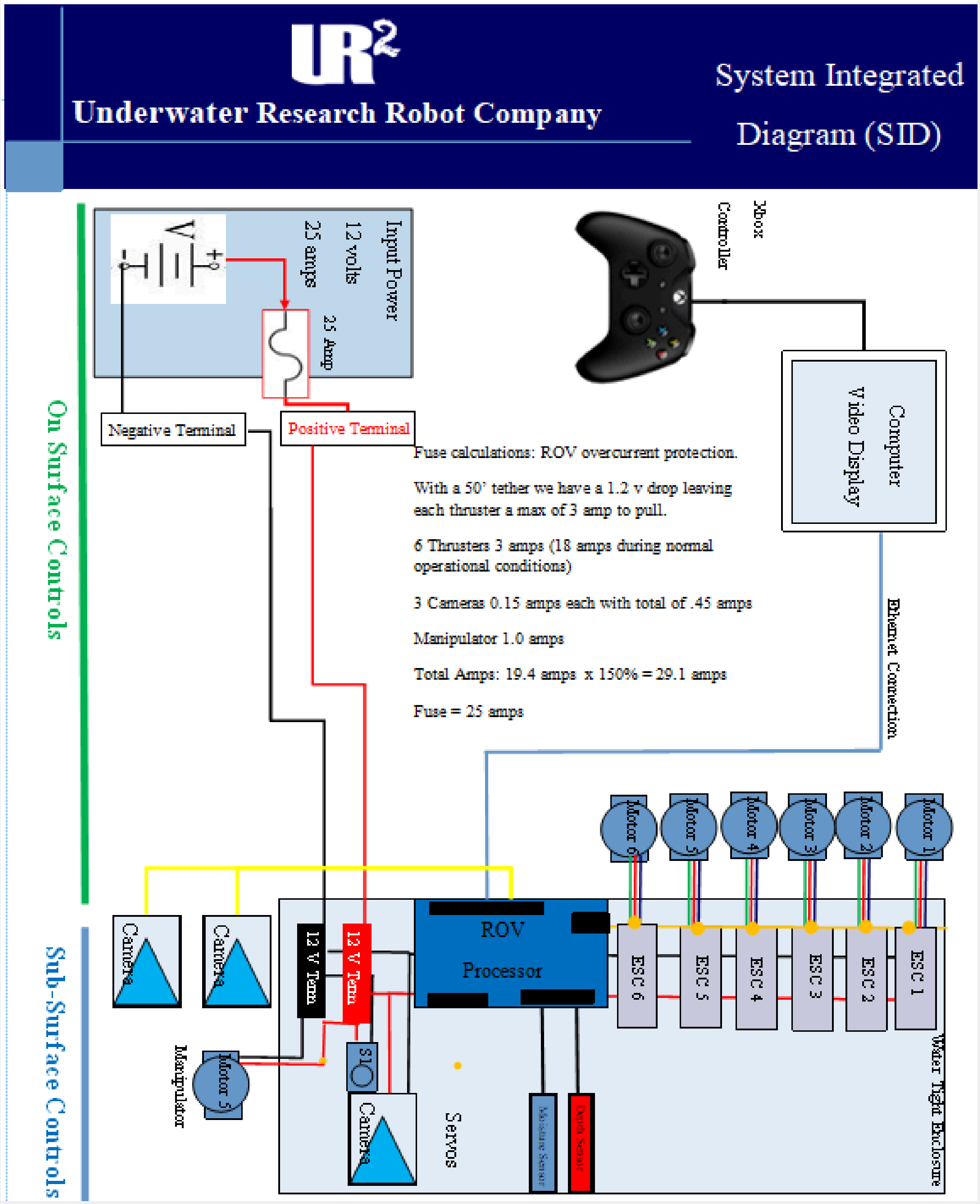


Figure 10, CAD Image.

The design team developed the middle section of the frame to securely hold the electronics enclosure in place. This enclosure not only houses all of Stingy's electronics but also serves as a stabilizing backbone for the frame. The design team sized the curved section just over the midpoint to allow the enclosure to snap-in securing the enclosure to the frame.

Design Rationale

System Intergrated Diagram (SID)



Design Rationale

Control Software

Stingy's Raspberry Pi system provides a budget-friendly solution for reliable processor control. The code and Navigator collaborate to interpret analog input from the joystick into the required electronic speed controllers for the T100 thrusters. Using QGround Control, drone flight software on our HP Minicomputer, UR2 can manage the thrusters, camera, and manipulator with an Xbox Controller. This streamlined and compact system enables our robot to operate efficiently and swiftly. UR2 can customize our control program to meet specific mission needs by experimenting with various programming commands. The Design Rational System Block Diagram features the Xbox game controller, offering pilots a familiar operational interface. Not only is the controller cost-effective compared to building one, but it is also robust and capable of enduring heavy usage.

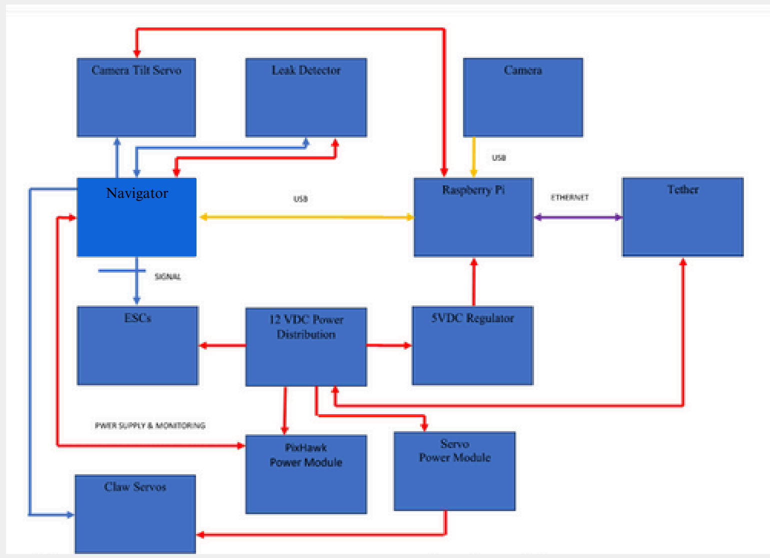


Figure. 11 System Block Diagram

Our company collaborated with mentors from the US Naval Surface Warfare Center to gain a deeper understanding of Stingy's operational system. In the fall of 2023, UR2 engaged with coders to grasp basic Python control and command code. Applying these lessons, we developed Raspberry Pi control for our vertical profiler. This process allowed us time to draft basic code to steer the functions of the vertical profiler.

Figure. 12 UR2 built a control station this year rather than developing a control box. With Stingy being an attached to a control box, UR2 can pack the ROV into a traveling case and pack all the surface controls with it.

This learning experience gave Sting's team a strong understanding of how to develop the control system. It also allowed us to create a vertical profiler that works.

Design Rationale

Tether

Stingy has stood out as our first ROV to eliminate the hardwired connection to the surface control box, simplifying operations by removing the need for a three-person team to manage the ROV as a single unit. We reduced the number of conductors by sixty-six percent compared to our previous ROVs by removing the extra hardwires needed for cameras. Previously, each additional camera necessitated the integration of two power wires and a signal wire, improving the pilot's visibility and increasing the tether's weight. You can find detailed information about our tether SID in the appendices of this report.

Our progress in tether technology began with enhancing Stingy's photogrammetry capabilities for mission tasks. With guidance from mentors at the US Navy Warfare Center, we collaborated with Deepwater Exploration, experts in underwater cameras. With technical assistance from Deepwater Exploration, UR2 utilized companion software tailored for Blue OS, allowing up to nine cameras to stream over a single network connection. This software enabled us to integrate more cameras without extra wires in the tether, which now only requires three wires. By mastering video streaming, UR2 improved our capacity to incorporate more cameras for mission success and reduced the tether size by fifty percent.

The detachable tether from the control box has significantly simplified its management. This modification reduces tether twisting, resulting in smoother ROV operations. It also allows for easier maintenance and replacement of the tether, reducing downtime and increasing the efficiency of our operations. See appendence for tether protocol.

Control Station

The UR2 design team drew inspiration from their time aboard the vessel Octanist, shifting their focus from a control box to a control station. This year's mission requirements prompted a reevaluation of their traditional approach to designing a control box for their ROV. With the need for additional hardware support for photogrammetry on the surface control side, they saw the necessity of rethinking their control box setup. By hardwiring Stingy's tether to a control box and exploring new possibilities for topside controls, the team aimed to leverage Stingy's upgraded machine vision to the fullest.
During their time on board the vessel Octanist, they observed the control station used by the ROV pilots for their submersibles. This experience led them to repurpose an older desktop workstation slated for recycling by the school district. The sturdy, mobile workstation, crafted from durable welded steel, provided valuable insights into expanding the pilots' monitor access beyond the limitations of a standard control box.

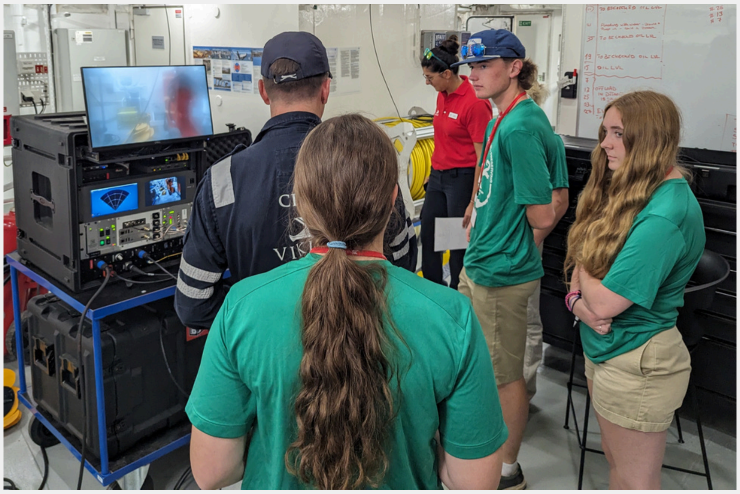


Figure. 13 shows members of UR2 team working the *Octantist* ROV operator working through prelaunch checks done prior to ROV operations. Getting to see pre-launch checks used help us develop our own.

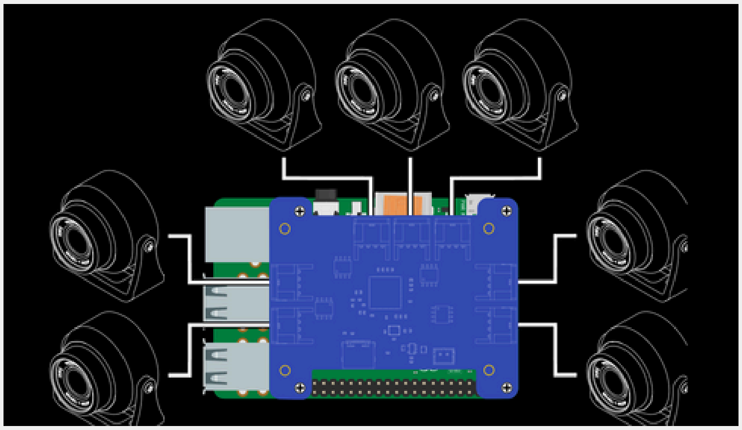
Design Rationale

Machine Vision

This year's ROV build, Stingy, introduces two groundbreaking UVC-compliant cameras featuring innovative patent-pending technology. These cameras, with HD USB output and an IP69K waterproof rating, are equipped with a cutting-edge Sony sensor and a unique 4-layer PCB for exceptional vision in low-light conditions.

Our exploreHD cameras are renowned for their color accuracy, delivering natural and appealing images. By utilizing H.264 compression technology and an open-source camera driver, UR2 can effortlessly stream up to 7 cameras simultaneously without compromising quality or facing significant delays. Additionally, with appropriate bitrate adjustments, Stingy can support an unlimited number of cameras for streaming.

With the invaluable support of Deepwater Exploration, Stingy is now furnished with the first plug-and-play machine vision-capable subsea camera. This integration of exploreHD camera technology is pivotal for the Underwater Research Robotic Company's development of a cutting-edge multi-camera setup for ROVs, facilitating seamless video streaming from multiple cameras via a single ethernet connection. Presently, Stingy can stream three cameras, but with additional hardware integrated into Stingy's enclosure, it can comfortably stream nine cameras using a single Ethernet connection (Figure 15).



Buoyancy

Our team invested significant effort into developing a precise buoyancy calculation to fully understand the Stingy's buoyancy and its importance in assessing our ROV's performance. We factored in all components except the hardware in our total displacement calculation. The analysis revealed that Stingy would be positively buoyant by around 520 g, with the hardware weighing approximately 300 g. This slight positive buoyancy would help offset the weight of the tether. We also considered Stingy's total tether buoyancy, which was reduced by half this year through a new design. As part of this design, we opted for a data cable engineered to be neutrally buoyant, further reducing the tether's weight on Stingy. To support the tether's weight, we plan to add buoyancy at the surface, preventing it from dragging during ROV operations.

Buoyancy Calculations				
Part	Water Displacement (cm^3)	Weight In Air (g)	Weight of Water Displaced (g)	Net Buoyancy (g)
Total Frame	2,272.4	726	1,800	+1,704
Enclosure	2,078.3	2,334	2,074.2	-259.8
External Cameras	94	168	94	-74
Gripper	203.6	529	203.6	-325.4
Thrusters	680.4	1206	680.4	-525.6
Total	5,328.7	4,963	4852.2	+519.2

Figure. 14 Show our buoyance calculations for our ROV design this year, Stingy. As you can see form the chart Stingy will be positively buoyant making is easier for Stingy to lift heavy objects.

In Figure. 15 From Deepwater Exploration illustrates the hardware connections for a potential layout of a seven-camera setup on an ROV using their stream board connected to Raspberry Pi 4.

Design Rationale
Mission Tasks

Gripper

The mission requires the ROV to lift and connect many devices, leading the design team to consider building or buying a gripper. Our current gripper is on its third competition and would need to be rebuilt and upgraded; the team decided to purchase a new Newton gripper from Blue Robotics. We integrated the gripper into Stingy's framework and mission design. The gripper can open its jaws to grasp objects up to 6.2 cm in diameter, featuring plastic jaws secured with custom aluminum screws for a corrosion-resistant and lubrication-free mechanism. A linear actuator, powered by a geared brushed motor and lead screw, drives the jaws, connected to a brushed ESC on Stingy's onboard computer. Control of the gripper is managed through an Ethernet connection to the surface and operated with an Xbox controller. The gripper is suitable for depths of up to 300m.

A stationary gripper was not working well in our initial operation test with the mission props. We need to be able to change the position of the grippers based on the task. The gripper design can rotate 360 degrees to reposition as needed, with the pilot adjusting its position using a programmed servo signal sent through the Ethernet connection from the surface to Stingy's computer. This flexibility allows Stingy to efficiently complete tasks like turning a valve 360 degrees. By purchasing the gripper, the team saved design time and could focus on more challenging tasks.

We integrated the positioning system into the original frame by designing a structure that fits within the 1-inch square tubing. This enabled us to utilize the frame's strength to secure the gripper effectively.

Substrate Sampler

Stingy’s task involves collecting substrate from a designated sampling area. Initially, UR2 drew inspiration from an acorn collection rake, which looked like an oversized whisk attached to a stick. Despite our attempts to ensure its functionality, it only worked well with small rocks and would occasionally come loose. Eventually, UR2 opted for a scoop design that lets the substrate settle in the slots to securely hold the rocks.

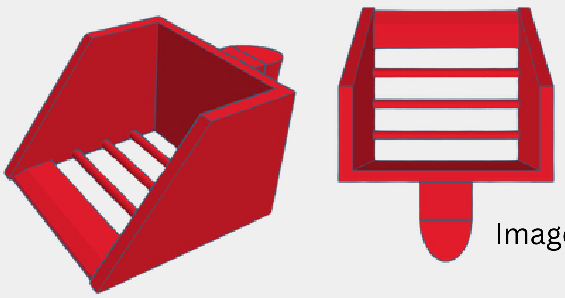


Image: G Wirgau

During the design research phase of the substrate sampler, UR2 chose to create a second sampler. This design was influenced by the recently introduced Blue Robotics sampler. It features two sizable suction cups on the gripper, enabling the ROV to gather substrate material. To enhance its functionality, we designed a component that slips onto the gripper jaws. This allows us to affix large rubber disks to extend the jaws and reach the substrate surface for rock collection.

Image: Frame connection part with bult-in gripper placement. G Wirgau

Design Rationale

Mission Tasks

Photogrammetry

Last year, UR2 explored the idea of creating a 3D modeling platform for Stingy to scan underwater objects and use the scans to produce scaled replicas. Instead, we decided to analyze and use CAD last year. This year, UR2 collaborated with partners to establish a process for capturing and transforming images into 3D replications.

Our objectives for implementing photogrammetry with Stingy were twofold. Firstly, UR2 aimed to enhance the vehicle's capabilities to carry out tasks. Secondly, UR2 sought to utilize the technology for our operational ROV, Dallas, to create images of historical artifacts like shipwrecks in local water bodies.

To achieve our mission, UR2 teamed up with Deepwater Exploration (DWE) to grasp the necessary steps and components. Setting up the hardware on Stingy and configuring the software for streaming multiple videos required time and guidance, as none of us had a software development background to create our own code. DWE provided us with the necessary guidance. Once UR2 successfully streamed and captured video using Stingy, UR2 needed software to render the images. After exploring various platforms, we opted for ZDF as it was highly recommended for beginners and seemed like a promising advancement for us.

Figure 18. Temp Sensor, image by Lydia T

Figure 16. Stingy is equipped with three forward facing.

Recover Line Clasp

Attaching a recovery line to the Multi-Function Node presents some engineering challenges. Last year's task had something similar, and we struggle to complete it. Most team at Worlds last year did not even attempt it. This year the task allowed us to create our own recovery line and have engineer a tool that is easy to attach and can be done reliably. UR2 used a carabiner that has two attachment point and designed to maximize the ROV position to increase the force to attach it. Figure 17 show our Recover Line.

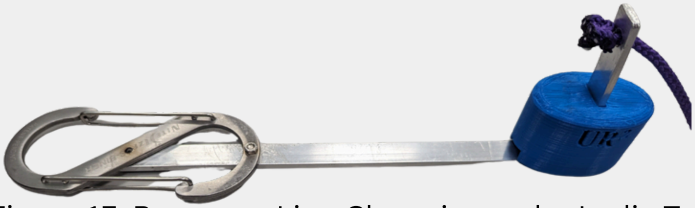


Figure 17. Recovery Line Clasp, image by Lydia T

Temp Sensor

Our temperature sensor, used to confirm the activation of the SMART Cable, features a straightforward yet dependable design that we developed for last year's project. UR2 modified a fish tank temperature sensor with an LCD by extending the cable to 10 meters. A temperature sensor is also installed on the ROV as a backup measure.

Mission Tasks

Vertical Profile: Float

UR2 has dedicated the past two years to developing a Vertical Profiling Float named Baby UR2. Baby UR2 measures 76.2 cm in length with a circumference of 7.62 cm, crafted from PVC pipe that tapers down to 5 cm to accommodate the syringe. The float's interior features a linear actuator, driven by a DC motor linked to a rack-pin mechanism connected to the syringe plunger's top. Additionally, a Raspberry Pi controls the motor and generates a Wi-Fi signal for surface connection to execute our autonomous mission. The float is equipped with 12 AA batteries, with six powering the Raspberry Pi and the remaining six driving the DC motor.

Baby UR2 successfully completed the MATE 2024 mission after overcoming various challenges. Adjusting buoyancy and descent, we discovered issues with positive and negative buoyancy. This was rectified by altering the syringe size from 300 ml in the initial Float Prototype to 1200 ml. Despite this modification, positive buoyancy persisted. To resolve this, UR2 designed a cap using On Shape for the float to house the added weight, assisting in achieving neutral buoyancy. Testing revealed that Baby UR2 required 5.8 lb to maintain neutral buoyancy for successful descent and ascent.

Operated by Python code on the Raspberry Pi, Baby UR2 controls the motor and linear actuator to raise the syringe plunger for water collection as it descends. During the 30-second descent, a pressure sensor gathers data. Once the cycle completes, the linear actuator lowers the syringe, and the float ascends. Upon surfacing, the software reconnects to the Raspberry Pi, collecting data to generate a depth graph.

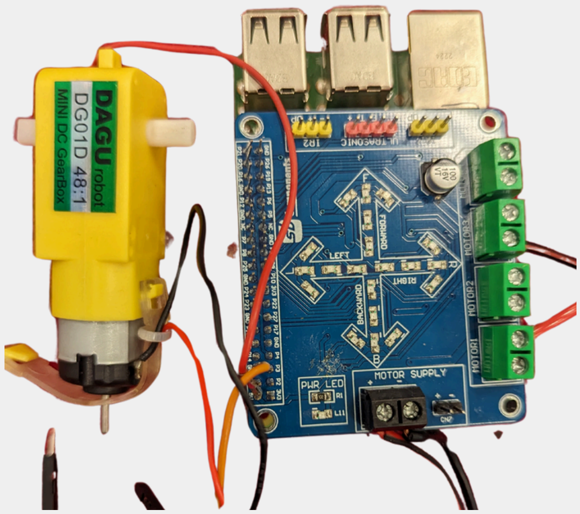
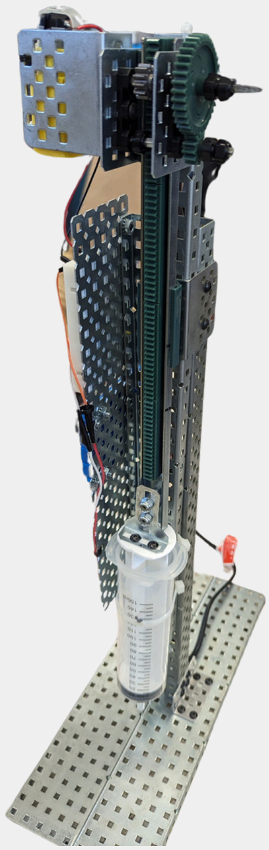


Figure 19. Developing the Software Test: Last year, our attempt to create a thruster-controlled float faced challenges related to weight and insufficient power. UR2 transitioned to buoyancy control, reduced power usage, and tailored the mechanics to function with a small DC motor.

Mechanical Prototype: Figure 20

After developing the software and motor control, we proceeded to construct the mechanical movement of the Float. Our goal was to fit all components into a 70mm space.



Testing and Troubleshooting

Prototyping and Failing Fast

One of our goals this year as a team was to reduce the overall size and weight of the ROV. To do this, the team decided to find smaller thrusters. Our design team sourced a thrusters called U2 mini that, after testing, were just as efficient and smaller than the T100 thrusters that the team already had experience within previous years. Working with drone engineers from US Naval Warfare Center, they model for us how bigger isn't always better and the design really needs to fit the task.

UR2 used the U2 thrusters on a prototype Drag Racing ROV to test the speed of the mini U2 thrusters. The team tested the thrusters by participating in the Square One IVD Vehicle Design Drag Race Competition, coming out with one of the fastest times in Michigan. When building the drag racer, the team used it as a prototype to create a new frame for the MATE ROV Competition, using cardon-nylon as the skeleton and 3D printing as the skin to cover the ROV (Figure 22). As a team, we needed to test the capability of CADing the skin with Fusion 360 and testing the solidness of the carbon nylon. While making the frame to test the carbon nylon, the team ran the Drag Racer in the water before the 3D printed skin was added in a test pool to test its buoyancy with the U2 thrusters, which the team found was negatively buoyant so by adding a little bit of foam the drag racer became neutrality buoyant. Then, UR2 added the 3D neutrally buoyant skin. In Addition, we built a prototype ROV to test the U2 mini thrusters' reliability underwater for a more extended period and to test the agility of these thrusters when moving props and when several thrusters are moving at once.

Thruster Comparison Chart		
Thruster Type	Kort	Force (Newtons)
Standard Bilge Pump (500 gpm)	No Kort Open Prop	2.5 N
Standard Bilge Pump (500 gpm)	3D Printed	7.5 N
Blue Robotics T100	Standard	20 N
Blue Robotics T200	Standard	29 N
ApisQueen U2 Mini	Standard	13 N

Figure 21.

Thruster Comparison Chart
In our testing of various thrusters, UR2 used a standard bilge pump thruster as our baseline data. Our objective was to determine if running four U2 minis as vertical thrusters could generate more vertical power using less current compared to running two T100s. With four U2 thrusters, we can achieve 52 N of thrust while consuming 12 amps. On the other hand, using T100 thrusters, we can produce slightly over 40 N while drawing 15 amps. Although Blue Robotics offers higher thrust, the decision involves balancing power constraints and lifting capacity.

Figure 22. The image displays the finished dragster. Employing this design platform enabled us to quickly identify and rectify issues in a small design that utilized the same materials as our MATE ROV, Stingy. Through a blend of 3D printing, frame size adjustments, and thruster configurations, we efficiently addressed design flaws and shortcomings.

Testing and Troubleshooting

Prototyping Vehicle Design

The team set up the test pool with props from last year's MATE ROV Mission for our first test, and The prototype seemed to be able to quickly adjust and quickly get from the top to the bottom of the pool, which is a significant factor when competing in the Michigan Regional where you compete in a 4-meter drive tank. For our Final Test of these thrusters, UR2 simulated what it was like at a MATE ROV competition with stress on the ROV and the ROV being in and out of the water. To do this, the team competed in Square One Underwater Innovative IVD Vehicle Design where the ROV had to complete underwater tasks in 15 minutes 3 separate times. The Prototype proved its durability and reliability with the U2 Mini thrusters. The ROV was also efficient in the 3-meter-deep section of the pool, getting up and down quickly. The ROV also proved its capability and ability when it completed all the tasks requiring several thrusters moving at once. The results of our testing proved that the U2 Mini thrusters were just what the team was looking for, beginning with smaller and lighter thrusters but still being reliable for the MATE ROV Competition. With the team's newly found knowledge from testing the Drag Racing and Prototype ROV, the team applied it to Stingy, reducing the weight by 30% and the size by 33% over last year design.

With String’s prototype, UR2 worked on developing a control system using an Arduino PWM control (Figure 24). Through another network meeting with the Navy, Marcos Barrera, AI Research Engineer for Seafloor Systems Inc., introduced us to Robot Operating Systems (ROS). UR2 started working with this system, but it is more that we could take on this season. Our hope is to develop ROS into all our new ROV designs. We have team members prototyping a autonmous surface vehicle that will serve as our test platform.

Figure 23. After finishing the dragster project, we moved on to prototyping an ROV powered by four U2 Minis. The frame was constructed using PVC material. Since UR2 had previously tested the building materials for Stingy’s frame, we decided to skip building a new one. To connect the thrusters to the frame, we 3D printed different thruster adapters. It took us three attempts to get it right as the thrusters kept breaking the mounts due to the force.

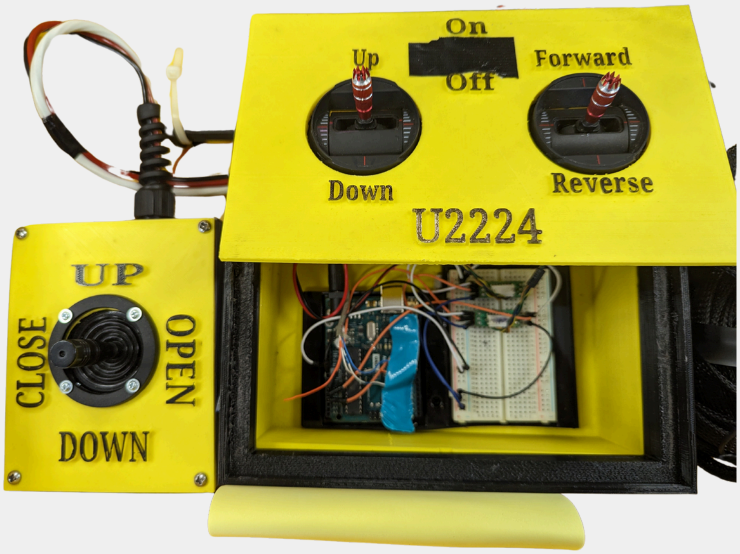


Figure 24 is an image of our Arduino PWM control system that UR2 designed for the Stingy prototype.

Operations and Safety

At UR2, we prioritize safety above all else. We take all necessary measures to ensure the safety of our team members, mentors, customers, and the general public. We provide comprehensive training to every team member to prevent accidents and ensure safety at every stage of their work. We believe in maintaining a safe and supportive learning environment by implementing and adhering to strict safety standards every time we meet. We follow a "check twice" policy and encourage our team members to ask about our safety checklist.

Before working on equipment or handling parts, every member of our team completes a rigorous ten-hour OSHA safety class. This comprehensive training ensures everyone's safety and helps prevent accidents. Additionally, we have two certified lifeguards on deck at all times.

As a company, we wanted to ensure that safety was extended to our working environment and the actual ROV. The vehicle incorporates two strain reliefs that prevent the tether from being ripped out. The first strain relief is located on the back of the ROV and is a simple carabiner clip that clips onto a cable thimble. This setup attaches to all the wires from the enclosure, preventing strain. The second strain relief is attached to the side of the control station so the tether is securely attached. The ROV also has an in-line fuse that is positioned 30cm from the point of power. Both top thrusters are surrounded with yellow and black warning tape as a visual warning to anyone around the ROV. In addition, all thrusters have a 3D-printed guard over them so that no fingers can enter the vicinity of the propeller. Finally, all of the ROV's edges are rounded, so there is no risk of anyone cutting themselves while picking up or working with the frame.

Our motto is simple - a safe company is a happy and productive company.

We have developed Job Sight Analysis (JSA) that guides the team to make a safety assessment on hazards while working topside with the ROV. We have also included our Safety Check Sheet in the appendices of this report.

Figure 24. Part of our daily safety procedures is keeping the workspace clean and making sure that the floor is clear of tripping hazards. With a large tank of water in the workspace, UR2 have to work to keep the floor dry.

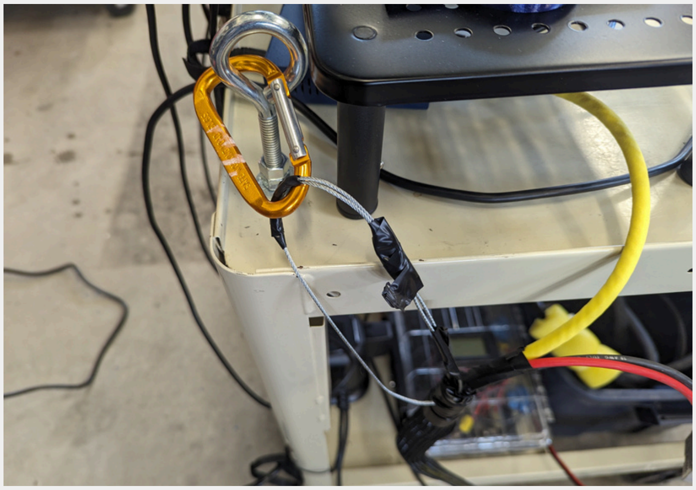


Figure 25 shows how to secure the tether to the control station, we enclosed the end of the tether in a PVC pipe and connected it to a steel cable. The steel cable is fastened to an I-bolt using a carabiner.

Business Accounting

Funding Sources

This year, UR2 managed to secure four funding sources to create our most advanced vehicle to date, Stingy. We allocated approximately thirty percent of our funding to Stingy's development. We dedicated the remaining funding to collaborative projects, enabling us to test and enhance Stingy's capabilities. By leveraging funding across multiple projects, UR2 can further our research and seek donations to support our initiatives.

Source	Grant Total
MISTEM Grant	$4,000.00
NOAA Foundation Grant	$5,000.00
Regional 9 MiSTEM Grant	$2,000.00
Donations	$4,000.00
Total Company Founding	$15,000

Figure 26 shows the main sources of our income for the 2023 to 2024 ROV season. We attempt to write grants for projects that help us advance the development of new designs. The Figure below total ROV cost.

ROV and Float Cost

UR2 spent a total of $2,527 on new parts for Stingy, and the total value of reused parts in this year's ROV is $800. UR2 also reused a previously purchased electronics enclosure with a repurchase value of $750. If we incorporate this into the overall value invested in the development of Stingy, the ROV would appraise it at $4077. This sum encompasses items that were used, reused, and donated.

Buy vs Reuse

UR2 has allocated more resources to acquire new parts for enhancing Stingy. Last year, our failure rate was higher as a result of the breakdown of used parts. For example, our Float project from last year primarily utilized outdated Electronics components, leading to an unreliable Float. While our pursuit of funding demands resourcefulness with our existing parts, the challenge of worn-out parts hindering our progress is counterproductive to our fundraising efforts. Demonstrating our achievements makes it much simpler to secure funding. This highlights the delicate balance between financial responsibility and success.

Category	Description	Cost or Value	New or Reused
ROV Structures	ABS Filament	$125	New
	Plastic Tubing	$60	New
	Enclosure and Electronics tray	$252	Reused
Propulsion	6 U2 Mini Thruster	$260	6 New and 4 Reused
Electronics	6 Electronic Speed Controllers	$150	6 New and 4 Reused
	Navigator Board	$325	New
	2 DWE HD Cameras	$800	New
	Xbox controller	$65	New
	3 Servos	$150	New
	180 Wide view Camera	$65	Reused
	Wiring	$50	Reused
	12 Penetrators	$80	New/Reused
Tether	Mesh Casing	$53	Reused
	Fantom ROV tether cable	$20	Reused
Mission Tools	Vertical Float	$350	New/Reused
	Substrate Sampler	$10	New
	Measuring Device	$10	Reused
Miscellaneous	Control Station with Monitors	$160	New/Reused
	Ballast Weights	$50	Reused
	HP Micro Computer	$200	Reused
Total Funds Spent		$3,235	

Figure 26a: funds allocated for the development of the ROV

Business Accounting

Buy vs Build

During the design phase of a new vehicle, we often focus on whether to purchase components or manufacture them. With our expertise in 3D replication and computer-aided design, our ability to create rather than buy has greatly expanded. This innovative approach paves the way for new possibilities. However, we cannot produce certain items within our budget using a 3D printer. In recent designs, we have fully 3D printed our frames. This year, we opted to buy plastic tubing and 3D print the connectors instead. This decision helped us reduce the overall buoyancy of the ROV. The cost of the tubing was less than that of two spools of filament.

While developing our ROV prototype this year, UR2 collaborated with middle school students to create a Kort valve for the conventional bilge pump thruster. Although the Kort valve successfully enhanced the thrust of the bilge pump thruster by 300%, it fell short compared to the output of a manufactured brushless thruster. When competing at a global level, maximum thrust is essential. We found that constructing a thruster was less efficient and dependable than using a pre-built thruster. Figure 27 shows our current projects and funding for those projects. Developing the projects and seeking funding does require a lot of work. Still, the opportunity of these projects allows us the fiscal freedom to purchase items we can use to prototype new vehicles that UR2 would not have to do with just seeking funds for an ROV build. UR2 can test prototypes at a grant's expense.

Projects	Description	Invested
Square One Competition and ROV Prototype	Parts to build prototype and competition registration	$900
Viking Cruise Line Substate Sampler Project	Cost for this project includes developing the Sampler, testing, and building an ROV to deploy the sampler	$4,500.00
Autonomous Surface Vehicle Project	Developing a prototype and creating a functioning vehicle	$2,0000
Regional LEGO Competition	Funding for this event came from a separate grant we wrote just for the competition in partnership with NOAA.	$1,600
Elementary SeaPerch Project	This year we create an in school program to develop interest in ROV projects using the SeaPerch materials	$$600

Figure 27. Project Funding

Category	Description	Cost or Value	New or Reused
Extra Parts	4 Test Servos	$72	New
	Backup Pie Board	$134	New
Competition Costs	Competition Registration	$265	n/a
	Printed Poster Board	$25	New
Travel Expenses	Travel Expense to Worlds.	$12,500	Fund Raising Totaled $13,000 in Grants and Donations
Other Expenditures	Pool time	$900	n/a

Figure 28. Additional Team Expense

Grants	$8,500
School Pay Donation Site	$1,000
Local Credit Union Matching Donations	$2,500
Personal Donations	$1,000
Total Raised	$13,000

Figure 28a. Team Fund Raising Breakdown

Conclusion

The development of this year's ROV design, known as Stingy, commenced a week after the last World Championship. To guide our design choices in achieving our three primary objectives, we established a design criterion outline. As a team, our goals were to decrease the ROV's overall size and weight, create a new operating system, and construct a dependable vertical profiler named "Float." Our team is proud of what UR2 accomplished this year, and UR2 are already building ideas for next season.

Furthermore, our team has made a positive impact in the community by engaging with over five hundred elementary students, three hundred middle school students, and mentoring three high school ROV teams. Additionally, we have continued to provide a research platform for local stewardship conservation working with dozens of community partners.

Community and Project Partners

Our OnShape and Fusion 360 Mentor

- STARBASE Alpena: Steve Tezak

Technical Advisors

- US Naval Surface Warfare Center Crane: Debra Walker
- Seafloor: Marcos Barrera
- Peraton: Janine Frederick
- Paul Coleman
- Quade Kimball

Team Support

- Thunder Bay National Marine Sanctuary
- Alpena Public Schools
- Marine Advanced Technology Education Center
- MISTEM
- All the volunteer divers and NOAA staff members that make everything possible.

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All pictures of team members used in this technical documentation were taken by Lydia Thomson and Sarah Rabbideau.

Operations and Safety Check Sheet

Operation and Safety Check Sheet

Pre-Power	Yes	No	If No...
Area is clear of tripping hazards			Clear the deck of tripping hazards before moving on
All team members have proper PPE ☐ Safety Goggles ☐ Hair pulled Back ☐ Closed toed shoes			Obtain proper PPE before going near the ROV
Teather is free of tangles			Untangle tether and lay out on the pool deck
Strain relief is attached			
No visible damage inside the enclosure			Do not put ROV in water. Fix the damage first
The enclosure is sealed fully			Make sure the enclosure is sealed before placing in water
Thrusters are guarded and free of debris			Clear debris and attach guards
ROV Launch			
Control box powered on			Power control box and ROV on
Pilots keep hands off controls			
Payloader shouts "Hands on" before grabbing the ROV			
Rov placed in water and visually checked for leaks showed by bubbles			
If no leaks the payloader shouts "Launch" then lets go of ROV			
When payloaders hands are off ROV the payloader must shout "Hands off"			
Pilot shouts "Power on" and begins driving ROV			
ROV Retrieval			
pilot shouts "returning to surface"			
when ROV is at surface payloader			

.			
Leak Detection			
Power down ROV and remove from water quickly			
Visually try and find the source and cause if the leak			
Verify location of leak			
Create an action plan to stop leak			
Carry out action plan Check ROV systems for damage			
Pit Maintenance	Yes	No	If no...
Pit is organized			Tidy up the pit.
All materials are put in the proper place and are not a tripping hazard			Place materials in proper places where they are not a tripping hazard.
Check that ROV and teather are put in proper location			Correct the location of the ROV and teather
Dry ROV and be ready for the next run			Take time to dry the ROV or place it in a space where it will dry in time for next run.

Pre-Power	Yes	No	If No...
Area is clear of tripping hazards			Clear the deck of tripping hazards before moving on
All team members have proper PPE ☐ Safety Goggles ☐ Hair pulled Back ☐ Closed toed shoes			Obtain proper PPE before going near the ROV
Teather is free of tangles			Untangle tether and lay out on the pool deck
Strain relief is attached			
No visible damage inside the enclosure			Do not put ROV in water. Fix the damage first
shouts			
ROV Retrieval			
Pilot shouts "returning to surface"			
When ROV is at surface payloader shouts "Power off"			
Pilot indicates power has been shut off			
Payloader pulls ROV from water using tether restraint			
When ROV is on the pool deck payloader shouts "ROV on deck"			
Team prepares to pack up ROV			
Loss of Power/Communication			
Power off ROV then back on on ROV to regain power			
If still no communication pull ROV in via tether			
Check for leaks that could be the cause			See leak detection
If communication/ power is restored continue the run			

Appendences

Safety Training Chart

Team Member and Job	Basic Safety Training	10 Hour OSHA Safety Certification	Certified Lifeguard	15 Hour OSHA Safety Certification
Lydia Thomson (CEO)	☑	☑	☐	☑
Sarah Rabbideau (Safety Officer)	☑	☑	☑	☑
Kylie Gagnon (Payloader)	☑	☑	☐	☐
Lucas Thomson (CTO)	☑	☑	☐	☐
Lizzie Rabbideau (Tether Handler)	☑	☑	☑	☐
Gus Wirgau (Pilot)	☑	☑	☐	☐
James Rawling (CO-Pilot)	☑	☑	☐	☐
Myah Rondeau (Project Specialist)	☑	☑	☐	☐
Abbey Glover (CFO)	☑	☑	☐	☐

Each team member must have basic training on safety in the lab and the importance of personal protective equipment (PPE). The team also follows a safety protocol requiring anyone on deck or who works on equipment to have a 10-hour OSHA Certification. In addition, the team has two certified lifeguards on deck at all times. Our final safety measure is that our team CEO and Safety Officer have taken an additional 5-hour OSHA Certification.

Appendences

Tether Protocol

- Tether is stored under the control station in storage tub
- Check if topside tether carabiner is clipped to I-Bolt on control station
- Remove ROV end of tether from storage tub
- Make sure tether is not twisted or tangled
- Lay tether out on deck and avoid placing it in high foot traffic area
- Recheck connections on both ROV side and control station ends of the tether

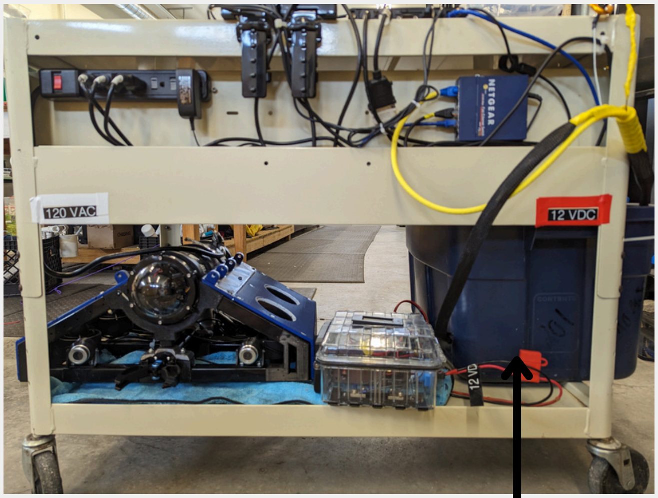
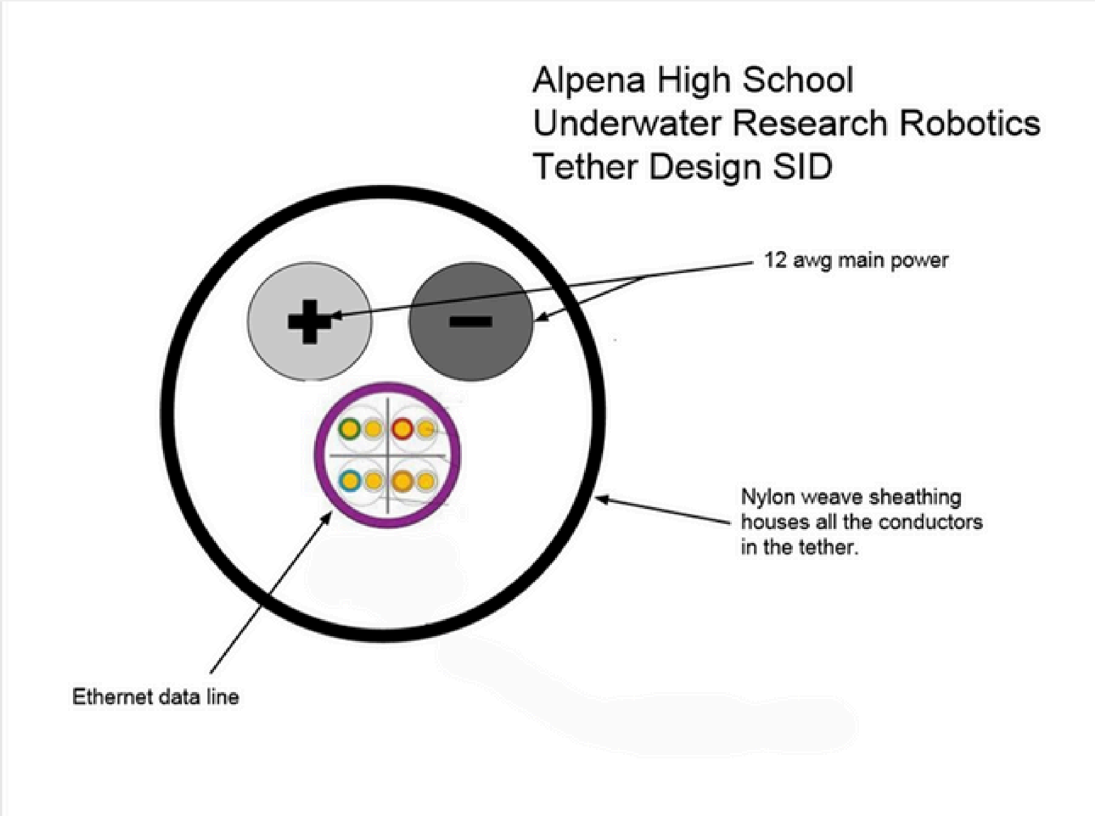


Image: Back of control station

Tether storage tote

Tether SID



Non ROV Device SID