

Underwater Remotely Operated Vehicles Team (UWROV)

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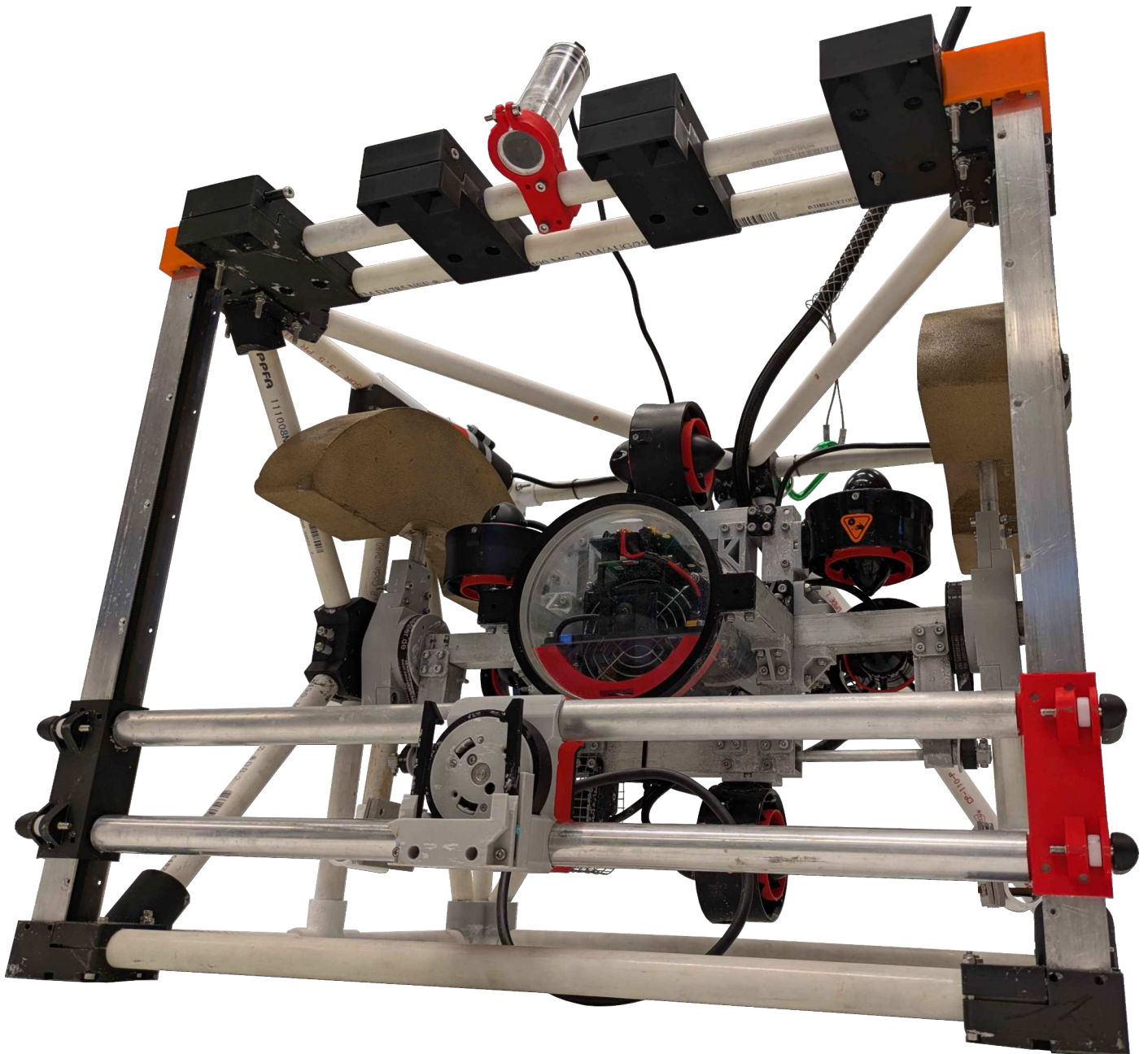
at the University of Washington

Seattle, WA, United States

Mentored by Rick Rupan, Alnis Smidchens

Table 1: Complete List of UWROV Personnel and Roles

Rowan Newell (CEO)	Henry Lam (Cameras and Sensors)	Andrew Grieve (Manipulators)
Ellen Leier (CAO)	Aadithya Menon (Custom Electronics)	Carissa Willems (Manipulators)
Imants Smidchens (CTO)	Logan Blondin (Custom Electronics)	Ian Choy (Manipulators)
Suzu Yoshikawa (Business Lead)	Krishna Maanasa Ramadugu (Float)	Jerry Chan (Manipulators)
Marcus Kwek (Mechanical Lead)	Lawrence Tang (Float)	Lucy Carlisle (Manipulators)
Abirami Subramanian (Science Lead)	Luke Wells (Float)	Melody Drewfs (Outreach)
Ayla Crowell (Electrical Lead)	Emmett Van Mason (Gantry)	Aarav Shah (Propulsion)
Ethan Yang (Software Lead)	Rohan Rairkar (Gantry)	Wanhao Zhang (Simulation)
Quinn Pfeifer (Software Lead)	Anuj Jung Thapa (Image Recognition)	



The Underwater Remotely Operated Vehicles (**UWROV**) team at the University of Washington's School of Oceanography is a company composed of undergraduate students who design, build, market, and compete in the **MATE ROV Competition**. UWROV is excited to present *Conduit*, the team's newest remotely operated vehicle (ROV). *Conduit* is designed to meet the **2026 MATE Request For Proposals (RFP)** and thus operate in **harsh conditions** including, but not limited to: cold environments, strong currents, waves, and saltwater, all of which pose challenges to making an effective ROV. The engineering work that went into *Conduit*'s development addresses the ongoing need for better systems in coral sample collection, subsea observatory maintenance, and mapping complex environments. *Conduit* features a combination of **proven systems** and **novel designs** like a rotating buoyancy arm for enhanced stability, a multi-axis gantry for precise alignment, and automated tool-changing capabilities to accomplish more in less time. In order to keep costs low without compromising on performance, *Conduit* was manufactured largely in-house by UWROV employees, reusing stock materials in the development of new custom systems. Original software addresses challenges like image recognition and coral garden ridge modeling. This document provides an overview of the design and development of *Conduit* and how it addresses the 2026 MATE RFP.

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Teamwork

Project Management

Company & Personnel Overview

UWROV consists of a leadership team and employees, with positions and roles detailed in *Table 2* and *Figure 1*. Both personnel and their roles are detailed on the title page in *Table 1*. All UWROV personnel collaborate in **interdisciplinary project-based teams** that focus on specific components of the ROV to meet the needs of the MATE RFP.

Table 2: UWROV Positions and Responsibilities

Position	Responsibilities
CEO	Sets long-term goals, manages leads, and maintains external relationships.
CAO	Oversees team operations, internal records, and administrative processes.
CTO	Establishes technical vision and guides integration between technical leads.
Technical Leads	Guide employees working on projects in their domain and oversee safety.
Employees	Work on interdisciplinary projects, consulting leads for guidance.

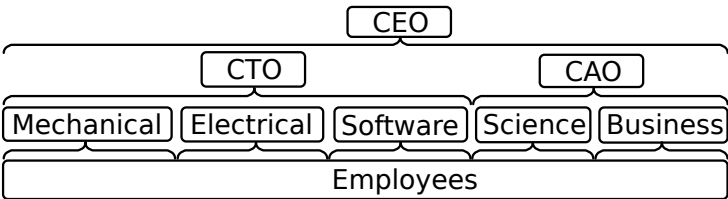


Figure 1: UWROV Organization Chart

Schedule

Conduit was developed in structured phases to align with the timing of the MATE RFP as seen in *Table 4*. These phases are marked by **milestone-driven events** (stars) to provide deadlines and performance expectations.

UWROV’s onboarding phase consists of Mini-MATE, an in-house-developed 8-week version of the MATE ROV Competition. New employees are trained in small group settings with lead mentorship and demonstrate skills at the **Mini-MATE Competition** in late November, shortly before the release of the 2026 MATE RFP.

Ideation begins after onboarding employees, spurring the prototyping and integration phases. These phases intentionally overlap to align with UWROV’s iterative design process. Proofs of concept are necessitated by the UWROV **Winter Expo** in early March, where UWROV personnel present the core concept and prototype of *Conduit* to shareholders.

After further refinement, *Conduit* begins deployments, practicing tasks from the MATE RFP in water. Field readiness is demonstrated at the UWROV **Open House** in early May, where *Conduit* conducts live pool deployments for the public.

Resources, Protocols, and Procedures

UWROV manages various resources, protocols, and procedures to ensure timely completion of **mission objectives** and **cohesive management of day-to-day operational problems**. UWROV emphasizes **fully cloud-based** resources (*Table 3*) that support real-time collaboration for efficiency in developing *Conduit* to meet the needs of the MATE RFP.

Table 3: Resources and their applications

Google Suite	File storage and sharing
Outlook	Communications with shareholders
Discord	Internal communications
Onshape	Mechanical CAD
KiCAD EDA	Electrical CAD
GitHub	Software development
Notion	Project management, daily documentation
Overleaf	Technical documentation

UWROV project management protocols utilize **Agile** [1] development methodology, with short-term project subteams working towards larger-scale, long-term goals for the ROV. Through short-term projects, personnel work in parallel on challenges presented in the MATE RFP. Both projects and personnel are **interdisciplinary**, allowing passion and curiosity to drive rapid development toward the mission objectives.

UWROV procedures consist of weekly full team meetings, open shop time, and in-water testing. Weekly full team meetings draw from Agile methodology through **standup** (*Figure 2*), where personnel provide updates on project progress and share blockers. Other personnel then provide feedback and possible solutions, solving day-to-day problems. Leads host open shop time to provide mentorship and encourage cross-project collaboration. In-water testing is conducted on an as-needed basis, with increased frequency during prototyping, integration, and deployment phases.

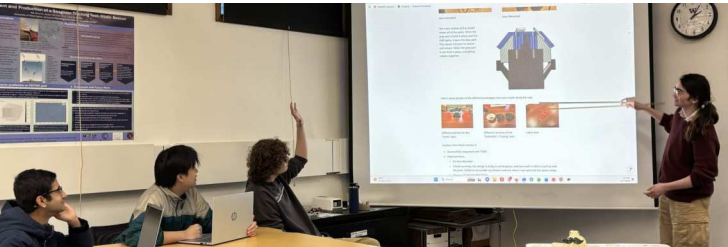


Figure 2: Employee Presenting Notion Page During Standup.

Table 4: UWROV Year-Round Schedule

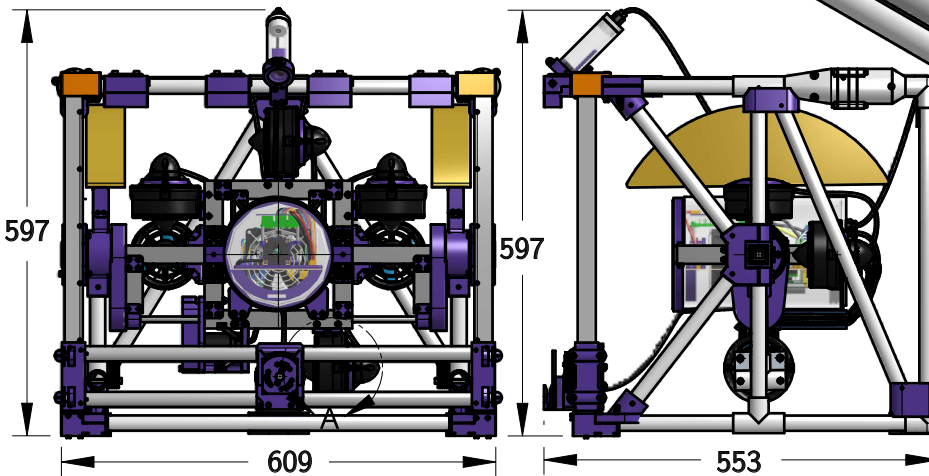
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Onboarding		★						
Ideation					★			
Prototyping								
Integration							★	
Deployments								

Conduit

All dimensions in this document are in millimeters unless otherwise specified!

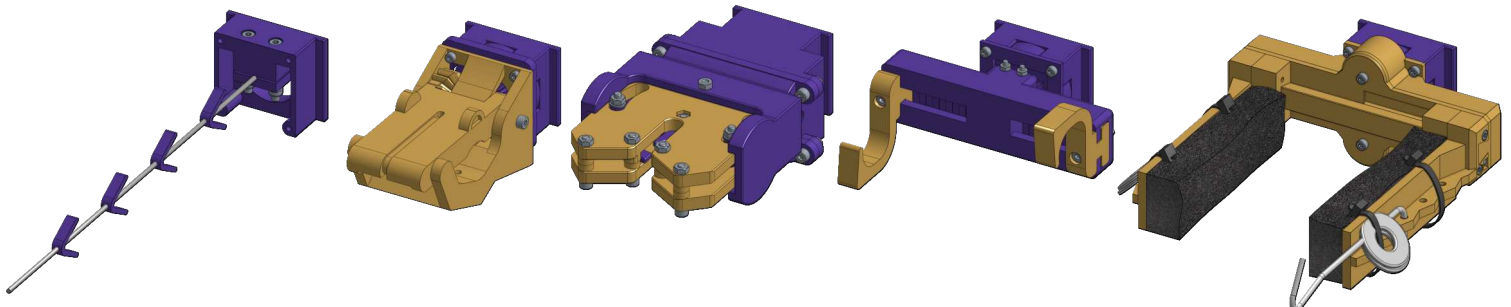
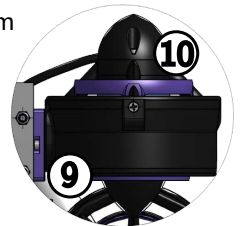
Conduit is a five degree of freedom (DOF) ROV optimized for the completion of MATE RFP tasks with a focus on ease of operation and efficiency. Buoyancy arms create addressable pitch and increase stability. A CoreXY gantry and tool switching system allow for fine control over the manipulators with specialization for coral sampling, species identification, and whale safe fishing gear. Risk of damage to the ROV and environment is minimized through the external frame, TPU bumpers and thruster guards. Sensors, cameras and stabilization software provide assistance to pilots and allow for the completion of a wide range of challenging tasks.

④ Dual Axis Gantry Manipulator System



- ① IMU for Advanced Stabilization
- ② Wetlink Wiring Penetrators
- ③ Dual Buoyancy Arms for Pitch Control
- ⑤ PCB based Electronics Bay
- ⑥ Protective External PVC Frame
- ⑦ 4 DOF Control using 6 Blue Robotics T100 Thrusters

- ⑧ Three Camera System
- ⑨ Standardized Thruster Mounts
- ⑩ Hydrodynamic IP2X Thruster Guards



Task 1.1

Coral Collection

Task 2.3

Lobster Pot Recovery

Task 2.4

Buoy Anchor Recovery

Task 2.5

Subsea Observatory

All Purpose

Horizontal Claw

Design Rationale

Problem Solving and Design Process

Conduit was developed from the ground up to address the 2026 MATE RFP. UWROV uses a **concurrent engineering approach**, with the following design process:

Identify Problems and Constraints: Problems and constraints are defined based on last year’s performance of UWROV’s ROV *Boxfish 2.0* and the MATE RFP. UWROV identified 23 issues with *Boxfish 2.0*, with stability and precise alignment being the most impactful.

Brainstorm Solutions: In agile project groups, many solutions are considered to each problem. For each issue identified with *Boxfish 2.0*, groups devised 3-10 targeted solutions, classifying each by project type, effectiveness, cost, complexity, and more. At the end of this process, there were 125 solutions to potentially implement. An excerpt of this list is in *Table 5*.

Table 5: Excerpt of *Boxfish 2.0* Pain Points and Solutions

Issue	Proposal	Project	Impact	Cost	Scope
Stability	Top-buoyant	Mech ▼	5/5	\$\$	Med
Stability	Smarter PID	Code ▼	3/5	\$	Large
Stability	Better IMU	Elec. ▼	3/5	\$\$\$	Small

Design and Prototype: After selecting the most effective design(s), prototypes are made. Working prototypes are kept so as not to lose functionality during iteration.

Test: Prototypes are tested, and the data from testing informs the design and further iteration of the part. A system that underwent multiple iterations is shown in *Figure 3*.

Push to Market: Once a design has been sufficiently tested in the context of the full ROV, it is included in the final design. When planning, UWROV prioritizes problems that are presented in the MATE RFP, relate to ROV reliability and performance, and are beneficial to building skills of employees.

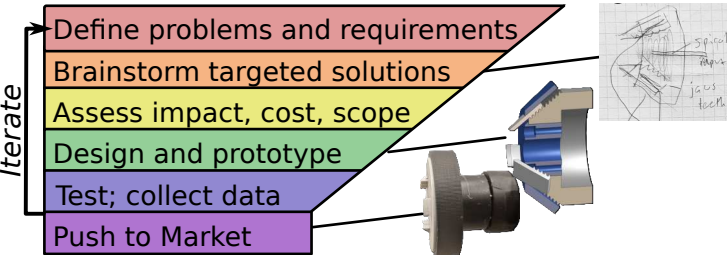


Figure 3: Manipulator Chuck Design Process

Systems Approach

Conduit’s system design approach focuses on innovation, integration, and iteration. Mechanical, electrical, and software subsystems are designed in parallel, with tradeoffs made to maximize performance. Pain points identified in last year’s ROV, primarily in stability and alignment, as well as this year’s focus on operation in harsh conditions, shaped Conduit’s architecture. The need for stability influenced the decision to move from a 6-DOF to a 5-DOF vehicle, with controllable pitch via rotating buoyancy arms. Additionally, precise task operations in a tight operational timeline drove the development of a gantry with onboard tool switching.

UWROV has developed an end-to-end **digital twin** of the ROV, with electromechanical CAD and simulated component interactions for testing software in virtual environments. UWROV also created a digital twin of the operating environment and the parts its ROV must interface with as defined by the 2026 MATE RFP (*Figure 5*). An open-source version of the digital twin environment was published on the **same day** as the prop building specification was released (Jan. 7th, 2026).

By maintaining a fully integrated CAD assembly in Onshape, issues like clearances and camera Field of View (FOV) (*Figure 4*) can be checked before components are fabricated. Ensuring model accuracy also helps predict where to add buoyancy and ballast and determine visibility via camera placement.

Subsystem integration is key to Conduit’s design. Thruster positions and orientations from the CAD model feed into a dynamic thrust allocation solver to map between controller inputs and an arbitrary thruster layout. The software further integrates data from the onboard IMU and Bar02 pressure sensor into PID controllers for depth hold and stabilization.



Figure 4: Physical Camera FOV and simulated comparison

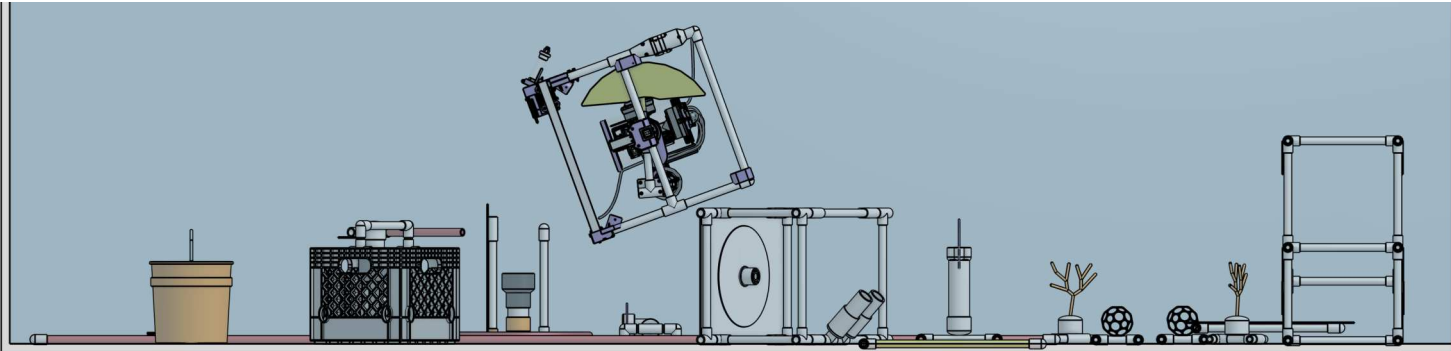


Figure 5: Digital Twin of Conduit in UWROV’s MATE RFP Environment

Vehicle Structure

Conduit makes trade-offs in **cost**, **size**, and **weight** to create a low-cost, lightweight, and stable ROV capable of fine manipulator control. *Conduit* uses primarily reused scrap components, trading off higher performance parts for a lower total cost (\$3910.60). *Conduit*'s large frame (553x609x597mm) limits maneuverability, but allows for a **dual axis gantry** and **buoyancy arm**. The dual axis gantry allows fine control in a 350x450mm area, removing the need for fine maneuvers when retrieving coral samples and servicing subsea observatories. The buoyancy arm increases weight (2618gf), but provides stability and pitch control when retrieving lobster pots and operating in currents. Overall, *Conduit* is lightweight at **under 18kg**, allowing for ease of deployment and transport.

Vehicle Systems

Component Selection

Conduit consists of a pressure hull, frame, dual axis gantry, buoyancy arms, and manipulators.

Conduit's custom pressure hull is an **acrylic** cylinder and front plate with a **6061 T-6 aluminum** backplate. These parts are manufactured on a lathe in-house to ASME AS568 standards for O-ring sealing [2]. Several materials were considered for the hull, with relevant properties on *Table 6*. Acrylic's clear appearance, low density, and saltwater resistance outweigh the tradeoff of its lower compressive strength. The lower thermal conductivity of acrylic is addressed with highly conductive aluminum backplate and fans for convection inside the hull. Aluminum was also chosen for its lower cost, machinability, low density, and compressive strength suitable for the MATE RFP. While aluminum may corrode quicker than stainless steel or titanium, the decreased lifespan of the vehicle was worth the exchange for significantly lower cost and weight.

Table 6: Proposed Hull Materials [3–10]

Material	Cost	Machine in-house?	Yield Strength	Density kg/m ³	Corrosion Resistance
Aluminum	\$	yes	530MPa	2830	Medium
Acrylic	\$	yes	120Mpa	1185	High
Stainless	\$\$	no	700MPa	7720	High
Titanium	\$\$\$	no	970MPa	4430	High

Conduit's frame houses the gantry, buoyancy arms, and pressure hull. It combines Schedule 40 1/2" PVC and aluminum, reducing weight while maintaining structural integrity at critical points. The inner frame mounts the pressure hull and utilizes aluminum boxtube for its low density, availability as scrap components, and strength. The outer frame protects *Conduit*'s systems from collision-related damages, and utilizes PVC for its weight reduction and availability from past projects. The dual axis gantry at the front of the outer frame is made of aluminum U-channel and round tube to account for higher loading requirements, such as when handling whale safe fishing gear.

All corners and joints of the frame are custom 3D printed using **PLA. TPU 95 A** is used for bumpers and to cover sharp edges due to its malleability and shock absorbing properties. Parts are printed at 100% infill so that water does not seep in, which would change the buoyancy of the ROV and make it harder to control and stabilize. Similarly, most components in *Conduit*'s manipulators do not require as much structural integrity as the frame, and are also made of PLA. However, certain elements that undergo high torque are made of aluminum or steel.

All mounting and frame construction is standardized to **M2, M3, and M4 hardware**, allowing serviceability, modularity, and corrosion resistance. This modularity makes it easy to rapidly modify and reuse parts of the ROV during development, streamlining the team's design process.

The two buoyancy arms on either side of *Conduit*'s pressure hull reuse a low density syntactic foam, as it is significantly more buoyant than other foams while maintaining a similar weight. Additionally, it does not compress under pressures, maintaining buoyancy. **316 stainless steel** counterweight was used for its high density and low cost to weight ratio.

Horizontal Claw Case Study

The horizontal claw manipulator uses a cushioning material to safely interact with fragile coral samples and scientific equipment. Two **trade studies** were conducted to determine this material. First, the relationship between force and compressibility was investigated through the Arbor Press Deformation Study. As seen in *Table 7*, the L Black Foam (large pores) had the largest increase in force while still being compressible, with Orange Foam showing the opposite. Black and White Rigid Foams exhibited excessive stiffness and were not desirable.

Table 7: Arbor Press Deformation Study Results

Material	Weight on Scale (gf)					
	1mm	2mm	5mm	10mm	15mm	20mm
4% TPU Hex			205	309	705	7,500
5% TPU Hex			350	580	1,375	7,200
6% TPU Hex			640	790	2,490	7,600
S Black Foam			650	950	1,200	3,000
L Black Foam			1,100	1,500	2,100	3,800
Orange Foam			200	250	380	660
Green Foam			260	293	410	1,600
Black Rigid			2,300	4,750	10,000	N/A
White Rigid			510	2,087	7,340	N/A
Uncut Silicone	1,600	7,500	N/A	N/A	N/A	N/A

Material	Initial Width (mm)				Width after Coral Task (mm)				Width after Connector Task (mm)			
	Front		Middle		Front		Middle		Front		Middle	
	L	R	L	R	L	R	L	R	L	R	L	R
S Black Foam	30	25	35	30					30	25	35	28
L Black Foam	40	32	40	31					40	30	39	36
Orange Foam	25	26	26	26	24	25	26	26	26	26	26	26
Green Foam	30	25	26	25	27	27	25	25	26	25	24	24

The Saltwater Deformation Study collected data using the University of Washington Saltwater Tank, UWROV's sole testing facility. Having the manipulator perform under these conditions showcases its ability to excel under various conditions, both freshwater and saltwater.

As *Conduit* was still under development, UWROV's previous ROV, *Boxfish 2.0*, was used to retrieve two official 2026 MATE ROV props using different types of foam on the manipulator. A coral from task 1.1 and the power connector from task 3.2 of the MATE RFP were chosen for testing due to their difference in diameter and weight; the coral prop being 265g and 69mm wide, and the connector prop being 111g with a 4mm screw hook attachment. The width of each foam was measured before and after each dive to gather data on plastic deformation. The optimal material would complete both tasks efficiently and sustainably.

Ultimately, as seen in Table 8, the optimal material, S Black Foam, plastically deformed the least compared to its original form before entering the water. Utilizing this foam will boost design sustainability by decreasing the frequency at which the foam would have to be replaced.

Design Evolution

Conduit has undergone several revisions (Figure 6). The original design envisioned a single buoyancy arm and two pressure hulls, centering the buoyancy forces and allowing a single motor to control pitch. However, two pressure hulls would have obstructed visibility and made the electronics difficult to wire, so the design changed to two arms and a central hull. This change improved coral surveying with photogrammetry and sampling by improving the field of view. The frame was intended to be made of carbon fiber.

The second iteration utilized a PVC square frame and a two belt system to control the gantry. PVC was chosen instead of carbon fiber due to its availability. This frame design was too flexible, causing significant deflection within the gantry system. As a result, the frame deformed heavily when experiencing heavy loads such as while retrieving the lobster pot. Additionally, the two belt gantry system used was very bulky, which obscured the frontal camera and reduced the range of motion that the gantry could access. This made it harder for pilots to perform tasks effectively.

As a result, various upgrades were made. Most significantly to prevent flexing in the frame. Triangle bracing was added, and some PVC components were replaced with aluminum U-channels and round tube to make the front plane of the ROV more rigid. This allowed the gantry system to function under heavier loads. In addition, a simplified one belt gantry system could be fully concealed within the frame, decreasing environmental risk. Lastly, an additional downward facing camera was added to allow the pilot a top down view of the manipulator. These measures made *Conduit* much more robust and easy to operate.

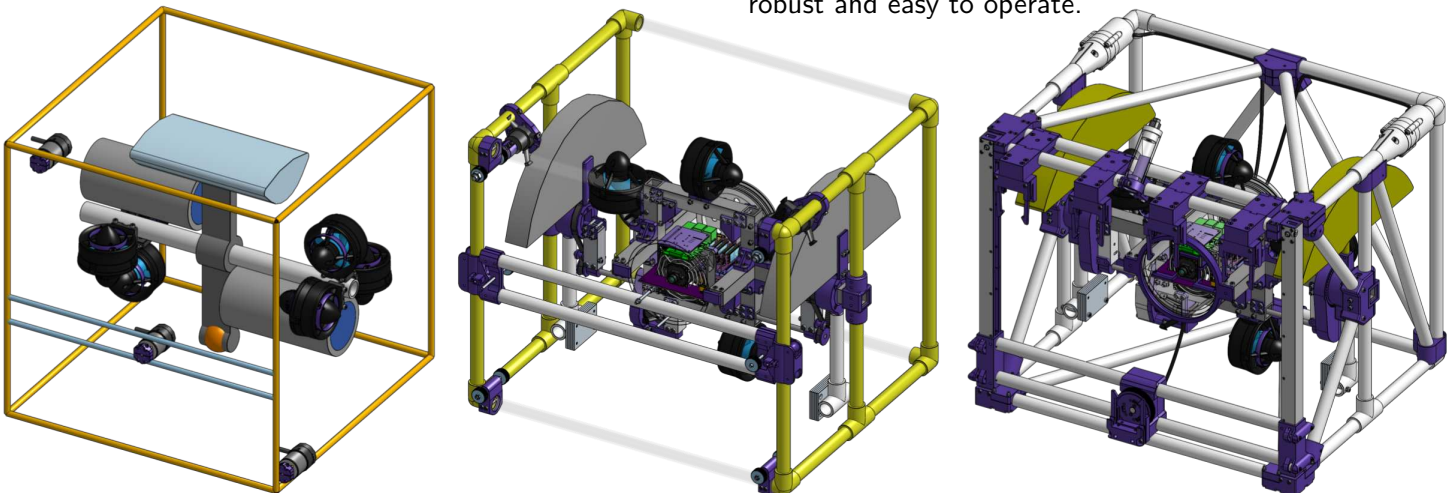


Figure 6: Conduit Iterations

Electrical System

Vehicle Electronic Design and Cabling

Electrical routing in *Conduit* occurs almost exclusively via **custom-designed printed circuit boards (PCBs)** designed in **KiCad EDA**. This provides a major overhaul and improvement to the form and function of electrical systems. A motherboard (*Figure 7*) facilitates all main routing with cabling from the tether plugging in promptly after entering *Conduit*. Components interface with the motherboard via individual daughterboards (*Figure 8*) that have simple **plug and play connections**. The PCB electronics use space in the hull considerably more efficiently, providing a very **stable and consistent structure** to all component connections. This also leads to much better thermal management since a larger fan was able to fit into the saved space, and the channels between the rigid components have much better airflow compared to large amounts of cabling.

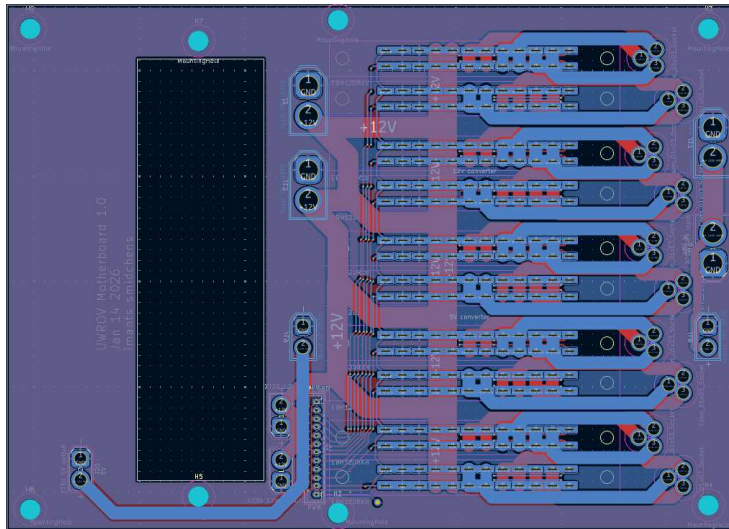


Figure 7: Conduit Motherboard PCB

The daughterboards (*Figure 8*) form a loop between the motherboard and a component, routing all inputs from the motherboard to the component, and outputs from the component back to the motherboard. This means **each component is an isolated system**, only connected via its daughterboard to the motherboard, never directly to another component, and therefore much easier to test and replace as needed.

There are **10 Blue Robotics Electronic Speed Controllers (ESCs)** onboard *Conduit*. Their daughterboards slot into the motherboard via Goldfinger connectors in an array directly in front of the fan for better thermal management.

There is one 48V-12V and one 48V-5V power converter onboard *Conduit*. These turn the 48V power from the tether into usable voltages for the components. The daughterboards for the converters are plugged into the underside of the motherboard, keeping these larger components out of the way of the rest of the electronics. All 12V systems use **XT-60** connectors and all 5V systems use **XT-30** connectors. The boards also have access points for currently unused trim pins on the converters in case of future developments.



Figure 8: ESC Daughterboard PCB

As the one exception to routing via the motherboard, the onboard **Raspberry Pi**, which sits above the fan, takes an Ethernet cable directly from the tether and has a USB to the camera. All other connections go through the Pi HAT (*Figure 9*) which neatly routes the many control pins of the Pi into standard connectors for the fan, sensors, and PWM to the motor controllers. The Pi HAT also serves as the mounting point for the Inertial Measurement Unit (IMU). To add more space, the distance between components was increased by rerouting signals to the JST GH pin. The ground was also routed to a JST connector.

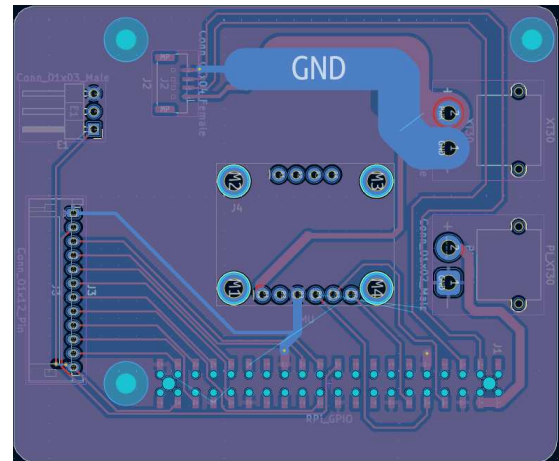
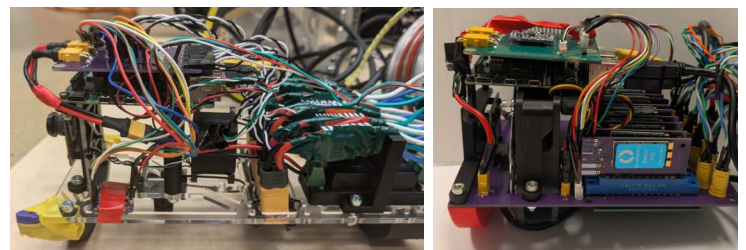


Figure 9: Pi HAT PCB

A comparison between this year's and last year's electronics bay is shown in *Figure 10*. The electronics bay is more compact, and wiring is significantly cleaner, making it easier to diagnose problems and replace components, as well as increasing airflow through the system.



Boxfish 2.0

Conduit

Figure 10: Electronics comparison with last years' ROV

Tether Design

Conduit's tether was designed for **flexibility, durability, and reliability**. At 15 meters, it is long enough for coral sampling and sensor recovery while mitigating tripping hazards.

A **Blue Robotics Fathom Tether** with ethernet terminals crimped on both ends is used for data transfer. It connects directly to the surface station laptop and onboard Raspberry Pi. Two **10 AWG marine-grade wires** supply 48V DC power (*Figure 11*). The ROV's **Full Load Amps (FLA)** was measured at **9A at 48V**, meaning the tether dissipates less than 0.5 Watts [11]. The power cables connect to the MATE power supply via SBS50BLU Anderson Powerpoles, with an inline 25A Littelfuse, as well as a resettable 30A inline breaker that serves as an **emergency shutoff switch**.

Both ends of the tether have **noncorrosive stainless steel mesh grips** that latch onto the **wrap-around braided sheathing** when pulled, providing strain relief. Inside the sheath, cables are twisted together to increase flexibility. With a working strength of 35 kg and breaking strength of 155 kg, the tether is strong enough for the ROV to be **safely lifted** by it [12]. The tether is **neutrally buoyant**, with foam attached on an as-needed basis to prevent excess tether from tangling underwater. The tether is fully **detachable**, simplifying transport, servicing, and allowing for a potentially longer tether in deep water deployments.

Tether Management Protocol

1. Designate a tether manager for deployments
2. Tether manager prevents kinks and tangling in tether when coiling and uncoiling
3. Tether is connected to surface station strain relief, power, and ethernet in their respective orders
4. Strain relief is provided on both the ROV and surface station sides
5. Tether manager will provide sufficient tether length to allow optimal ROV performance
6. ROV pilot must avoid close maneuvers and movements around obstacles to prevent tangling
7. Ensure no one damages tether components by stepping on it
8. Tether manager will disconnect the tether from the surface station and power source
9. After disconnection of the tether, the tether manager coils the tether for organization

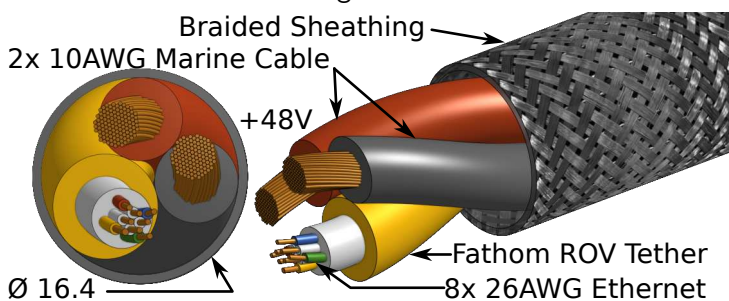


Figure 11: Cross Section of the Tether

Control System

Conduit's design served as the basis for assessing its control system requirements. This drove the development of **independent control systems** for the gantry, thrusters, and buoyancy arm. *Conduit* supports multiple manipulators with differing requirements through **unique control profiles** for each manipulator, allowing *Conduit's* pilot to maintain full functionality on a single controller. Control system requirements were documented in *Notion*, associated with the relevant electromechanical system projects. UWROV verified these requirements in a digital twin simulation using CAD models of the vehicle and environment. The simulation includes an end-to-end controls pipeline that emulates communications between the ROV and surface station, and a physics engine to practice piloting with differing controls layouts. Once *Conduit* was manufactured and assembled, all systems, including controls, were rigorously evaluated through **in-water testing**.

UWROV uses a **software-based** control system. A **surface station laptop** and an onboard **Raspberry Pi 4** communicate through **WebSockets**. The Pi sets up a Dynamic Host Configuration Protocol server to allow the devices to connect via Ethernet without the need for an intermediate modem.

The surface station software has three components: **Interface**, **Control Core**, and **Task Code**. The Interface parses pilot inputs from a Logitech controller into commands sent to the Control Core. The Control Core translates commands into **pulse-width modulation** values (PWM) and sends these to the Raspberry Pi (*Figure 12*). The Pi relays PWM from the surface station to motor controllers, and transmits sensor and camera data back to the surface. The Task Code component handles automations processes like photogrammetry (see *Original Software, Unique Solutions*). *Conduit's* software is implemented in **Godot** and **Python**. Godot's capabilities as a game engine allow it to accept inputs from many types of controllers, and provide a visual of the ROV's orientation. Python is used throughout the rest of the ROV's system for movement computations due to its flexibility and readability, at the cost of higher memory overhead.

UWROV's software development process heavily emphasizes the use of version control software, specifically through **Git** and **GitHub**. All code development is done in **branches**, and when ready to be integrated, a **pull request** is made to merge changes into the main codebase, requiring the approval of a **software lead**. Testing methodology leverages the digital twin simulation, allowing employees to deploy code remotely, and in-water testing sessions allocate time for debugging new software with the ROV in a controlled environment.

The control software combines several features that improve system and operator performance. Data from an onboard accelerometer is fed through a **Kalman filter** to reduce noise, then combined with depth sensor data to inform a **depth-hold mode**, autonomously keeping the ROV at a constant altitude for flying transects or maintaining position in a flume.

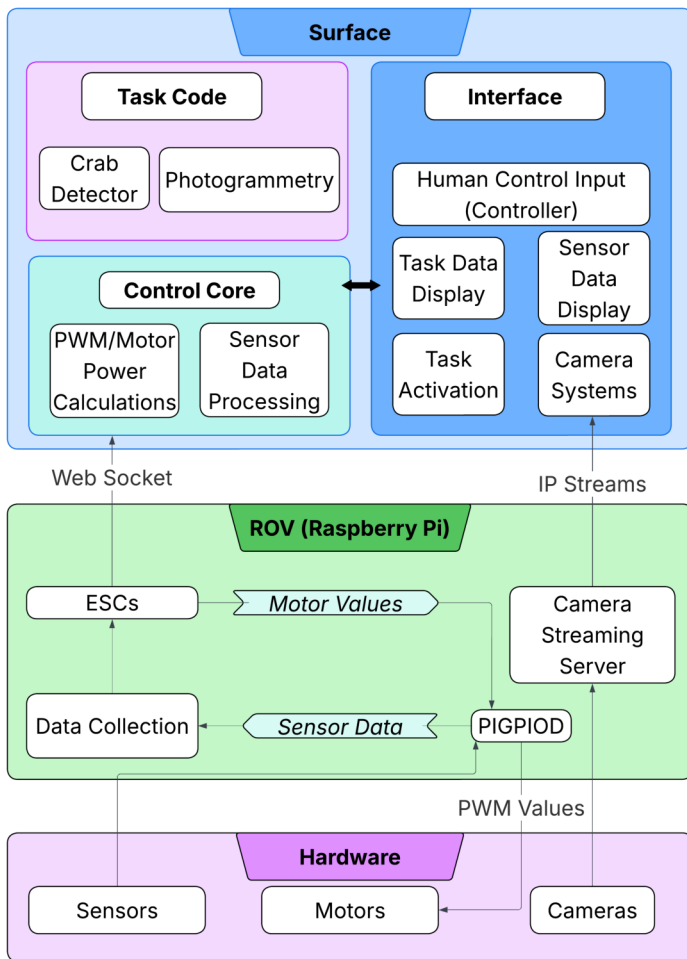


Figure 12: A Flowchart of all Control Systems

Original Software, Unique Solutions

To automate the process of modeling coral gardens based on sparse video data, UWROV has created a feature to assist in generating **scaled point cloud photogrammetry models**. Given a continuous video stream, the program corrects for lens distortion, crops out the visible ROV frame, then identifies the least-blurry frames via the Laplacian sharpness metric. For each selected frame, depth and orientation data inform a camera position estimate. This is fed into the **DepthAnythingV3** library to project a depth map onto the pixels of the original frame (Figure 13). This data is then fused into a global point cloud, and a preliminary model is presented to a surface-side analyst for annotation. The analyst selects coordinate pairs and adds annotations for known distances. These annotations are averaged to inform the overall model scale, which can then be used to determine unknown distances.

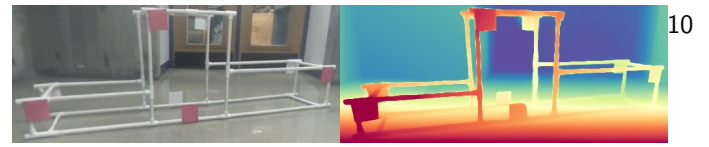


Figure 13: Pixel Depth Estimation used for Point Clouds

To mitigate invasive species, a **YOLO-based object classification model** is trained to automatically visually scan the seafloor, labeling any crab as either an invasive or native species. This is achieved by providing the model a sample of human-labeled frames and training it to best predict the labels. It is then evaluated on previously unseen data to ensure it has not overfit to the training set.

To fly the transect, depth, IMU, and camera data are leveraged to maintain position. By zeroing the depth sensor on the floor of the pool, a height-hold using a **PID controller** can be performed at a known elevation. At this height, the size of the blue square section in the frame is known, and a square crop of the camera feed is performed at the beginning of the mission. This will ensure the blue square is included in the frame and the red square is excluded. Within this frame, **RGB pixel thresholding** is used to isolate the blue square. PID control is used to keep the blue square in the center of the camera frame. The controller then drives the thrusters, applying the necessary force to hold the ROV's position.

Propulsion

Conduit uses six Blue Robotics T100 thrusters with two thrusters on each coordinate axis. The buoyancy arm dictates pitch, and while *Conduit* has roll authority, the syntactic foam prevents the ROV from tilting, resulting in a 5-DOF system, with four degrees coming from active thruster control. Propellers pointing in the same axis have opposite-handed directions. This is so that the thrusters counteract each other's rotational moment and prevent the ROV from experiencing unwanted rotation. Figure 14 demonstrates how *Conduit* can achieve five degrees of freedom.

All T100 thrusters were reused, reducing development cost. Despite this, they are well suited for usage on *Conduit*. Each thruster has a maximum power draw of 135 W, keeping the overall power budget well below the 1.5 kW that the tether provides. Moreover, T100 thrusters are capable of producing 24.7 N of thrust, so the ROV has a theoretical lift capability of ~48N in water, more than required to lift components in the MATE RFP like basket stars (15N) or lobster pots (20N)

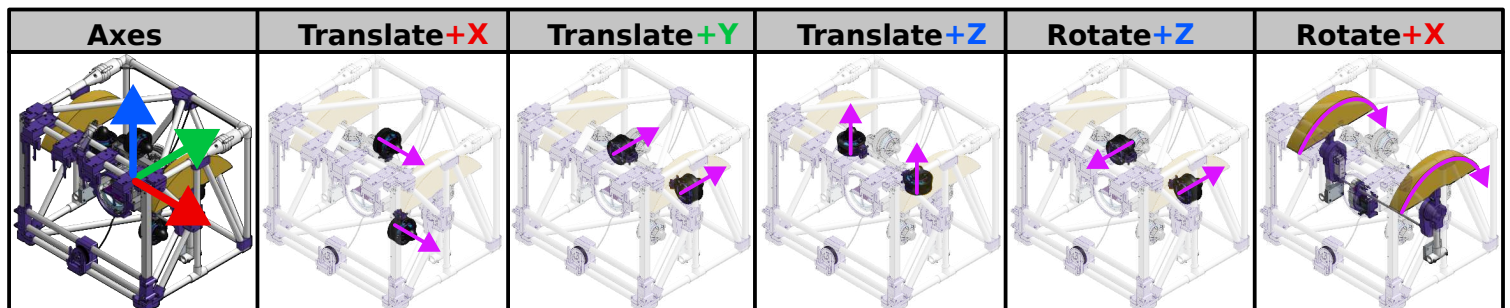


Figure 14: Diagram of the ROV's Propulsion System

Buoyancy and Ballast

Conduit uses a **novel** buoyancy arm system to control its pitch. The system is composed of two **rotating arms** with syntactic foam and steel plates on opposite ends. This means the center of gravity (CG) is at the center of the ROV and does not change when the arms rotate, simplifying the control system. The difference in densities between the materials causes the center of buoyancy (CB) to be biased towards the foam and rotate with the arms. Shifting the CB relative to the CG creates a **restoring moment**, resulting in a new equilibrium pitch orientation for *Conduit* (Figure 15). By utilizing buoyancy to adjust pitch, *Conduit* is **passively stable**. This means it will maintain its pitch in the presence of external forces or unwanted rotation from inertia without needing to continuously run thrusters, reducing power consumption. At the same time, *Conduit* can adjust its pitch, giving it more options to interact with and view objects of interest easily.

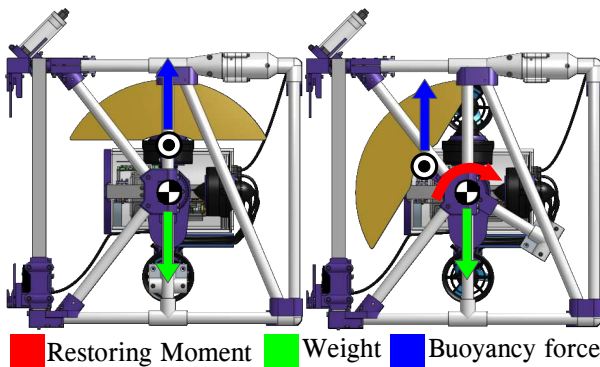


Figure 15: Buoyancy arms in a neutral position (left) and rotated to create a moment (right)

The main source of buoyancy comes from *Conduit*'s custom pressure hull and buoyancy arms, providing 19.94 kg of buoyant force. UWROV's digital twin CAD model was used to predict ballasting needs before making actual adjustments to the ROV. Ballasting steel plates are attached to the frame to compensate for extra buoyancy, which additionally allows the center of mass to be adjusted according to external load distributions from manipulators. Additionally, the Blue Robotics Fathom ROV Tether is leak-proof, flexible, and neutrally buoyant (in saltwater), mitigating additional buoyancy adjustments. When testing in freshwater, foam is attached to the first 10 meters of tether, leaving roughly four meters of tether that extends below the surface.

Payload and Tools

Cameras

Conduit has three cameras that capture relevant areas around it but minimize onboard compute and integration complexity (Figure 16). A **Low-Light ELP Ultrawide Fisheye Camera Module** with a working horizontal FOV of 141° is used to pilot the ROV and track the gantry position. It was chosen for its excellent image quality and minimal processing load on the onboard computer. It is located in the center of *Conduit*'s acrylic hull to maximize **overall visibility**.

An **Arducam 2MP Low-Light USB camera** with a working FOV of 88° is used for a **bird's-eye operational view** when interacting with underwater elements like basket stars (Figure 16). It was chosen primarily for its compact package, allowing it to fit into a custom 32mm external acrylic housing. It is mounted to the top of the PVC frame to minimize its impact on the motion of the gantry or buoyancy arms.

Another **Low-Light ELP Ultrawide Fisheye Camera Module** is used to monitor the tether and reduce the likelihood of getting caught or tangled underwater. It was chosen to maximize overall visibility of the tether while aiding micropile installation so that contact with the micropile does not occur. It is located in the acrylic hull to simplify electrical integration.

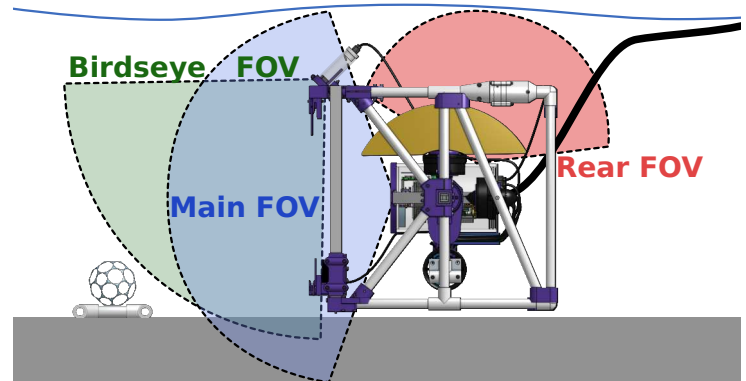


Figure 16: Camera FOV on *Conduit*

Sensors

Conduit is equipped with a **Blue Robotics Bar-02** depth sensor to measure external pressure and temperature. The pressure readings are used to calculate the depth of the ROV, which feeds into the controls for precise operations like flying transects. An **Adafruit BNO055 9-Axis IMU** provides linear and angular acceleration data. It is primarily used to track the ROV's orientation relative to earth's gravity, which enables fixed pitch control with the buoyancy arms.

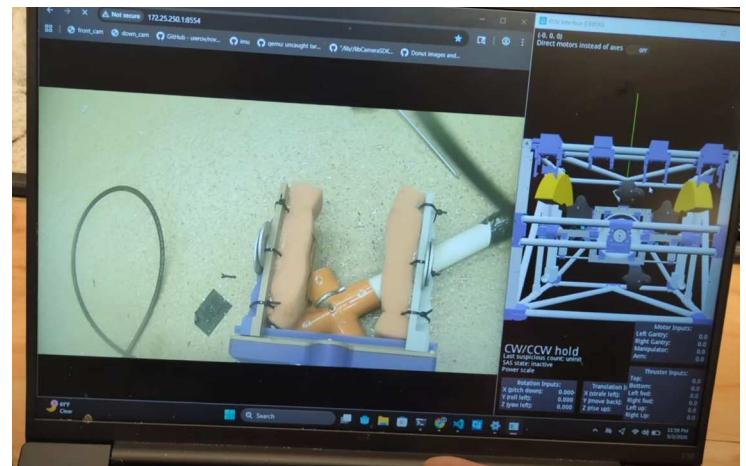


Figure 17: Bird's-eye Camera FOV in controls interface

Dual Axis Gantry

The dual axis gantry allows the modular manipulator interface to move in a 2D plane. This system is highly inspired by **CORE XY** 3D printer designs and uses a **belt differential system** to move. Rotating two motors on a belt path in either the same or opposite directions allows the tool head in the center to move anywhere within a 2D plane (*Figure 18*).

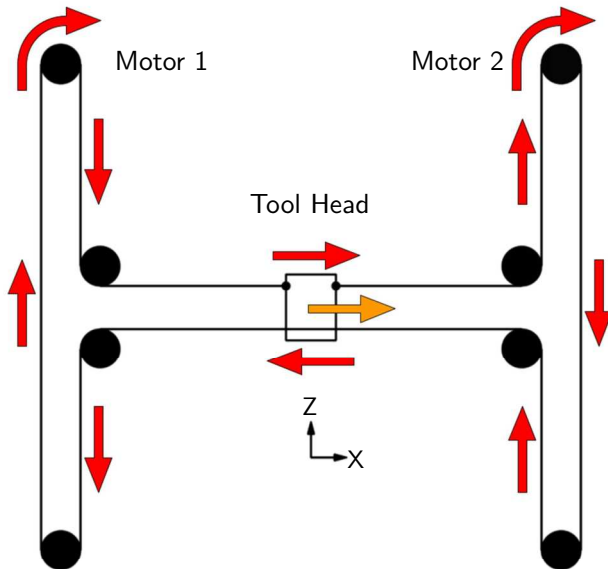


Figure 18: Belt Diagram of Dual Axis Gantry

This belt layout was chosen primarily to decrease the inertia of the tool head; having both motors fixed to the frame makes the system lighter and more responsive. Additionally, using a **single belt** for both axes means the motion system takes up less space and is easier to shield. All sprockets and idler bearings are fully housed within either structural frame pieces or the sliders that run within the aluminum C-channels on either side. This covers all potential pinch points, mitigating risk of injury when handling the ROV.

One of the major benefits of a gantry motion system over a more traditional multi-axis arm is that it is more easily trackable and controllable. The gantry is constrained to moving on a plane, which makes the control system very intuitive and easy to implement. Additionally, it allows the ROV to determine the position of the tool head using **AprilTags**. The cost of using additional sensors, such as rotary encoders, to track the position of the tool head would have been much greater than using existing cameras. This opens up the potential for the gantry to be controlled without pilot input.

The gantry also allows the ROV to change between onboard tools. **Four tool hubs** at the top of the gantry (*Figure 19*) can each store a unique tool. These tools are retained by **latches** on the tool head and a **ball detent mechanism** on the tool hubs, which hold them in place until actuated by the tool head. To use a manipulator, the tool head enters the tool hub, causing the latches to disengage. The tool head attaches to the manipulator, pulling it from the ball detent mechanism. When storing a manipulator, the tool head is

moved to a tool hub, attaching the manipulator to the ball detent. The tool head is then free to disengage and pick up a different manipulator. This new system is a significant upgrade to the key latch system used on *Boxfish 2.0*, no longer requiring a human operator to exchange tooling. Having four tools on *Conduit* allows the vehicle to perform multiple distinct actions without returning to the surface. For example, *Conduit* can attach a recovery line to the buoy anchor and install the new eDNA sensor in a single trip by equipping both manipulators required for those tasks at once, or retrieve all four coral species and basket star samples in a single descent.

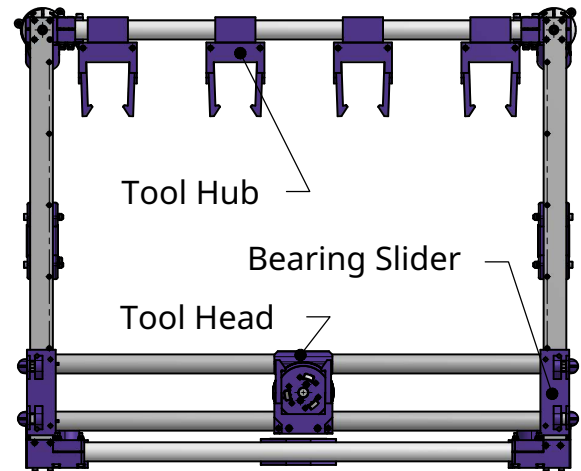


Figure 19: Full Gantry Assembly

A **drill chuck** inspired design (*Figure 20*) is used to engage with rotating adapters on the tools, allowing different manipulators to be actuated. As the tool head enters the tool hub, the upper face of the tool hub clamps down on the outer ring of the drill chuck system. This allows the chuck jaws to emerge and clamp down on the manipulator. Rotating the motor clockwise causes the jaws to clamp down, while rotating counterclockwise causes them to disengage.

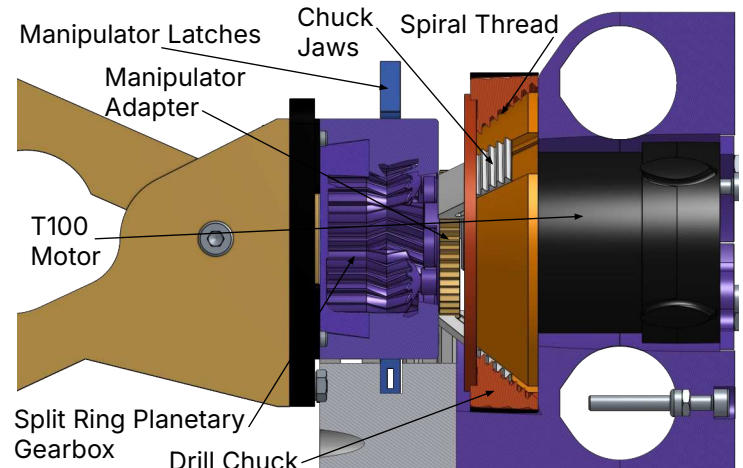


Figure 20: Detail View of Drill Chuck Mechanism

These systems give *Conduit* significantly more precision when completing underwater tasks, as well as allow it to complete missions much faster due to decreased surface trips.

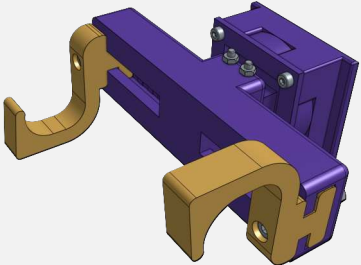
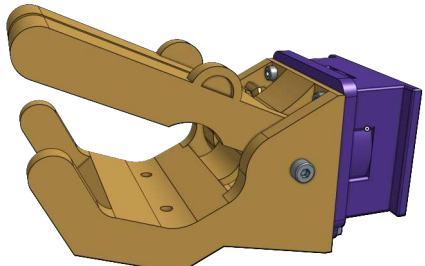
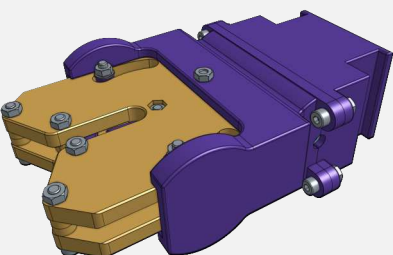
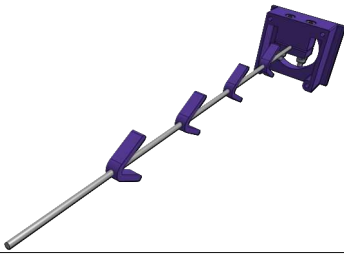
Manipulator Design

13

Conduit is designed to work with **five interchangeable manipulators** (Table 9) able to perform all physical tasks specified in the MATE RFP. *Conduit's* modular manipulator system is compatible with both dynamic and static manipulators. Dynamic manipulators achieve independent motion through a high reduction ratio gearbox driven by a brushless motor. UWROV designed the gearbox to have a 42:1 gear reduction, be fully 3D printable, and open-sourced it to the MATE community.

Static manipulators do not move relative to the ROV, and instead take advantage of the gantry system and the ROV's agility to align and maneuver props. Multiple modular static and dynamic manipulators can be pre-installed in the tool-exchange interface, allowing *Conduit* to be equipped with all necessary manipulators for different MATE RFP task environments without needing to resurface.

Table 9: Manipulator designs

CAD Model	Image	Description
		"Cookiecutter Shark" Dual claws spin the handle of the observatory to clean the camera. Clockwise rotation securely latches the two hooks onto the handle, transferring torque. Counterclockwise rotation easily disengages the manipulator for resurfacing. <i>Used in task 2.5 of the MATE RFP</i>
		"Whale Shark" Stable vertical claw lined with foam to protect handled objects. The thickened body and specialized jaws shape allow the manipulator to support the weight and round handle of the lobster pot and T-shaped eDNA sensor. <i>Used in tasks 2.3 and 2.5 of the MATE RFP</i>
		"Goblin Shark" Detachable clamp mounted to a housing on the ROV connected via fishing line. The clamp is designed to detach when secured around a U-bolt, serving as a recovery line to retrieve the buoy anchor. <i>Used for task 2.4 of the MATE RFP</i>
		"Sawshark" Bendable steel rod with inward pointing TPU barbs slide into crevices in the basket star easily but prevent outwards slipping until the ROV resurfaces. <i>Used for task 1.1 of the MATE RFP</i>
		"Basking Shark" Parallel motion horizontal jaws powered by a rack and pinion aid in handling items of variable shape up to 118 mm in diameter. Foam to protect both the target items and claw parts is optimized through an in-house trade study. <i>Used for all other tasks</i>

Float Design

NanoFloat 2.0, UWROV's profiling float for 2026, was designed with the 2026 MATE RFP in mind (*Figures 21, 22, 24*) **NanoFloat 2.0** excels at **efficient profiling and remote transmission of data** as part of **Task 4 of the MATE RFP: MATE Floats Under the Ice** of the MATE RFP. Its design revolves around its operational simplicity, unique custom software, and task execution consistency even in extreme conditions.

From antenna to fully extended piston, *NanoFloat 2.0* has a length of 280.35 mm and a weight of 1.54 kg. *NanoFloat 2.0* is equipped with two custom-machined endcaps that fit on an acrylic hull with two threaded rods. The float contains a universal mounting plate that holds all components, including a Printed Circuit Board (PCB), battery, motor, piston and strain relief clips.

NanoFloat 2.0's buoyancy engine consists of a machined **6061-T6 aluminum piston** that extends and retracts from the hull using an N20 DC motor, thus completing vertical profiles by changing the internal volume with a displacement-volume ratio of **0.027:1**. The piston material was chosen for its low cost, easy machinability, corrosion resistance, and high density. A limit switch in the form of a FSM4HJ tactile switch is placed to prevent over-retraction of the piston and, in turn, internal flooding of the hull.

The central **Seeed Xiao ESP32-C6** microcontroller controls the operation of *NanoFloat 2.0*. It is flashed with the custom firmware, *nanOS*, which delivers all core profiling float functions condensed into a profiling mission function. After deployment, the user activates this function by sending a start command from a surface 915MHz radio receiver to the onboard 915MHz transmitter.

The ESP32-C6 microcontroller controls the depth of the float using a combination of motor encoder counts, depth, and pressure data from the sensor. This allows *NanoFloat 2.0* to make buoyancy changes, and depth holds at two distinct depths to collect data, by course-correcting its position. The ESP32-C6 microcontroller also communicates with the **Blue Robotics Bar-30 sensor** over the I2C bus to receive depth and pressure data. It then transmits this data, along with a timestamp and a company number, to the surface via both **915MHz radio and WiFi transmission**.

NanoFloat 2.0 is powered entirely from a **6-volt DC NiMH internal battery pack** made up of **5 1.2-volt AA batteries** paired with a **1A fuse**. These specifications remain under the 2.0A maximum restrictions for NiMH AA batteries (*Figure 23*). Individual components have been tested for maximum current draw, which helped confirm 1A as the appropriate fuse with a 92% safety factor. *NanoFloat 2.0* is built with parts optimized for cost and performance for **under \$130**.

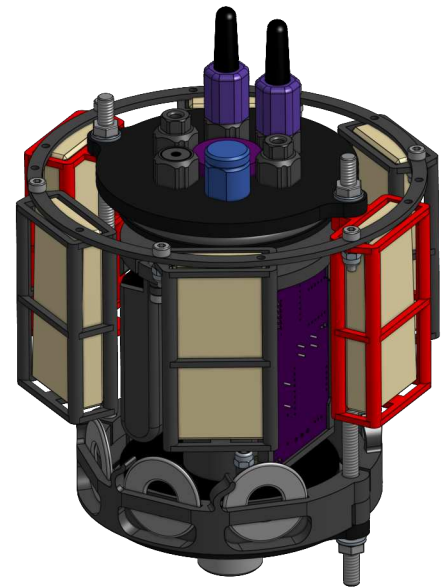


Figure 21: *NanoFloat 2.0* Onshape CAD

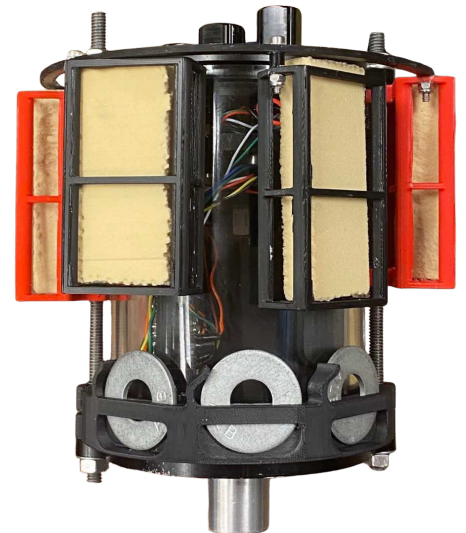


Figure 22: *NanoFloat 2.0* Assembly

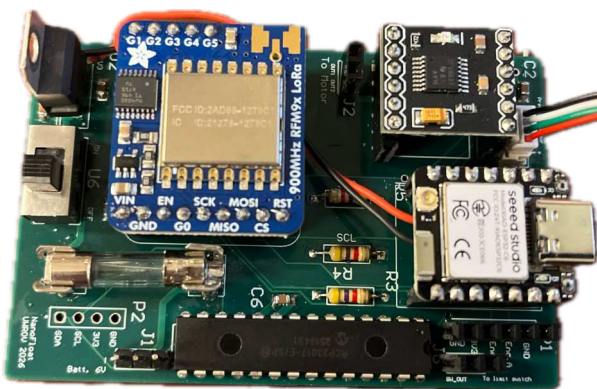


Figure 23: *NanoFloat 2.0* PCB & Fuse

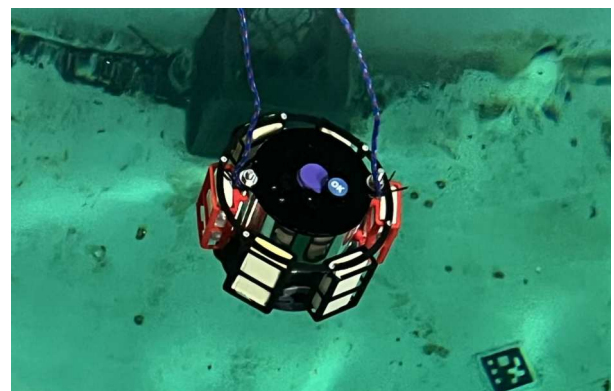


Figure 24: *NanoFloat 2.0* in Saltwater

Build vs. Buy, New vs. Used

Conduit is developed completely from the ground up. In order to maintain a functional test platform for software, tools, and mission strategy, no components were taken off of last year's vehicle (*Boxfish 2.0*). Leveraging surplus components accumulated over the last decade coupled with a design focus on using materials available on-hand (Aluminum boxtube, 1/2" PVC, 3D printing filament, etc), the development cost of creating a whole second ROV was drastically reduced.

In general, UWROV purchases components when development complexity exceeds in-house capabilities. UWROV reuses systems when they meet existing requirements and are not a performance bottleneck. For the 2026 MATE Competition, UWROV established a core vehicle concept targeted towards deployment in a flume environment and precise operations in wind and waves, optimizing for cost and performance.

Table 10: Reused Purchased UWROV Systems

System	Justification (Outsourced, Reused)
Blue Robotics Thrusters	Meets requirements: Provides sufficient thrust and maneuverability for MATE RFP tasks, including maintaining position in flume and navigating around coral gardens.
Surface Station	Meets requirements: Handles control inputs, communicates with ROV via tether, adequate display, compute power for automatically building photogrammetry models, recognizing invasive species.
Raspberry Pi 4	Meets requirements: Compute, power draw, systems control, supports camera & data streaming.

Table 11: Reused Custom-built UWROV Systems

System	Justification (In-house, Reused)
Thruster Guards	Meets MATE RFP requirement MECH-006: IP2X rated, low drag, compatible with B.R. thrusters.
Manipulator Gearbox	Meets requirements: Modular interface for tools from current and previous seasons, adequate gear reduction to adapt high-speed brushless motors for lower-rpm applications like clearing biofouling.

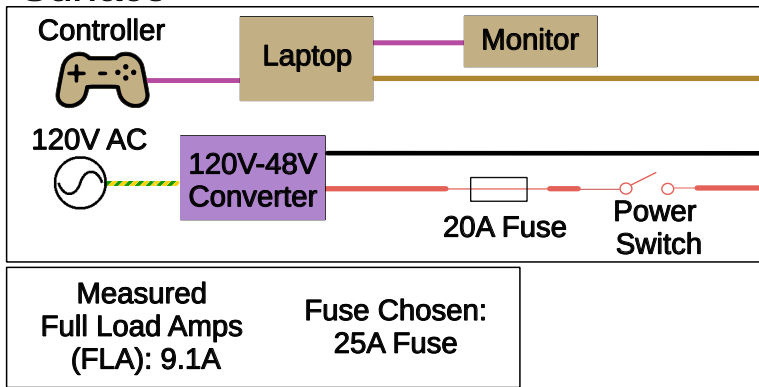
Table 12: Newly Purchased UWROV Systems

System	Justification (Outsourced, New)
USB Cameras	Cameras are required for RFP tasks like crab recognition and photogrammetry. UWROV did not have enough surplus cameras for <i>Conduit</i> . Currently manufacturing cameras exceeds the team's capabilities.

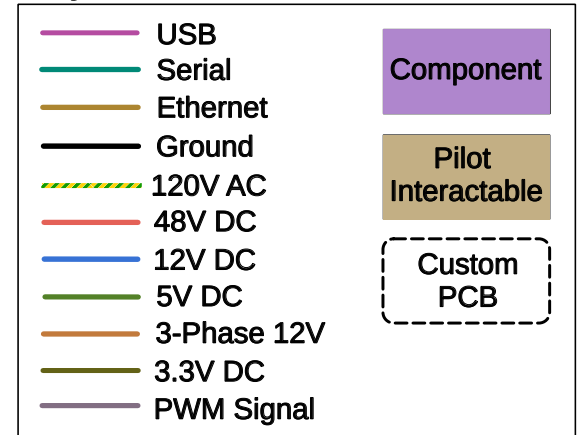
Table 13: New Custom-built UWROV Systems

System	Justification (In-house, New)
Pressure Hull	Meets MATE RFP requirement MECH-001 for mission depth. Manufacturing in-house is cheaper and offers more internal space than commercial solutions.
Electrical Mainboard ESC Daughterboards	Meets mission requirements for power distribution. Simplifies internal wiring and aids in debugging. Custom breakout PCB increases modularity, simplifies troubleshooting, reduces number of wires.
48V-12V module	Meets MATE RFP requirement ELEC-003E for voltage & power. Custom breakout PCB offers greater electrical protections, improves serviceability, aids debugging.
Frame	Meets structural requirements. Uses materials available on-hand to reduce development cost.
Bumper System	Meets MATE RFP requirement MECH-007 for protecting environment and users from sharp edges. Bumper design is specialized for <i>Conduit</i> 's custom frame geometry.
Gantry System	Meets MATE RFP requirement MECH-008 for shrouding, increases pilot dexterity for collecting coral samples, interacting with whale-safe fishing gear, and performing maintenance on offshore systems.
Buoyancy Arm	Meets mission requirements for stable operation at various orientations and conditions (e.g. flume). Such systems are not currently available off-the-shelf and necessitate in-house development.
Tool Interface	Onboard tool changing enables swapping of specialized manipulators for every MATE RFP task.
Manipulators	Specialized tools improve consistency and speed in tasks like coral and basket star sampling, recovery line deployment, and installing micropiles.
Tether	Meets MATE RFP requirements ELEC-009E, ELEC-015E for current, voltage, serial communication. Manufacturing in-house allows more control of tether length for MATE RFP requirement MECH-003E.
Float	Meets MATE RFP Task 4.1 requirements for buoyancy engine specifications, mission depth, size constraints. Meets MATE RFP requirement ELEC-NRD-001, ELEC-NRD-003, ELEC-NRD-004 for onboard power, battery composition, fusing. Meets MATE RFP requirement ELEC-NRD-006 for pressure relief.

Surface

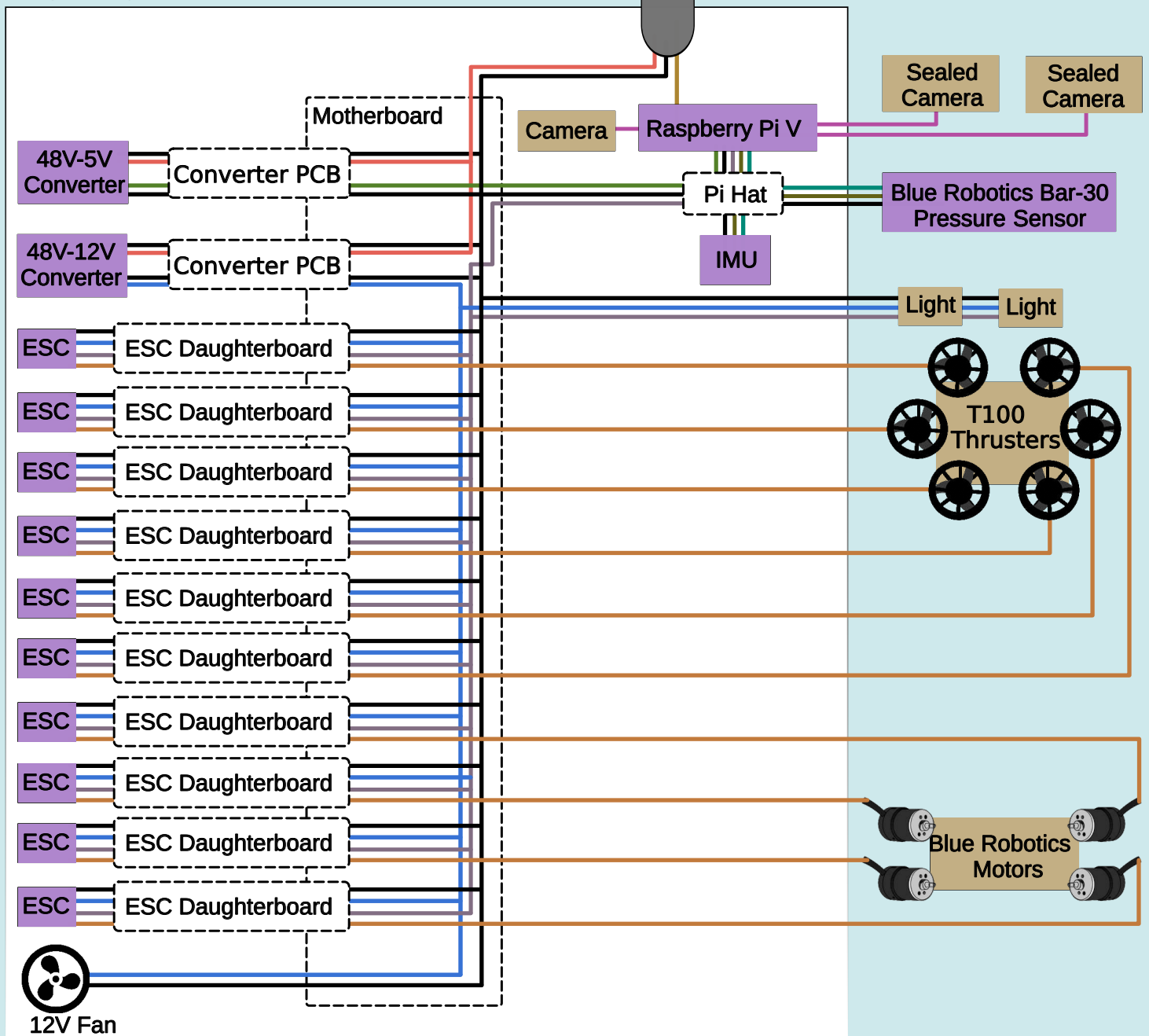


Key

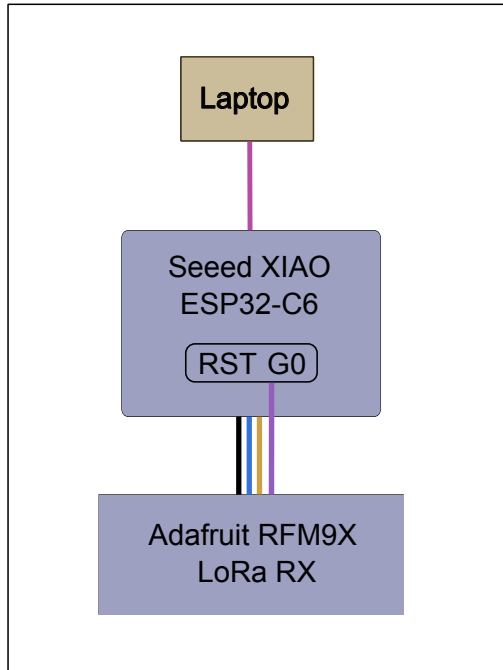


In-Water

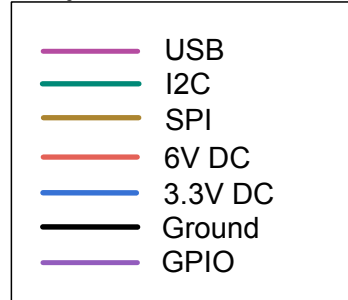
ROV Hull



Surface



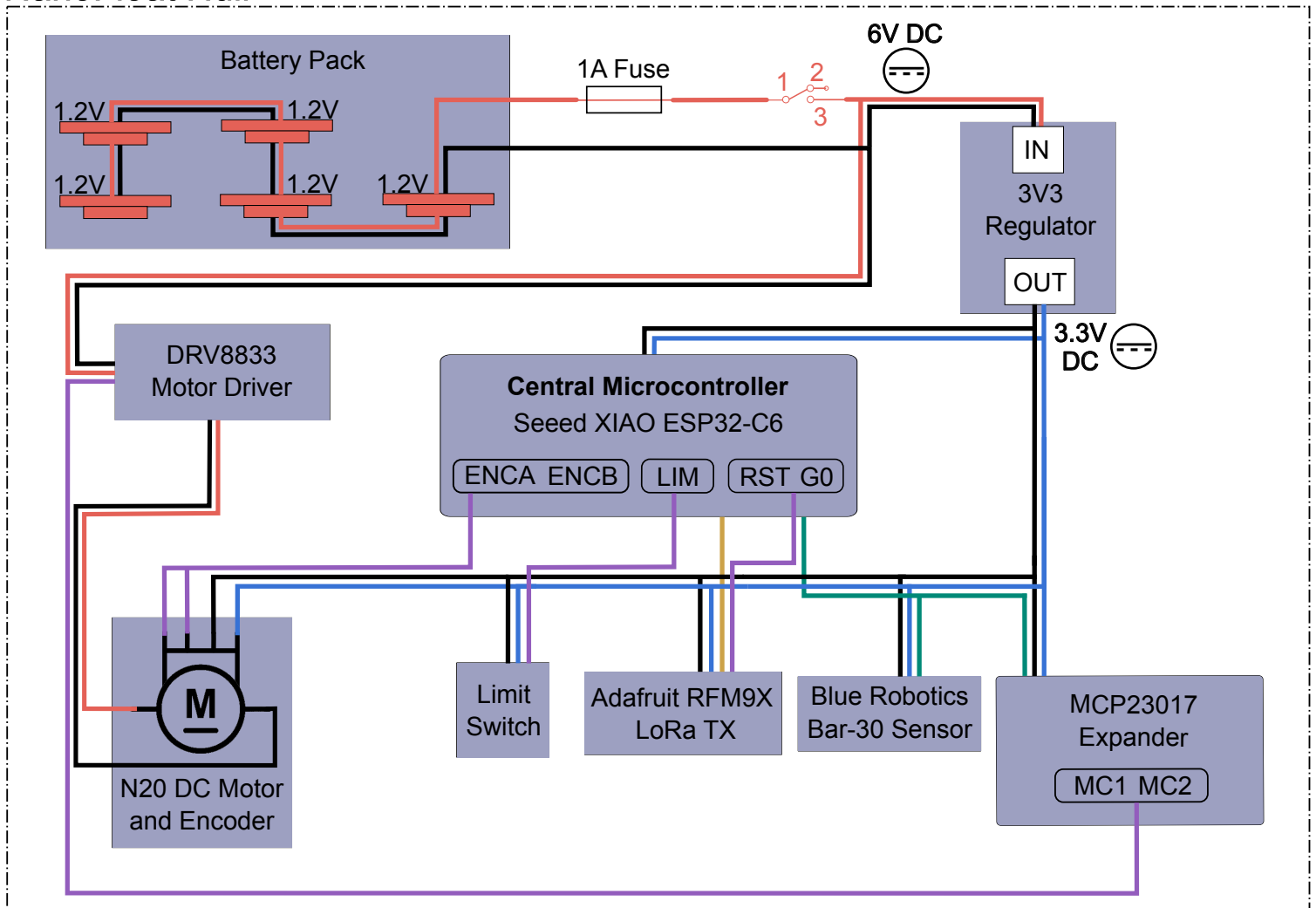
Key



Fuse Calculations

Max stall current from motor: 320 mA
 Max stall current through XIAO ESP32-C6 with sensor: 80 mA
 Max stall current through LoRa RFM9x radio with sensor: 120 mA
 Total max current during buoyancy change: 520 mA
 Total max current during waiting mode: 200 mA
 Fuse: 1A
 Safety factor: 92%

NanoFloat Hull



Safety

UWROV's safety philosophy is to **mitigate risks** long before unsafe situations occur. Personnel and equipment safety are highly prioritized due to an influx of new employees with little to no experience with engineering equipment. Within UWROV's leadership team, **safety oversight is shared**



Figure 25: PPE Worn During Testing

among all leads, each ensuring that employees associated with their area of interest learn and comply with safety standards set forth by the team and local regulations.

Personnel Safety

Before using the fabrication shop, all employees undergo **mandatory shop safety training**. This training covers safe usage of hand tools, safety equipment location (first aid kits, fire extinguishers, eye showers), accident procedures, required PPE and shop attire (safety glasses, closed-toed shoes, etc.), chemical storage locations, and emergency contacts. In order to use power tools, such as a drill, bandsaw, lathe, bench grinder, and miter saw, employees must undergo **one-on-one, live training with an experienced lead**. This includes training, a written exam that covers the different parts of the tool and operational procedures, and a practical exam where the employee demonstrates their proficiency with the tool.

Equipment Safety

Preventive safety measures surround the design development of *Conduit*. By making hazards visibly clear to employees and eliminating dangerous features and surfaces, UWROV upholds its commitment to safety. Sharp edges or corners of the frame have been filed down or covered with soft bumpers to prevent injury to users and the environment. *Conduit*'s thrusters are covered by **custom 3D-printed IP2X compliant thruster shields** to avoid employee harm during ROV operations and prevent cables from being caught in the thrusters. To ensure safety in the gantry system, all moving belts are routed inside structures and are covered by IP2X compliant shielding. Thruster shields and other 3D-printed components designed by UWROV are **open-source**, with many other MATE ROV teams also utilizing the team's designs.

There are **no exposed electrical connections** within the pressure hull; electrical connections are done through enclosed connectors and spliced wires that are twisted together before soldering. Compared to *Boxfish 2.0*, more electrical connections in *Conduit* are in the form of a Printed Circuit Board (PCB); this prevents loose connections and other errors, as wires are internal within the PCB instead of being directly soldered to components. Additionally, an internal fan in the pressure hull circulates air to prevent the formation of

hotspots, making the internals safer to handle. Air circulation also decreases the risk of thermal damage to sensitive components, ensuring safe electrical operations within the hull. The tether is protected from damage through a braided cable sleeve, along with tether strain relief on the ROV and surface station. To ensure the ROV does not leak during deployment, UWROV's standard operating procedure includes pulling a vacuum on the pressure hull if it has been opened since the last deployment. Utilizing a custom-built 12V vacuum pump with **<0.25mL/min bleed rate**, the hull is pulled to at least -50kPa (pressure differential equivalent to a 5 meter depth underwater) and observed for at least 10 minutes (*Figure 26*). A 2% drop in vacuum over 10 minutes indicates a leak and pre-deployment is immediately halted to locate and fix it.

$$Q_{std} = \frac{V}{\Delta t} \cdot \frac{\Delta P}{P_{std}} = \frac{1.824L}{3600s} \cdot \frac{800Pa}{101325Pa} = 0.24mL/min$$

Figure 26: Hull Internal Pressure Bleed Rate Calculation

Operational Safety

UWROV identified potential hazards during ROV operations in a **Jobsite Safety and Environmental Analysis (JSEA)** and implemented operational checks to mitigate potential risks. Examples include ensuring proper restraint of tools and equipment, clamps on materials being manipulated, and removing loose debris in or around the ROV. The built-in questions in the surface station software upon booting up remind employees to ensure proper safety procedures during operation, such as verifying if the thrusters and thruster guards are secure. When deploying in the testing facility on-site, UWROV members are required to wear **Personal Flotation Devices (PFD)**, remove all loose objects, and maintain a clean, hazard-free environment (*Figure 25*).

When operating in cold or icy conditions, all employees are required to wear **warm, protective clothing**. Ensure that contact with cold water stays under 15 seconds and that clothing items do not come into contact with cold water and cause heat loss. Employees must monitor their and their coworkers' physical conditions [13]. In case of waves, **water-sensitive electronics must be elevated above ground level**. Tether manager must ensure **tether management is orderly** and untangled from both objects and individuals.

UWROV's safety considerations during ROV deployments ensure the **safety of the environment**. Hard safety cut-offs, stability software, and precise movements are utilized when handling fragile samples, servicing subsea observatories, and navigating delicate habitats like coral gardens.

Safety Procedures

UWROV's safety procedures minimize the potential for accidents to occur while assembling and deploying the ROV. The safety procedures have been drafted, reviewed, and confirmed by dedicated safety personnel under two documents [see [Appendix A: Safety Checklists](#) and [Appendix B: Lab Safety Policy](#) for ease-of-use by UWROV employees.

Critical Analysis

UWROV employs a **data-driven** engineering approach to designing, testing, and troubleshooting. This season, *Conduit* was tested in-water for **over 40 hours**.

When testing the vehicle in a pool environment, recordings from onboard camera streams, pilot feedback, and vehicle operation recordings from the surface are used to make the most of limited pool availability. When testing outside the water, a variety of strategies are combined with diverse tools. Below are three case studies in different systems that underwent extensive prototyping, troubleshooting, and testing.

Onboard Power

UWROV has historically experienced power converter crashes, despite theoretically being well under their power budget. UWROV hypothesized that the **transient load** during motor start triggered **overcurrent** protections and that switching motor directions produced enough back EMF to trigger **overvoltage** protections. A test environment was designed with two submerged thrusters in a bucket and an oscilloscope measuring the 12V supply current (*Figure 27*) through a 3.7 mΩ resistance wire inline with the main 12V power output.

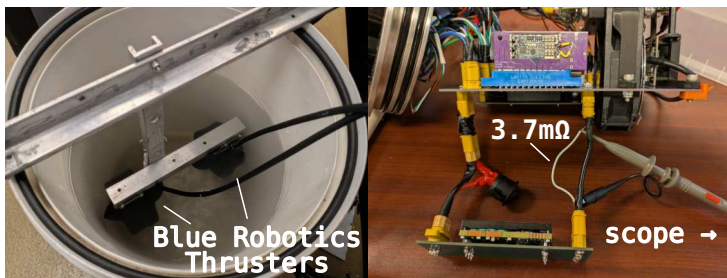


Figure 27: Bucket + Scope Test

Using the test data, the transient power consumption was calculated, and a **capacitor bank** with inrush limiting was designed and integrated into the power converter PCB. After measuring the voltage across the converter and 12V bus with the protective circuit in between, the loads on the converter (*Figure 28*) decreased. The lower plots graph the voltage at the ESCs, showing a 1.4V drop during motor startup, a 1.2V increase due to back EMF, with spikes up to **7.5V above nominal**. The upper plots show a decrease in load on the converter in overcurrent and overvoltage conditions; a voltage drop of 0.3V during startup (78% reduction), a 0.4V continuous increase from back EMF (66% reduction), with spikes reduced to 1.3V (82% reduction).

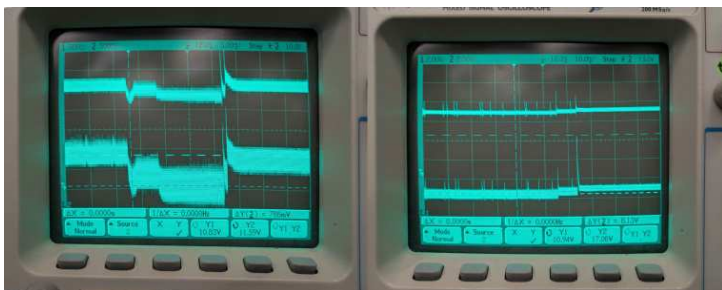


Figure 28: Overcurrent and overvoltage mitigation

Hull

19

Conduit's hull underwent rigorous design, analysis, and testing before deploying with essential systems onboard. MECH-001 of the MATE RFP lists a 5m operational depth capability for the ROV housing. *Conduit*'s hull was designed to exceed this with a target operational depth **20 times greater**. UWROV validated the design with hydrostatic FEA (*Figure 29*).

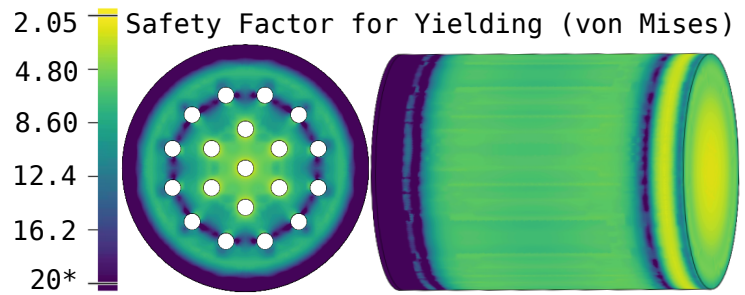


Figure 29: Hull Hydrostatic FEA at 100m Depth

After manufacturing the components in-house, the hull underwent extensive seal testing: With the hull closed, a 50kPa vacuum was pulled and after 10 minutes a drop was observed, indicating air leakage into the hull. To identify the source of the problem, the hull was pressurized to 150kPa, and soapy water was applied to all surfaces that were potentially leaking. This identified two reused Blue Robotics penetrators that were no longer completely sealing. Replacing these penetrators and ensuring the contact surface was completely smooth fixed the issue, and *Conduit* has had no leaks.

Gantry Motion System

Rigidity and minimal friction are essential for the operation of a gantry system. One of the major challenges with *Conduit*'s gantry system was binding, where the gantry would bend on the frame when attempting to lift one side. This caused the gantry to be unable to move. Many variations of wheel-based rollers were designed to keep the gantry rigid, but the frame being made of PVC, was ultimately found to be not feasible due to its flexibility. To combat this, the front sides of the frame were replaced with aluminum C-channels, increasing rigidity and allowing compliance with IP2X standards around the belt. After replacing the PVC with C-channels, a simplified sliding system was tested, but eventually, bearings were used again to reduce friction. A total of **30 unique prototypes** were made (*Figure 30*). Each version was tested by collecting qualitative data on friction when moving and whether it bound up on the frame.



Figure 30: A selection of past gantry sliders and wheels

Budget

Before development began, budgets from the team's past two MATE ROV seasons were compared to actual spending and a high-level budget was created for the current season (*Table 15*). The biggest considerations for the new budget were the high cost of travel (*Table 14*) due to the location of the competition and the research and development required to develop a completely new ROV. Past initiatives such as shop space safety were continued in this new budget; however, allotments were adjusted based on past spending. Although the total budget decreased, additional fundraising was done to offset the lack of available funds from past sponsors as well as increased predicted costs. The team reused tooling, equipment, and materials whenever possible to minimize cost. UWROV received a large donation from the Student Technology Fee (STF) at the University of Washington to purchase tooling and electrical equipment.

To ensure that the team kept to the proposed budget, information on every purchase, such as reasoning and other options considered, had to be presented to the CEO, CAO, and CTO for approval. Without this approval, UWROV's money could not be spent. This system ensured that the team stayed on budget and kept leadership aware of purchases. A full breakdown of the project costing can be found in *Appendix D: Cost Accounting*. The only budget category that was not closely followed was Team Operations, as shirts from last year's season had to be purchased during this season, summing to double the anticipated cost of shirts. Even so, the budgeted amount was not significantly exceeded and the total spending is below the amount allotted.

Table 14: Costing for world championship travel

Category	Description	Cost (USD)	Qt.	Subtotal
Airfare	Reimbursement per employee	\$300.00	10	\$3000.00
Lodging	Lodging rental, total (Dorms)	\$3344.50	1	\$3344.50
			Total:	\$6344.50

Table 15: Comparisons of previous annual budgets and this season's spending (all in USD).

Category	Description	2023-2024 Allocation	2024-2025 Allocation	2025-2026 Allocation	2025-2026 Spending
Shop Safety	Items used for shop safety.	\$200.00	\$200.00	\$200.00	\$59.60
Tooling & Equipment	Items used in the lab for fabrication, designing, etc. Includes replacement parts or supplies.	\$1,000.00	\$500.00	\$600.00	\$204.44
Research and Development (R&D)	Prototypes and materials used in UWROV's iterative design process.	\$3,000.00	\$3,000.00	\$3,000.00	\$1,233.08
MATE ROV Surface Station	Items used for the surface side portion of the MATE ROV.	\$1,600.00	\$150.00	\$100.00	\$15.99
MATE ROV Structure	Items used for the MATE ROV frame, tether, and pressure hull.	\$1,600.00	\$150.00	\$400.00	\$335.38
MATE ROV Power Electronics	Items used for the internal electronics of the MATE ROV, including sensors, power converters and more.	\$2,500.00	\$700.00	\$800.00	\$515.71
Float	Materials, electronics, and more used on the Float.	\$700.00	\$500.00	\$500.00	\$101.75
Team Operations	Items used to run the team. Includes team branding and subscriptions.	-	\$500.00	\$1,000.00	\$1,661.93
Competition Logistics	Shipping costs for checking in luggage with the ROV.	\$350.00	\$350.00	\$400.00	\$89.19
Competition Fees	Registration fees for the MATE ROV Competition.	\$500.00	\$475.00	\$675.00	\$650.00
Competition Travel	Transportation and lodging for the MATE ROV Competition.	\$10,000.00	\$10,000.00	\$8,000.00	\$4,360.51
	Total	\$21,450.00	\$17,025.00	\$15,675.00	\$9,227.58

Acknowledgements and References

Acknowledgements

UWROV's operations would not be possible without support from its sponsors. The team is incredibly grateful for the help and support it has received this year, and thanks the following organizations and people for their contributions:

- Many thanks to MATE II for the organization of the MATE ROV competition and creation of opportunities for students to learn, design, and build ocean technologies,
- Rick Rupan and Alnis Smidchens for their mentoring and guidance of UWROV,
- The University of Washington School of Oceanography, Sam Drucker, and Sasha Seroy for laboratory/classroom space and support,
- The Applied Physics Laboratory at the University of Washington and Marine Technology Society for the continued guidance and support,
- Andrew Meyer for oversight of UWROV's lab space, machining guidance, and technical support,
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- Spokbee and Olis Robotics for financial support,
- and the UW Student Technology Fee for financial support.

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Appendix A: Safety Checklists

ROV Construction:

Disassembly:

- ☐ Outside of ROV and work surfaces are completely dry.
- ☐ Work surface is free from debris, including metal shavings, hair strands, dirt, and equipment.

Before Closing ROV Hull:

- ☐ Ensure no wires are disconnected or loose, and no wire conductors are exposed to avoid electrical hazards
- ☐ The pressure hull has no clouding or cracking, and the inside of the pressure hull is completely dry.
- ☐ O-rings & grooves are clean, undamaged, and lubricated (no hairs, dirt, or metal shavings).
- ☐ No wires are pinched between components or the walls of the pressure hull.
- ☐ Remove pressure vent plug to avoid pressure build-up while closing.

While Closing ROV Hull:

- ☐ Align backplate end cap with main cylinder. Maintain alignment during the entire closing process.
- ☐ Check that tether wires are oriented at the top of the backplate.
- ☐ Use a vacuum pump attached to the pressure vent to pull the backplate endcap onto the ROV.

After Closing ROV Hull:

- ☐ Insert pressure vent plug and verify it is screwed all the way in.
- ☐ Internal assembly is horizontally level.
- ☐ Endcap is flush with the main cylinder.
- ☐ Visually verify that all O-rings form a complete seal.
- ☐ Pressure hull retaining arm is raised.
- ☐ Verify strain relief is attached.

ROV Operation:

Pre-Deployment:

- ☐ There are enough company employees present to safely operate the ROV (at least one Operations Director, Pilot, and Poolside Tether Manager).
- ☐ There is no damage in the ROV frame or pressure hull (watch out for clouding & cracks).
- ☐ Clear the poolside of all loose objects and debris.
- ☐ All ROV attachments (thruster shrouds, buoyancy and ballasting elements, thrusters) are secure.
- ☐ There are no loose connections in the pressure hull.
- ☐ Ensure the tether is laid out neatly without tangling, and away from common walkways.
- ☐ Power supply is completely dry and away from the side of the water to avoid electrical injury.
- ☐ Surface station tether strain relief carabiner is attached to a rigid structure.
- ☐ Surface station laptop is plugged in, powered on, and connected to ROV.
- ☐ All personnel are wearing PFDs, close-toed shoes, safety glasses, no loose clothing, and long hair is tied back.
- ☐ Recovery equipment (pole, net, etc.) handy.
- ☐ Control center and tether staging area are clear of clutter and tripping hazards.

Pre-Initialization:

- ☐ Ensure no parts have come loose from the ROV.
- ☐ Verify that all connections are secure to avoid damage to the ROV or electric hazards.

Deployment:

- ☐ ROV Handler exchanges tools and payloads on ROV.
- ☐ Pilot announces "READY FOR HANDS ON".
- ☐ ROV Handler lifts ROV by its frame and announces "HANDS ON", and holds it in the water in the deployment zone.
- ☐ Pilot announces "READY FOR HANDS OFF" when ROV state has stabilized based on cameras & data.
- ☐ ROV Handler releases ROV and announces "HANDS OFF" when no longer touching the ROV.

During Operation:

- ☐ Poolside Tether Manager is following designated tether management protocols to prevent entanglement.
- ☐ Operations Director is facilitating communication between poolside and surface side.
- ☐ To minimize the risk of tripping, do not run near the pool.

Resurfacing After Operation:

- ☐ Pilot navigates ROV to launch & deployment zone, then announces "READY FOR HANDS ON".
- ☐ ROV Handler picks up the ROV by its frame, then announces "HANDS ON".

Post-Deployment:

- ☐ If ROV was deployed in saltwater, thoroughly rinse or submerge in freshwater to prevent corrosion on the ROV.

Appendix B: Lab Safety Policy

1. Never work in the fabrication shop without lead supervision
2. Wear lab-appropriate clothing at all times in the lab: safety glasses or side-shields; close-toed, no-slip shoes; gloves (never when working with rotating/moving machinery); no loose clothing; no rings, watches, or bracelets; long hair must be tied back.
3. All injuries or accidents must be reported **immediately** to a lead and Shop Supervisor.
4. If you are in doubt as to a proper or safe procedure, **stop work** and ask for guidance.
5. Report unsafe or hazardous conditions wherever noted. Correct them if possible.
6. Eating or drinking is prohibited in lab spaces.
7. Be thoroughly knowledgeable concerning the equipment you are using.
8. Use tools for their intended purposes only.
9. Do not use fingers or hands to remove chips from moving or stationary machines; use dustpans and brooms.
10. Never adjust a moving or rotating machine unless motion is necessary to make adjustments. Always allow the machine to come to a standstill before making adjustments or repairs.
11. Never leave a machine running while unattended, unless machinery is intended to do so.
12. Do not attempt to slow down or stop rotating moving equipment with hands or tools.
13. File or deburr all machined parts or stock with sharp edges.
14. Always clamp or secure the workpiece properly.
15. Use appropriate respiratory protection when working with dusts, mists, fumes, or vapors.
16. Read the Safety Data Sheet (SDS) for all lubricants, resins, adhesives, or other chemicals you are working with.
17. Pay attention to what you are doing; cease operations if you are distracted and unable to concentrate.
18. Use proper techniques and obtain assistance when lifting, moving, or carrying loads.
19. Watch for tripping hazards; do not place material or objects in passageways or areas with high foot traffic.
20. Know the location of fire extinguishers, fire exits, eye washes, and first aid kits.

Adapted from the UW Mechanical Engineering Machine Shop Rules [14].

Appendix C: Efforts to Design and Manufacture Every Component

The digital twin of ROV *Conduit* includes internal wires and foam modeled in parametric CAD to ensure clearances, leveraging **novel custom scripts** written by members to generate complex geometry. Tools are modeled to a level of detail including **zip ties**. Every feasible component was manufactured in-house where possible: buoyancy arm syntactic foam, manual milling and lathe operations, all to tight tolerances. (*Figure 31*)

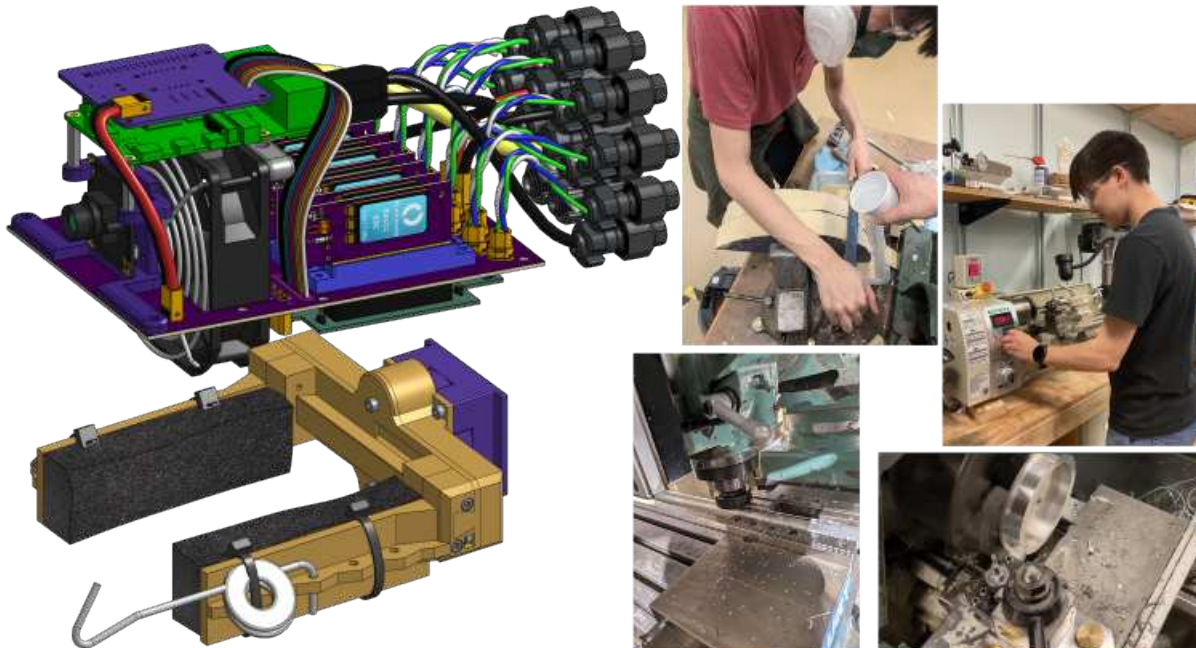


Figure 31: Exemplary CAD modeling of the electronics wiring and the "basking shark" manipulator, and UWROV members manufacturing various parts of *Conduit*

Appendix D: Cost Accounting

Date	Type	Item/Description	Notes/Source	Value*	Balance*
Rollover Balance					
7/1/2025	Rollover Balance		General Fund	4573.29	4573.29
7/1/2025	Rollover Balance		Previous APL Funds	1632.85	6206.14
Income					
7/1/2025	Cash Donated	Award Money	2025 MATE Competition	1000	7206.14
7/1/2025	Cash Donated	Donation	Donation from Spokbee	1350	8556.14
12/24/2025	Cash Donated	Crowdfunding	Fall 2025 Fundraising Campaign	230	8786.14
1/5/2026	Cash Donated	Donation	Funds donated by APL-UW	2000	10786.14
2/14/2026	Cash Donated	Crowdfunding	Winter 2026 Fundraising Campaign	3758	14544.14
4/9/2026	Cash Donated	Crowdfunding	Spring 2026 Fundraising Campaign	795	15339.14
4/24/2026	Cash Donated	Donation	Donation from Olis Robotics	200	15539.14
Shop Safety					
9/18/2025	Parts Donated	Wall-mounted eyewash	Donation from STF	(54.95)	15539.14
9/18/2025	Parts Donated	Latex Gloves for PPE	Donation from STF	(19.98)	15539.14
10/26/2025	Purchased	Mounting Magnets	To mount eyewash	(13.20)	15525.94
10/27/2025	Purchased	Saline Solution	To fill eyewash bottles	(46.40)	15479.54
1/9/2026	Parts Donated	Air Purifier	Donation from STF	(301.11)	15479.54
Tooling and Equipment					
9/18/2025	Parts Donated	Cordless Drill	Donation from STF	(116.75)	15479.54
9/18/2025	Parts Donated	M3 Hex Key	Donation from STF	(6.29)	15479.54
9/19/2025	Parts Donated	2x Prusa CORE One	Donation from STF	(1898)	15479.54
9/19/2025	Purchased	O Ring Lubricant		(12.62)	15466.92
10/27/2025	Purchased	Drill bits		(10.44)	15456.48
10/29/2025	Purchased	M5 Metric tap		(11.02)	15445.46
11/17/2025	Purchased	Replacement Bandsaw Blade		(12.23)	15433.23
11/17/2025	Purchased	3D Printer Bed Springs		(6.07)	15427.16
1/25/2026	Purchased	M4 Hardware		(18.40)	15408.76
2/2/2026	Parts Donated	Miter Saw	Free on Facebook Marketplace	(369.00)	15408.76
2/22/2026	Purchased	Textured Print Bed		(71.81)	15336.95
2/26/2026	Purchased	Acrylic Solvent		(25.41)	15311.54
2/26/2026	Purchased	Acrylic Solvent		(25.41)	15311.54
3/12/2026	Purchased	M2 Screw Set		(11.03)	15300.51
Research and Development					
8/30/2025	Purchased	8mm ID Bearings	Prototype gantry	(10.91)	15289.6
9/28/2025	Parts Donated	ROV Locator Bundle	Donation from STF	(6115)	15289.6
9/30/2025	Purchased	Miniature tape measures		(22.6)	15267
10/16/2025	Purchased	Magnets		(43.95)	15223.05
10/26/2025	Purchased	2kg PLA Filament		(56.28)	15166.77
10/28/2025	Purchased	3mm Bearings		(17.64)	15149.13
11/3/2025	Purchased	Timing belt	For prototype manipulator	(28.95)	15120.18
11/24/2025	Purchased	6kg PLA Filament		(66.78)	15053.4
12/9/2025	Purchased	Joystick	ROV Control Research	(17.64)	15035.76
1/16/2026	Purchased	O-Ball	Props for 2026	(10.48)	15025.28
1/16/2026	Purchased	1/2in PEX tubing	Props for 2026	(5.23)	15020.05
1/16/2026	Purchased	3mm Bearings		(36.66)	14983.39
1/23/2026	Purchased	4mm ID Bearings	Prototype gantry	(10.71)	14972.68
2/5/2026	Purchased	RadCam	Beta Testing Blue Robotics	(500)	14472.68
2/7/2026	Purchased	Ceramic Bearings		(36.4)	14436.28
2/19/2026	Purchased	PLA Filament		(63.6)	14372.68
3/9/2026	Purchased	Nylon Bearings		(24.99)	14347.69
3/10/2026	Purchased	4mm Bearings		(8.83)	14338.86
3/14/2026	Purchased	TPU Filament		(49.74)	14289.12
4/5/2026	Purchased	12 Set Magents	Custom ESC Project	(12.1)	14277.02
4/5/2026	Purchased	22 Copper Wire	Custom ESC Project	(9.71)	14267.31
4/17/2026	Purchased	O-Rings		(7.49)	14259.82
4/20/2026	Purchased	48 to 12V Power Converter	Testing Current Protection	(184.66)	14075.16
4/21/2026	Purchased	1000uF capacitors		(7.73)	14252.09
ROV Surface Station					
9/18/2025	Purchased	Laptop Charger	For Surface Station	(15.99)	14236.1
7/1/2025	Reused	Laptop		(764)	14236.1
7/1/2025	Reused	Game controller		(20)	14236.1
7/1/2025	Reused	Display		(50)	14236.1
ROV Structure					
1/9/2026	Purchased	8mm 6061-T6 Aluminum Rod	Used on Buoyancy Arm and Gantry	(7.51)	14228.59
1/23/2026	Purchased	112T HTD3 Timing Belt	Used on Buoyancy Arm	(21.53)	14207.06
2/1/2026	Reused	1/2" PVC Pipe	8.5m used for frame	(21.51)	14207.06
2/1/2026	Reused	PVC Tees	Four used for Frame	(2)	14207.06
2/1/2026	Reused	1/2 in. PVC Side Outlet	Four used for Frame	(10.32)	14207.06
2/1/2026	Purchased	Fishing Line	Used for Task 2.4 Manipulator	(16.55)	14190.51
2/1/2026	Reused	Carabiner		(0.71)	14190.51
2/1/2026	Reused	Stainless Steel Hardware		(47.8)	14190.51
2/1/2026	Reused	Stainless steel ballast plates	Used on Buoyancy Arm + Frame	(2.2)	14190.51

Continued on next page

Date	Type	Item/Description	Notes/Source	Value*	Balance*
2/6/2026	Purchased	M2 Timing Belt	Timing Belt for Gantry	(48.16)	14142.35
2/7/2026	Purchased	Ceramic bearings	Used on Gantry	(4.85)	14137.5
2/22/2026	Purchased	Strain relief topside		(17.12)	14120.38
2/24/2026	Purchased	Aluminum Backplate Stock	Machined in house	(13.56)	14106.82
2/27/2026	Reused	Acrylic tube for pressure hull		(105.5)	14106.82
2/27/2026	Reused	Acrylic frontplate		(18)	14106.82
2/28/2026	Reused	8x Penetrators		(130)	14106.82
2/28/2026	Purchased	8x Penetrators		(130)	13976.82
2/28/2026	Purchased	3x Penetrator blanks		(18)	13958.82
2/28/2026	Reused	OK Plug		(12)	13958.82
3/9/2026	Purchased	Aluminum C-Channel		(12.55)	13946.27
3/9/2026	Purchased	Aluminum C-Channel	Used on Gantry	(12.55)	13933.72
3/27/2026	Purchased	Nylon Bearings	Used on Gantry	(2.4)	13931.32
4/8/2026	Reused	Syntactic foam	Used on Buoyancy Arm	(438.75)	13931.32
4/9/2026	Reused	Strain relief bottomsides		(17.12)	13931.32
4/26/2026	Purchased	Aluminum Tube	Used on Gantry	(30.6)	13900.72
5/1/2026	Reused	Camera Pressure hull		(18.67)	13900.72
5/1/2026	Reused	Camera Pressure hull backplate		(2.76)	13900.72
ROV Power Electronics					
9/19/2025	Parts Donated	Raspberry Pi 5	Donation from STF	(123.495)	13900.72
10/26/2025	Parts Donated	2x Underwater Lights	Donation from STF	(350)	13900.72
10/28/2025	Parts Donated	Bar02 Pressure Sensor	Donation from STF	(82)	13900.72
10/30/2025	Parts Donated	10x ESC	Donation from STF	(418)	13900.72
1/22/2026	Purchased	Motherboard		(55.62)	13845.1
1/26/2026	Purchased	10x esc daughterboard		(26.7)	13818.4
2/1/2026	Reused	10x T100	Thrusters, Buoyancy arm, Gantry	(990)	13818.4
3/4/2026	Purchased	USB: TTL Cable	Electronics bay	(12.99)	13805.41
3/30/2026	Purchased	Fathom 8-wire ethernet (15m)	Tether	(147.68)	13657.73
3/31/2026	Purchased	Pihat PCB		(9.59)	13648.14
4/2/2026	Purchased	Low light USB Camera	Top cam	(56.37)	13591.77
4/9/2026	Reused	10g power cables (30m)	Tether	(53.99)	13591.77
4/9/2026	Reused	Ethernet Extender	Tether topside	(5.495)	13591.77
4/9/2026	Reused	Anderson Powerpole	Tether topside	(10.13)	13591.77
4/9/2026	Reused	Littelfuse	Tether	(7.99)	13591.77
4/9/2026	Reused	22 gauge wire (1m)	Electronics bay	(1.06)	13591.77
4/12/2026	Reused	5v power converter		(41.08)	13591.77
4/12/2026	Reused	Adafruit BNO055 IMU	Electronics Bay	(34.95)	13591.77
4/12/2026	Reused	2x Fisheye Camera	Front cam, Back cam	(113.98)	13591.77
4/16/2026	Purchased	5v power converter pcb	logan	(2.25)	13589.52
4/18/2026	Purchased	12v power converter pcb	sannie	(2.38)	13587.14
4/20/2026	Purchased	12v power converter		(108.53)	13478.61
4/21/2026	Parts Donated	Power Supply (RSP-2000-48)	Donated by Progressive RC	(497.8)	13478.61
5/10/2026	Purchased	Protection Circuit PCB		(93.6)	13385.01
Float					
2/24/2026	Purchased	MCP23017 GPIO Expander		(6.95)	13378.06
4/26/2026	Purchased	DRV8833 Motor Driver		(1.4)	13376.66
5/1/2026	Purchased	RP-SMA Adapter Cable		(3.95)	13372.71
5/1/2026	Purchased	uFL SMT Antenna Connector		(8.64)	13364.07
5/1/2026	Purchased	Board Connector		(3)	13361.07
5/4/2026	Purchased	XIAO ESP32-C6		(7.66)	13353.41
5/11/2026	Purchased	Fuse Holder		(1.8)	13350.62
5/11/2026	Purchased	2.2uf capacitors		(0.99)	13345.66
5/11/2026	Purchased	100nf capacitors		(4.96)	13293.26
5/11/2026	Purchased	Custom PCB		(52.4)	13293.26
5/14/2026	Purchased	NiMH Reciever RX Battery		(10)	13340.62
Team Operations					
8/20/2025	Purchased	Website renewal		(67)	13226.26
11/18/2025	Purchased	2025 T-Shirts	Fulfilling orders from last year	(566.65)	12659.61
2/22/2026	Purchased	Printer Ink		(32.81)	12626.8
2/28/2026	Purchased	Grabbers	Used for environmental cleanups	(18.76)	12608.04
4/21/2026	Purchased	2026 T-Shirts		(976.71)	11631.33
Competition Logistics					
9/14/2025	Purchased	Marketing Display Printing, Shipping for 2025 comp.		(89.19)	11542.14
Competition Fees					
5/14/2026	Purchased	2026 World Championship Registration Fee		(650)	10892.14
Competition Travel					
9/1/2025	Purchased	Reimbursal for Rental Car for 2025 Championship		(776.13)	10116.01
11/10/2025	Purchased	Flight Reimbursal for 2025 Championship		(250)	9866.01
5/8/2026	Purchased	Housing for 10 members for 2026 World Championship		(3334.38)	6531.63
Total Purchased				9227.58	
Total Value (purchased, parts donated, reused)				22499.97	
Total Raised (cash and parts donated)				19685.38	

*All values in USD