2025 MATE ROV Competition

PIONEER Class

JELLYFISH

TRITON TECH ROV

Lynnwood, WA, USA

TEAM MEMBERS

Briar Taggart
CEO and Lead Engineer

Ty Tie-Sheng Gross
CFO and Manipulator Engineer

Sarah Abdullah
Documentation Lead and Manufacturing Technician

Ege "Bob" Mavinil
Manipulator Engineer

Duy "Ken" Vo Tan Mai
Programmer

Matthew Sunghyun Lim
Programmer

MENTORS

Dr. Rachel Wade
Dr. Tucker Howie
Jeremy Juetten
Ash Bystrom

Atlantis S.T.E.A.M.

EDMONDS COLLEGE

Jellyfish

Technical Report

Triton Tech ROV
Edmonds College
Lynnwood, WA, USA
Published May 21st, 2025

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Acknowledgements

Thank you to Edmonds College, MESA, MATE ROV, and Atlantis S.T.E.A.M. for supporting this project.

Thank you to our sponsor, Nadya Rajih, owner of Cozy Nest Daycare, for financially supporting Triton Tech ROV. Thank you to Atlantis S.T.E.A.M. and members of the team for donating materials and lending tools.

Thank you to Haley McConnaughey for reviewing our technical documentation. Thank you to Hillel Coates for assistance with fabricating 3D printed parts in the Edmonds College Engineering Lab.

Without the assistance of our supporters, this project would not have been possible.

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Abstract

Triton Tech ROV at Edmonds College proudly presents our competing Remotely Operated Vehicle (ROV), Jellyfish. This year marks the second year of Edmonds College's participation in the MATE ROV competition. This year, we decided to implement a completely new ROV design. With a mission to monitor, improve, and preserve our oceans and waterways, Triton Tech ROV implemented environmentally conscious and marine-minded methods in the design and operation of our ROV. We brought together a new team to apply their technical skills and innovation to design a reliable, safe, and effective ROV to aid environmental assessment and restoration of our oceans and waterways. The result of our work is an ROV with features such as a custom made aluminum and acrylic body, innovative implementation of the manipulator, and an on-robot control processing system. The purpose of this document is to explain the rationale and techniques implemented to make Jellyfish, and the challenges overcome during the design and build process.

Company Overview

Triton Tech ROV is a six-person team. We are assisted by our faculty mentors, Dr. Rachel Wade and Dr. Tucker Howie, along with our manufacturing advisor, Jeremy Juetten, and our mentor from Atlantis S.T.E.A.M., Ash Bystrom. Our team structure is as follows:

- Briar Taggart, **CEO and lead engineer**, managed the schedule and overall structure of the project, including task delegation and organization. In addition, they worked with every sub-team to ensure that the project would be completed successfully.
- Ty Gross, **CFO**, ensured that we kept track of our budget as the project went on and led our fundraising efforts. He also kept track of donations and re-used parts, and ensured that our budget breakdown remained accurate. In addition, he led fundraising efforts.
- Sarah Abdullah, **technical documentation lead and manufacturing technician**, organized and drafted the bulk of the technical documentation, communicating with the engineers and programmers to ensure that the documents reflected the product we created. She also acted as a manufacturing technician, helping lead the efforts to manufacture parts for the ROV.
- Our **manipulator team**, which consisted of Bob Mavinil and Ty Gross**,** designed and implemented a vertically opening manipulator with two degrees of freedom to ensure we can complete the tasks assigned, along with many other real-world ROV tasks.
- Our **programming team**, which consisted of programmers Matthew Lim and Ken Mai, often referred to as "controls and computing" in this document, created a control system involving streaming the cameras from the ROV, sending control signals to the ROV, and actuating the thrusters. They assisted with implementing the electrical system through code.
- Our **body team**, which was led by Briar Taggart and assisted by others on the team, designed the chassis and thruster configuration for the ROV, as well as modelling all thruster and camera mounting brackets.

While these were the assigned tasks for the project, there were many instances of multidisciplinary teamwork and miscellaneous tasks that were performed by various members of the team. As a small group, we often needed to step outside of our job descriptions to complete the project. We also sought feedback from others on the team frequently. Each member of the team also contributed to manufacturing, assembly, and testing of the ROV.

Project Process

Schedule

Due to a major change in leadership and team structure after the fall term, we had to begin our project in earnest in the Winter term during the first full week of January. Our projected and actual timelines are as follows:

Week:	Jan 5-11	Jan 12-18	Jan 19-25	Jan 25-Feb 1	Feb 2-8	Feb 9-15	Feb 16-22	Feb 23-Mar 1	Mar 2-8	Mar 9-15	Mar 16-22	Mar 23-29	Mar 30-Apr 5	Apr 6-12	Apr 13-19	Apr 20-26	Apr 27-May 3	May 4-May 10	May 11-17	May 18-24	May 25-31	June 1-7	June 8-14	June 15-21
Recruiting	■	■	■	■																				
Briefing		■	■	■																				
Brainstorming				■	■	■	■	■	■															
Fundraising			■	■	■	■	■	■	■	■	■													
Body CAD					■	■	■	■																
Manipulator CAD							■	■	■	■	■	■	■											
Electrical Component Research					■	■	■	■	■	■	■	■												
Programming									■	■	■	■	■	■	■	■	■							
Manufacturing and Assembly													■	■	■	■	■	■						
Marketing Development														■	■	■	■	■	■					
Technical Documentation															■	■	■	■	■					
Poster																			■	■	■	■		
Presentation Development																			■	■	■	■	■	
Piloting/Task Practice																	■	■	■	■	■	■	■	■
Competition																								■

Table I: Projected project schedule.

Week:	Jan 5-11	Jan 12-18	Jan 19-25	Jan 25-Feb 1	Feb 2-8	Feb 9-15	Feb 16-22	Feb 23-Mar 1	Mar 2-8	Mar 9-15	Mar 16-22	Mar 23-29	Mar 30-Apr 5	Apr 6-12	Apr 13-19	Apr 20-26	Apr 27-May 3	May 4-May 10	May 11-17	May 18-24	May 25-31	June 1-7	June 8-14	June 15-21
Recruiting	■	■	■	■	■	■	■	■																
Briefing		■	■	■																				
Brainstorming				■	■	■	■	■	■	■	■													
Fundraising			■	■	■	■	■	■	■	■	■													
Body CAD					■	■	■	■						■	■									
Manipulator CAD							■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Electrical Component Research					■	■	■	■	■	■	■	■	■	■	■	■	■	■						
Programming												■	■	■	■	■	■	■	■	■				
Manufacturing and Assembly													■	■	■	■	■	■	■	■				
Marketing Development														■	■	■	■	■	■	■				
Technical Documentation															■	■	■	■	■	■				
Poster																			■	■	■	■		
Presentation Development																			■	■	■	■	■	
Piloting/Task Practice																				■	■	■	■	■
Competition																								■

Table II: Actual project schedule (Projected after 5/21/2025).

Project Management

Our project structure and timeline were largely managed by our CEO. They coordinated the phases of the project, assigned deadlines while considering both input from the team and the major deadlines set by MATE ROV, and delegated tasks to members. Meeting agendas were also prepared by the CEO for the majority of general and sub-team meetings.

Tasks were generally delegated on a volunteer basis, with leftover tasks being assigned to available members, particularly those with relevant expertise. We strove to ensure that every member of the team got to work on portions of the project that they were interested in, had expertise in, or were willing to learn to execute. This ensured that members stayed engaged and invested in the project.

Throughout the design process engineers and programmers engaged in thorough documentation, which streamlined the production of this report later in the project.

Communication occurred during in person meetings as well as online over Discord. Clear and effective communication was built as the team became more comfortable and communication guidelines were implemented, such as encouraging members to be clear about what meetings and tasks they could attend and participate in and ensuring that the team felt comfortable raising concerns or asking questions. We also clearly coordinated the location and times of meetings using a shared calendar. When deadlines approached and work was unfinished, the team came together and planned supplemental meetings to complete project tasks. Meetings were held in the Edmonds College engineering labs, in the Edmonds College Materials Science Lab, and at Atlantis S.T.E.A.M.

Design Rationale

Design Process

Brainstorming began in January, with many ideas being shared regarding potential plans for the ROV. We discussed many aspects of the design, including the shape of the chassis, the thruster configuration, the electrical and programming architecture, and the manipulator. When it comes to design, we deliberated on many approaches for different parts of the ROV. We originally had ideas of creating an entire arm, with servos at the joints of the shoulder, elbow, wrist, and manipulator. Mainly, we considered the requirements of the ROV for the competition, such as implementing the ability to navigate freely and safely underwater, grasp and manipulate objects built from PVC pipes, handling very small objects such as pipe cleaners, and relaying camera footage to the surface for navigation and recording shipwreck areas.

We made several major decisions about tools that guided work on the project. One such decision was which CAD program to utilize for 3D modelling, and we chose to use the browser-based CAD program OnShape for multiple reasons. One, it is compatible across all operating systems because it runs on a web browser, and our group members utilize different operating systems on their computers. Onshape accommodates all of them. OnShape is also free for students, saving us on costs and budget management. The concurrent editing and file sharing capabilities of this program were also incredibly useful for our team. We decided to use Python for programming the back end, due to familiarity with the language in our team members who were new to programming. On the front end, we used the industry standard HTML, CSS, and JavaScript for ease of implementation and compatibility with various web browsers.

Many decisions changed over time due to circumstances, iteration, and further research. Our engineering process involved brainstorming, design engineering, and prototyping, which meant we generated ideas as a team, assigned aspects of the projects to individuals and sub-teams, and prototyped designs and made changes accordingly.

We worked to include every member in the design process, especially for major decisions. Whenever possible, we used data found through research—such as thermal properties of materials or the torque produced by a motor we were considering—to make our decisions.

Innovation

Since we designed an entirely new ROV this year, stepping away from a PVC pipe chassis and pneumatic manipulator and towards a design utilizing a custom aluminum and acrylic chassis with a servo-actuated manipulator. Significant innovation was involved in the creation of Jellyfish to provide our ROV with enhanced stability and improved mobility, providing a more dynamic and effective machine. Some innovations we designed which demonstrated the growth of our team upon last year's work are:

- Custom designed manipulator with two degrees of freedom utilizing two back-to-back water-resistant servo motors, allowing for finer control of objects underwater
- A two-point strain relief system, which protects the tether and was inexpensive to implement
- A hollow acrylic pressure vessel, improving buoyancy and allowing for almost all electronics to be housed on the ROV itself
- Original control system utilizing an ethernet connection to a web server on the onboard ROV computer
- A four-camera system allowing for all-around views underwater

Systems Approach, Electronics, and Software

For our overall system design, we considered the requirements of the competition and decided on a system that primarily converted and delivered power to the different components onboard the ROV itself. The onboard Raspberry Pi implemented this process by allowing us to directly connect to multiple cameras, thrusters, and servos with minimal components and straightforward wiring. The closeness of the servos to the computer controlling them allowed us to avoid using a booster for their signals, as we learned that servo signals decay over long cables.

We selected a Raspberry Pi 4B for our final ROV due to its ease of use, extensive documentation, and availability via donation from a team member. This onboard SBC (Single Board Computer) handles the server which interfaces with the control station, as well as controlling all servos and thrusters. It connects to an Adafruit Servo Hat, which sends Pulse Width Modulation (PWM) signals to as many as 16 servos, which is more than enough for our needs. This Servo Hat also has the benefit of providing up to 6V DC to the thrusters; we connected this to our two Sabertooth 2x5 motor controllers.

Each Sabertooth is connected to two thrusters: two vertical thrusters on the first, and on the second, horizontal thrusters on each side of the ROV. The Sabertooths are configured to use simplified serial with "slave select", which allows us to enable or disable each Sabertooth's ability to receive motor actuation signals, allowing us to use only one serial port to communicate with both controllers. We chose to use 0% to 100% power with our thrusters to simplify software implementation and because our thruster motors did not actuate reliably with lower speeds. This binary on and off system was also easy to control when piloting. We were able to reuse last year's ROV's Sabertooth motor controllers in order to reduce waste and save on cost.

In order to deliver the right amount of power to both the motors and the Raspberry Pi, we utilized two buck converters: one which lowered voltage to 5V with up to 5A current, and delivered it over USB-C to the Raspberry Pi, and one which could be adjusted to 6V for powering all motors, including servos for the manipulator as well as the thrusters. The latter could deliver up to 20A, which is more than sufficient for our needs. The power cables from the tether split to both of these using a power bus in the ROV pressure vessel.

Cameras

We utilized a 4 camera layout for Jellyfish. We chose 1080p low-light Arducam cameras because they were cost effective and built into waterproof housings. The low-light capabilities also made it ideal for underwater conditions, and they came with convenient adjustable mounts. The front camera is the primary camera, and it is displayed the largest on our control page, while other cameras are displayed in smaller boxes to its side. We selected cameras with waterproof housing to save time and costs on waterproofing efforts. While we were able to implement the built-in mounting brackets, we needed to design an intermediate bracket to allow a place for them to be mounted along the rods on the side of the pressure vessel. Our custom mounts were designed using OnShape and 3D printed with Polylactic Acid (PLA) and Polyethylene Terephthalate Glycol (PETG) and placed along the threaded rods on the sides of the ROV. Heat-set inserts were applied to holes in the bracket to allow us to screw the built-in metal brackets down to the custom mounts. The brackets were secured into place along the rods using zip-ties for cost and convenience.

We chose to position the cameras to be above the manipulator for ease of manipulating objects, one to provide a full view from the back of the ROV, and the left and right side cameras to provide an all-around view.

Software

Our software architecture consists of a front end, which is served from the Raspberry Pi (server) to the controlling (client) computer over ethernet, and a back end, which handles control signals sent from the client, via a Logitech G F310 wired controller that is connected to our computer. Our software stack includes Python on the back end, with HTML, CSS, and JavaScript code on the front end.

Front End

Our front end consists of a single file, `index.html`, which contains all the necessary HTML, CSS, and JavaScript code. The HTML and CSS arrange the cameras and data on controls, along with providing a button that sends the emergency stop signal.

For the UI Design, we used TailwindCSS to organize content into a responsive and readable layout. TailwindCSS is a highly customizable CSS framework that makes it fast and easy to build responsive and modern user interfaces directly within our HTML. We can apply pre-built utility classes that are highly compatible with all browsers instead of manually coding all of the CSS, thereby reducing development time. In addition to TailwindCSS, we utilized some custom styling to ensure a clear UI for our control station.

To connect to our controller, we utilized the Gamepad API for JavaScript. We chose this API because we needed a way to send controls through a browser, and Gamepad API is a simple built-in way to do this. It is straightforward to use and readily available, as well as being reliable and tested by time over many applications across the web. This was a very time efficient and user-friendly option for implementing controls. We utilized this API to frequently poll the controller for updated inputs from the joysticks for movement and the D-Pad for the manipulator.

The front end code then instructs any updated inputs to be sent through a websocket—described in the next section—to the server on the Raspberry Pi. The control inputs are sent in the form of a packet of data containing decimal values representing the position of the axes of the controller joysticks as well as other data types representing the inputs used to actuate the manipulator. These packets of data are prepared from the controller data provided by the Gamepad API using a JavaScript program built into the index.html file. JavaScript formats the data in a format called JSON (JavaScript Object Notation).

Back End

In order to communicate between the server (Raspberry Pi) and the client (the laptop with the browser), we utilized the `websockets` library in Python. Websockets are a form of internet connection that opens a two-way channel of communication between a client and server, allowing communication in both directions [1].

The JSON packet sent from the front end is interpreted by the `json` library for Python on the back end and each value is used to determine whether—and which of—the motors should be actuated.

Because websockets can close and become unusable, we also built in a feature which activates the vibration in the controller when the websocket becomes disconnected. This way, the pilot is immediately and conveniently informed if the connection becomes unstable. This is useful both in the troubleshooting process and in situ. As an additional safety feature, we ensured that, should the websocket connection close, all of the ROV's thrusters stop.

As discussed above, the Sabertooth motor controllers are configured in a way where they receive two signals; one being a single-byte serial signal stating how fast to turn and in what direction, and the other being a simple directive to either accept or ignore those serial signals. When the "ON" signal is received by the Sabertooth, it can receive commands to move.

Body

We created a detailed CAD model of Jellyfish's chassis after the creation of rough sketches during team meetings. The ROV's body consists of two custom shaped 3.175mm thick aluminum panels for the front and back of the ROV, and sixteen 381mm long by 6.35mm diameter threaded rods connecting the two together. These rods both protect the acrylic shell from impact damage and keep the pressure vessel sealed to avoid leakage. We selected aluminum for the plates primarily due to its heat sink properties, which allow the heat produced by the electronics inside the pressure vessel encased between the body panels to escape, preventing pressure buildup during use [2]. Aluminum is also relatively inexpensive and resistant to corrosion, making our ROV affordable and long-lasting [3].

The acrylic tube between these panels houses the electronic components on the ROV, which includes the Raspberry Pi 4B. We used 165.1mm diameter acrylic tubing. This was fortunately readily available to us from scrap material at the Edmonds College Material Science Lab, aligning with our company's value of waste minimization. While acrylic can be more prone to shattering from impact damage than other plastics [4], the aforementioned threaded rods surrounding it help to protect it from such damage. Four 3D printed PLA brackets are glued inside of the acrylic tube to hold a 3.175mm thick aluminum shelf, which was also selected due to its thermal properties. Slots were cut in the shelf to allow for using zip ties to secure electronics. We decided to use the four small brackets to hold the shelf rather than two long ones in order to keep the inner components lightweight and easy to secure and replace. PLA was selected for these components due to its affordability and ease of printing. The shelf slides in and out of the acrylic tube for ease of repair and upgrade. All exposed circuit boards that could potentially touch the shelf were covered with electrical tape and raised with plastic standoffs to avoid short circuits. Components were zip-tied to the shelf for security.

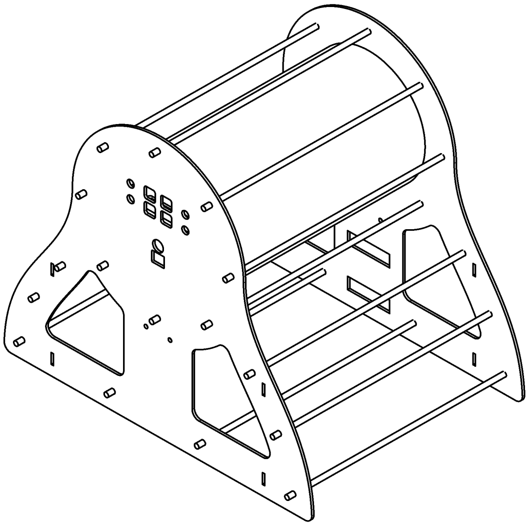

Fig. 1: Isometric Drawing of the Back End of the Chassis, Not Including Gaskets or Fasteners.

Custom-size gaskets cut from sheet rubber were applied to either end of the tube to ensure a good seal of the pressure vessel. Where the shelf slides in and out, notches were cut in the rubber gasket to ensure the shelf is removable. The gaskets were secured and sealed to each end of the acrylic tube with silicone caulk. This ensures no leaks into the pressure vessel and secures the gaskets in place to avoid slipping during assembly.

Prior to assembly of the ROV, we also designed side panels which were intended to direct water when moving up and down. However, despite being successfully manufactured, due to a need for more space for thruster brackets, these side panels were removed. Fortunately, the slots left behind in the design of the front and back panels proved beneficial when securing our ROV-side tether strain relief.

Buoyancy

The overall body design was intentionally lightweight and buoyant, so we added ballast to attain neutral buoyancy by increasing the mass of the ROV without severely increasing the water displacement. Even with the additional weight, our ROV is a very reasonable 11 kg, which is easy to transport, handle, and launch into the water. The structure of our ROV, with weights applied at the bottom and the buoyant pressure vessel at the top, also keeps our ROV upright easily without a need for thrusters to adjust its orientation in the water.

Propulsion

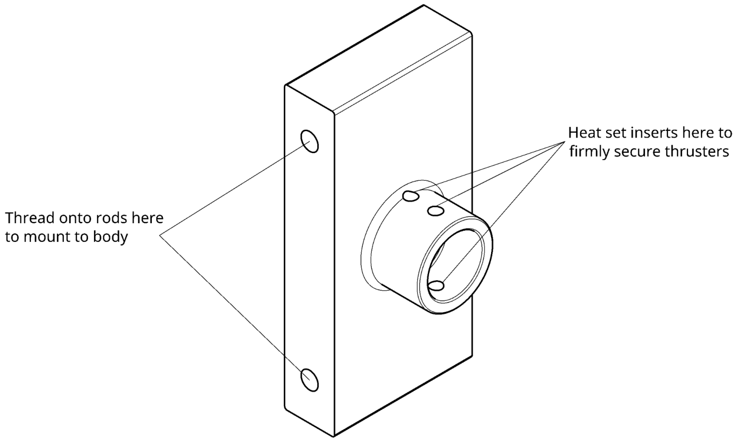

Fig. 2: Isometric View of Thruster Mounting Bracket.

During the beginning of our project, we researched and explored many ideas for our propulsion systems , we eventually decided to reuse last year's 500 GPH bilge pump-based thrusters for budgetary and waste reduction reasons. These motors are sufficiently powerful to move the ROV through water and are rated to only draw up to 2.5A of current, leaving us plenty of current for other electronics on our ROV. These Johnson Pump thrusters use 3D printed guards to protect the thruster, those handling the ROV, and the environment, as well as directing the water to increase efficiency of the thrusters. We selected a four-thruster configuration to ensure necessary degrees of freedom during maneuvering, while keeping control code and wiring to a minimum.

We utilized thruster mounting brackets that are 3D modelled and printed using PETG and PLA to connect the thrusters to the rods on the body. We chose these materials due to availability and affordability, as well as their material properties, and we tested the parts for durability upon printing. The thrusters are mounted onto the brackets first with a friction based connection. M3 heat set inserts are placed in openings on the top and bottom of the connection between the thruster and mounting brackets. M3 screws are used to further secure the thrusters in the brackets.

The bottom thruster mounting brackets (horizontal thrusters) are designed to be shorter than the top brackets (vertical thrusters), to accommodate the difference of the distance between the rods. The vertical thrusters are vectored and mounted at a 70° angle for improved movement performance and convenient attachment to the threaded rods without a need for more material to keep them pointing directly vertical. The horizontal thrusters are mounted to lower threaded rods on the sides near the bottom of the ROV to maneuver forward, backward, and rotate port and starboard.

Tether

Our tether consists of four components: three cables and a tube. One wire is an ethernet cable to connect the Raspberry Pi to our control station and the other wires are our 12 gauge 5V and Ground wires for power. The tube is 6.35mm silicone tubing, which is used to pull fluid into the ROV syringe when collecting water samples. The entire tether is covered with a sturdy and flexible 25.4mm diameter cable cover. It is secured at the ROV side and topside with zip ties and electrical tape to prevent tearing. We selected this cover to keep tether wires from tangling or becoming damaged during use.Our tether management protocol includes looping the tether during transport, and dedicating a tether handler to manage the tether in situ. This allows us to avoid tangles and keep the team safe from tripping, as well as ensuring the ROV does not get stuck.

Strain Relief

We utilized a two-part strain relief system for the ROV side for maximal safety and security of the tether. We used polypropylene rope to secure both points of the strain relief system due to its strength and ease of use. Zip ties were utilized to ensure knots would not come undone during use. A similar rope-based attachment system was used topside, but with different connection points.

ROV-Side

The rope on the first point of connection, near the ROV back panel, was secured to the tether using knots and zip ties. This point of the tether was attached to the side of the back panel securely with more rope and fastened further with zip ties.

At the top of the ROV, a rope segment is attached to the very top threaded rod on either side of the aluminum panel. On the tether, a coil of protective plastic is secured with electrical tape. Two thick and sturdy zip ties create a loop, to which a carabiner is attached. This allows us to easily clip the tether to the loop of rope attached to the ROV, providing a secondary strain relief that further keeps our cables safe.

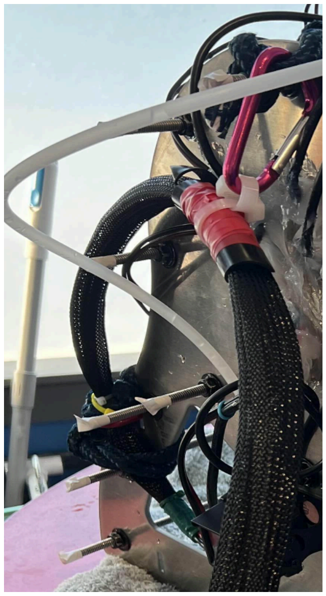

Fig. 3: Strain Relief for ROV Side

The two-point strain relief offers redundancy and guides the tether up to the top of the ROV to avoid it tangling near the bottom. It also helps prevent the tether from kinking where it is attached to the frame near the bottom and side of the back panel, preventing damage to the wires and tubing.

Topside

On the top side of the tether near the power side and controls, we utilized a single point strain relief system with two components, one of which is optional depending on situational options for securing the system. The primary component is made of rope and a chain link which opens and closes. The rope is secured to the tether with knots, zip ties, and electrical tape to keep everything smoothed down to the tether.

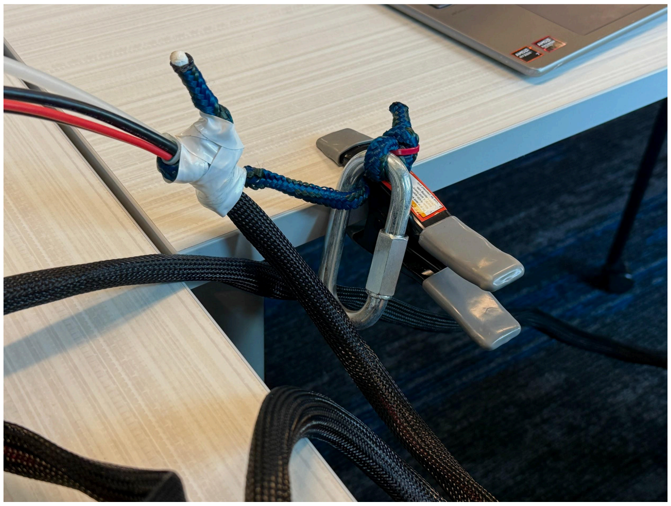

Fig. 4: Strain Relief for Top Side

The other end of the rope is secured similarly to the chain link. The rope can be looped around a table leg or other secure rod for a simple strain relief option. If no rod or similar attachment point is available, it can be hooked onto a clamp—the secondary component—which can be attached to a tabletop or other relatively thin and flat surface. This two-component, single-point strain relief system allows for flexibility depending on the available control area, and permits quick set-up and tear-down. It was also affordable and simple to implement.

Payload and Tools

Manipulator

Based on the mission tasks requiring handling of PVC pipe, pipe cleaners, and rope, we designed our manipulator to effectively grasp and move various sizes of objects. We initially planned to implement a manipulator arm with three joints, including a rotating shoulder, an elbow joint, full wrist rotation and flexing, and opening and closing of the claw fingers. While we prepared designs for this more complex arm and we are likely to implement that next year, this current version is capable of flexing vertically at the base, as well as opening and closing the grasping claw.

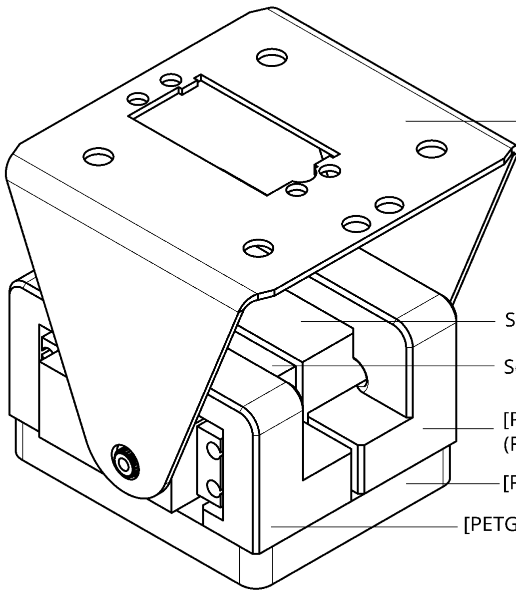

Fig. 5: Isometric Drawing of Base Hinge

Base Hinge Movement and Operation

The base consists of a hinge that flexes vertically via two mirrored servo motors. We selected Ecopower WP110 motors that are waterproof and each capable of 1.97 Newton-meters of torque, providing a comfortable buffer over our minimum calculated requirement of 1.3 Nm. The rotation of the left servo motor spline is inverted with respect to the right servo to achieve movement of the hinge. We selected two motors rather than one in order to have more power at a lower cost. The claw assembly and servo motor are secured to the hinge with M3 screws.

Base Hinge Mounting Harnesses and Backplate

The base is driven by two servos and secured directly to the front plate of the ROV body using three 3D printed PETG parts. The front body plate is sandwiched between two mounting harnesses and the backplate. One harness is mounted on each servo, and both snugly fit into narrow slots in the body plate. M3 screws are secured in heat set inserts across the base parts, ensuring that the arm assembly does not dislodge during operation.

Claw Movement and Operation

The claw is driven by a pinion gear powered by the same servo motor which drives both sides of the base. Instead of purchasing or machining a custom-fitted gear for the servo spline, we were able to utilize a servo horn attachment that came with the servo kit to connect the pinion gear to the spline. This same attachment was used to secure the hinge to the other two servo motor splines at the base.

Wrist and Claw Parts and Components

Pinion Gear: The steel pinion gear we purchased has a large circular gap in the center, so we designed a 3D printed spacer to fit between that and the aforementioned attachment. We implemented a rack and pinion system that converts rotational motion to linear motion perpendicular to the axis of rotation.

Gear Racks: To operate the actuation of the claw fingers, two racks move in opposite directions with the claw's fingers attached perpendicular to each end of the racks.

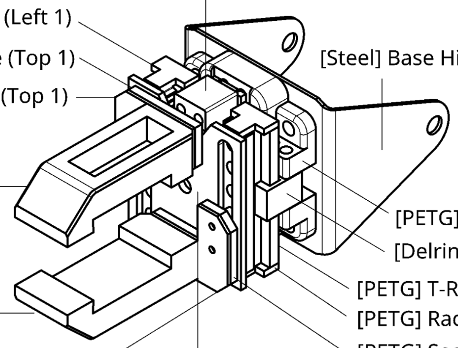

Fig. 6: Isometric Drawing of Claw Assembly

Sliding rails: We developed a custom sliding rail mechanism for both racks to attach the racks and to ensure proper movement. This involves a 3D printed PLA T-shaped rail and a waterjet cut Delrin anti-rail. The racks are attached with M3 screws in threaded inserts set into the rack and T-rail. Both these pieces follow the rotation direction of the pinion gear movement, allowing for smooth operation of the claw fingers.

Claw fingers: The claw fingers are 3D printed PETG extrusions with a TPU grip on the inside. The TPU grip ensures the claw fingers can effectively grasp objects in situ. The fingers are also attached to the rails and racks with M3 screws in threaded inserts, as well as 7mm diameter bearings nested along the shafts of the screws to ensure smooth motion.

Backbone: This large section of the claw secures the components together. It is attached to the side tabs of the servo via M3 screws in heat-set inserts. The Delrin anti-rails are also secured into hole extrusions at the top and bottom of the backbone. The anti-rails are positioned with proper spacing and clearance between the pinion and rack to ensure smooth gear movement.

Gear Protection

To ensure no objects interfere with the gear movement and avoid collisions with other components, we've implemented additional components to the servo structure, servo side tabs, and backbone. The geometry is centered around the gear.

The top and bottom locking tabs cover the servo screw tabs and extend forward from the servo. These locking tabs and the backbone secure the servo in place. To protect the pinion gear from debris or obstructions, a PETG panel secures over the servo and pinion gear with enough clearance to prevent grinding or disruption of movement.

Other Tools

In addition to our manipulator, we included a syringe system on our ROV designed to easily obtain water samples for testing. The syringe system involves a chamber and nozzle at the ROV side, which can be held by the manipulator or otherwise attached to the ROV to gather samples. It attaches to the silicone tube discussed in the tether section, which terminates topside at a detachable syringe. This syringe can be used to pull in water by producing suction. If necessary, the syringe can be removed, the plunger pushed back in, and the syringe reinserted into the silicone tubing to draw more water into the ROV-side chamber. Once the ROV returns to the surface, the sample can be retrieved for testing. This suits one of the tasks for our product demonstration as well as having great utility for real-world water testing, such as checking samples for chemicals, pH levels, or eDNA.

Sourcing Parts

Throughout our design and manufacturing process, we dedicated significant effort to the decisions regarding how we sourced and manufactured our parts, including deciding which parts to reuse from last year's ROV.

As we used a new design from last year's ROV, most of our ROV is built or designed from scratch in CAD and 3D printed. For 3D printed components, we utilized PLA and PETG as those are very cost effective options for filament. We were fortunate to receive donations of manufacturing materials from Edmonds College's Materials Science lab including aluminum, acrylic tubing, and steel. This kept us within our budget and permitted us to create a durable and upgradeable ROV design. We implemented our own rubber gasket instead of ordering a custom rubber gasket or manufacturing our own silicone gaskets. This was another cost-saving — as well as time-saving — option. Our usage of last year's thrusters was a very cost effective option. We were also environmentally conscious with this choice, as we didn't have to 3D print new shrouds or purchase new bilge pumps.

System Integration Diagram (SID)

The SID on the following page includes our experimental Full Load Amps (FLA) value, calculated by actuating all thrusters simultaneously while submerged, as well as our calculated FLA based on the current ratings of our components.

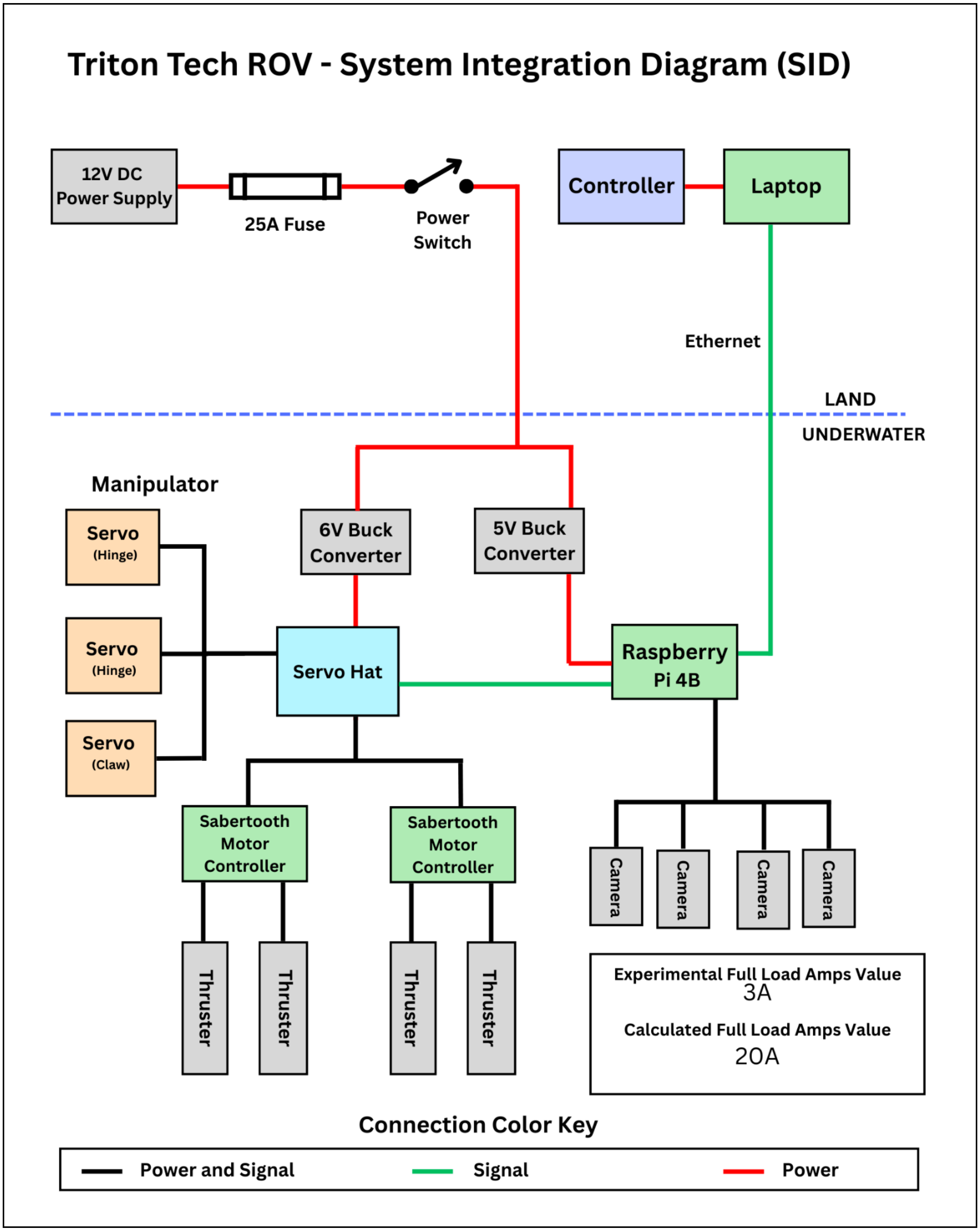

Fig. 7: System Integration Diagram (SID) for Jellyfish

Safety

We highly value the safety of those operating the ROV and those in the environment in which the ROV is operating. To ensure our ROV is safe for pilots and bystanders, as well as wildlife in real-world scenarios, we included 3D printed shrouds on our thrusters. Shrouds prevent objects from getting caught in the thrusters, which could cause injury to living beings if the ROV were deployed in oceans and waterways.

We also 3D modelled and printed PLA caps which are friction fit with electrical tape on the ends of the rods that stick out from the back panel. We have the option of heat-setting inserts to screw the caps onto the rods should friction fitting ever become unreliable. On the front panel, we applied lock nuts flush with the end of the rod to ensure nothing protruded there. These are implemented to prevent anyone handling the ROV from being injured by the ends of the rods sticking out of the body panels. In addition, they help prevent damage to the environment in which the ROV is deployed.

An emergency stop button was implemented in the UI on the controls, which sends a signal to the thrusters to stop. An emergency switch is also installed between the top side strain relief and the power supply, which cuts all power to the ROV. Additionally, we implement a fuse holder within 30 cm of the power supply. This holds a 25A fuse that breaks the connection when over 25A is detected, thereby cutting power to the ROV. All electronics on the ROV are rated to handle, at minimum, the current which would be provided to them up to the limit of that fuse. While MATE ROV requires this safety feature, it would be included on Jellyfish regardless as it protects the ROV from power surges that could break the electronics or cause electrical fires.

In addition to the engineered safety features, we created our lab and operation safety checklist with the well-being of the people working on and near the ROV in mind. Implementations such as PPE are standard for labs, but we included a detailed arrangement of rules in our safety checklist to ensure the complete awareness and protection of people working with the ROV.

Safety Checklist

Lab and Construction Safety

- Personal Protective Equipment (PPE) usage is required to reduce risk of injury. This includes:
- Safety goggles.
- Closed toe shoes.
- Tied back hair, no stray clothing/fabric.
- No rings/loose jewelry.
- Ventilation for soldering or applying epoxy.
- Understand emergency procedures and protocol such as where exits are located, eye-wash stations, AED machines, first aid kits, and fire extinguishers.
- No food or open drinks are permitted in labs.
- Be aware of your surroundings and people around you.
- If you or another person is injured, assess the situation, and notify the lab manager/advisor present immediately. Do not work while injured.
- Clean up stations after finishing working to maintain a clean and organized lab/working environment.

- Do not work alone. When working with machinery, always have a lab manager/advisor present.

Operation Safety

- Before turning on the ROV power supply:
    - The ROV power supply should be a minimum of two meters from the edge of the pool or other body of water, elevated on a stable and sturdy surface at least half a meter above the water's surface.
    - The topside strain relief for the tether must be firmly attached to a secure location.
    - The tether handler must clearly report readiness prior to power on.
- Clearly communicate "POWER ON" when the power supply is on and make sure everyone understands and repeats this. The tether handler must do the same for "POWER OFF".
- If anyone calls "POWER OFF", power must be immediately shut down.
- Tether handler should keep a close eye on the tether and ROV and make the team aware of any safety issues or other operational concerns

Testing and Critical Analysis

Prototyping

When prototyping, our general process involved manufacturing parts, test fitting, full assembly, and adjustments. Every time adjustments were made, the parts would be re-manufactured and re-assembled as necessary. To break it down further, our prototyping process for Jellyfish followed these steps:

1. If using raw materials, manufacture all necessary components.
2. Measure and test-fit manufactured components along with any involved off-the-shelf components such as fasteners or electronics.
    a. Return to step 1 as needed until parts fit together.
3. After a successful test fit, assemble the component.
4. Test the component for safety and functionality.
    a. Return to steps 1-3 as needed.
5. After all components for a larger system have been assembled and successfully tested, assemble the system.
6. Test and adjust components as necessary to achieve a safe and functional system.
7. Repeat steps 5-6 until the full system has been prototyped.

Troubleshooting

When testing the completed prototype for Jellyfish, we applied the following process:

1. Prior to launching the ROV in water:
    a. Power on the ROV and ensure it has booted successfully.
    b. Turn on the server back end by running `python backend.py` and connect to the control UI in a browser. Ensure that the controller is connected via USB to the client laptop.

   c. Test all directional inputs outside of the water to ensure all motors are running as expected. This can be done prior to starting the server with one of the test scripts, or after connecting with the controller.
2. Slowly lower the ROV into the water, watching carefully for bubbles or other evidence of leaking and immediately remove the ROV if any leaking is present.
   a. Address any leaking by drying the area and applying marine epoxy. Allow sufficient time for the epoxy to set before re-entering the water.
3. Once hands and arms are clear of the ROV, begin testing all directions of movement.
4. While moving the ROV, ensure all cameras are operating smoothly and with little or no lag.
5. Test the manipulator by exercising all degrees of freedom in every direction, including fully opening and closing the manipulator.

If any potential safety issues are encountered during testing, immediately stop all thrusters and remove the ROV from the water. If other issues are encountered, discuss with all pilots and the tether handler the best way to approach further troubleshooting. To troubleshoot:

1. Collect as much information as possible on the error and any related behavior.
   a. If there is not a safety issue that would make replication inappropriate, replicate the behavior to ensure it is repeatable.
2. If a solution is obvious, implement it immediately, followed by restarting the ROV and server.
3. If a solution is not immediately clear, follow these steps, with testing in between, repeating as necessary:
   a. Thoroughly check all mechanical joints for problems that could prevent or inhibit movement.
   b. Unplug and re-attach the controller.
   c. Refresh the UI.
   d. Reboot the server.
   e. Power cycle the ROV by turning power off and back on again.
   f. Research potential solutions.
   g. Implement and test potential solutions.
4. Ensure any related issues are also resolved prior to resuming operation of the ROV.

Tools that can assist with the troubleshooting process include the F12 troubleshooting menu in the browser and messages in the terminal of the Raspberry Pi.

Accounting

With a very limited budget for this project, we made significant efforts to save on parts and manufacturing costs. The following sections detail our budget breakdown, spending, and the retail cost of our Jellyfish ROV.

All prices given here are in USD.

Materials and Spending

Item	Source	Total Price
Raw Materials		
3.175 mm Aluminum Sheet	DONATED	$142.30
1.5875 mm Steel Sheet	DONATED	$105.00

Delrin	DONATED	$5.26
PETG Filament	DONATED	$14.00
PLA Filament	DONATED	$14.00
TPU Filament	Amazon	$10.95
6.25 mm Threaded Rods	Grainger	$42.55
Controls, Computing, Circuitry, and Electronics		
Servo Hat	Adafruit	$35.00
Ecopower WP110 Servomotors	Amain Hobbies	$199.96
Logitech Controller	Amazon	$19.99
Anderson Power Connectors	Digikey	$6.03
Fuse Holders	Amazon	$15.97
25A Blade Fuses	Amazon	$4.99
5V5A Buck Converter with USB-C	Amazon	$9.99
Adjustable Buck Converter	Amazon	$9.99
Power Switches	Amazon	$8.01
Ethernet Cable	Amazon	$37.99
Cable Cover (100ft)	Amazon	$22.99
Power Cable	Amazon	$71.99
Camera	Amazon	$219.96
RJ44 Connectors	DONATED	$1.00
Female to Female RJ45 Coupler	DONATED	$2.00
SD Card	DONATED	$20.00
Raspberry Pi 4B	DONATED	$80.00
Nylon M2.5 Screw Set Standoffs	DONATED	$2.00
Sabertooth	REUSED and DONATED	$120.00
Thrusters	REUSED	$240.00
Hardware		
Polypropylene Rope	DONATED	$5.98
Carbininer Clamp	DONATED	$7.44
Lock Nut Set	Amazon	$5.99
M3 Screw Set	Amazon	$7.99
M3 inserts	Amazon	$6.69
3x7x3 mm Bearings	Amazon	$8.29
Marine Heat Shrink	Harbor Freight	$23.96
Zip Ties	Amazon	$7.98
Pinion Gear	DONATED	$24,00
Hex Nuts	DONATED	$9.00
Flat Washers	DONATED	$9.00
Silicone Caulk	DONATED	$16.00
JB Weld Marine Epoxy	DONATED	$12.00

Total Budget Spent	Total Material Cost
$777.26	$1,606.24

Table III: Materials cost breakdown.

Budget

Our materials budget for this project was $800. $400 was provided through our yearly student organization budget from Edmonds College. $200 was kindly donated by Cozy Nest Daycare, our sponsor. That donation was matched 100% by Edmonds College. In addition to our monetary budget, we received several donations of parts and materials from Edmonds College, Atlantis S.T.E.A.M., and members of the team.

Our total expenditures from that budget came to $777.26 as shown in Table III.

Travel Expenses

Travel expenses were generously donated by MATE ROV to ensure that Triton Tech ROV would be able to attend the international MATE ROV competition this year. The costs are as follows:

Airfare	$1.080.50 (x6)	$6,483.54
Lodging	$1,484.00 (x2)	$2,968.00
Meal Stipend	$300 (x6)	$1,800.00
Van Rental	$598.69 (x1)	$598.69
	Total	$11,850.23

Table IV: Travel cost breakdown.

Wholesale and Resale Costing

Amount:	For:
$2,409.36	Material Cost x 1.5 (*For variable costs and future manufacturing*)
+ $500	Estimated R&D (*Reduced from total R&D expenses for per-unit price*)
+ $300	Estimated Manufacturing and Assembly Labor (*Per unit*)
+ $100	Estimated Marketing Budget (*Per unit*)
x 1.1	*10% Profit Margin*
$3,640.30	**Wholesale Cost of 1 Jellyfish Unit**
x 2	*Retail Markup*
$7,280.60	**Retail Cost of 1 Jellyfish Unit**

Table V: Wholesale and Retail Cost Breakdown for Jellyfish

The above cost does not include a power supply or laptop, but does include a controller and the full tether.

Job Safety and Environmental Analysis (JSEA)

Job Safety Analysis

JOB STEP	POTENTIAL HAZARDS	SAFEGUARDS	RESPONSIBLE PERSON(S)
Piloting ROV	**HAZARDS RELATING TO ROV:** Tripping hazard regarding the tether cables. **HAZARDS RELATING TO PERSON SAFETY:** General pool safety which includes: - No running around pool - No horseplay	● Make sure everyone in the pool area is aware of the ROV and where it is operating at all times. ● Cover tether and other cables along the floor with mats.	Everyone on the team.
Power management	Miscommunication regarding power supply leads to mismanagement and can cause serious injury.	● Clearly communicate "POWER ON" when the power supply is on, and ensure all who are present understand and repeat it. ● Anyone may call "POWER OFF", and all present must repeat it as the pilot switches off power. ● Only the tether handler may call "POWER ON", and the pilot must not switch on power without this call.	Primarily: tether handler and pilot. Additionally: everyone on the team must participate in echoing "POWER ON" and "POWER OFF".

Table VI: Job Safety Analysis

Environmental Analysis

When prototyping the claw, we realized the gear, composed of steel, was grinding against the rack, which is 3D printed, due to material composition differences. The consequence of this would be plastic fragments leaking into the surrounding water and environment, which are detrimental to ecosystems. To find a solution for this, parts would need to be replaced periodically to prevent excessive plastic fragmentation.

Any plastic parts also introduce microplastics into the environment. We recognize this damage and encourage future iterations on our product to minimize this impact by using fewer plastic parts when possible.

Great care was taken to ensure that materials exposed outside of the pressure vessel were secured and would not leave waste in the environment. We also ensured that all wires outside of the ROV pressure vessel were covered with insulation and/or marine grade heat shrink to avoid electrical harm to marine life.

Appendices

References

[1] TheKnowledgeAcademy, "What is WebSocket and How does it Work?," Theknowledgeacademy.com, 2023. https://www.theknowledgeacademy.com/blog/what-is-websocket/ (accessed May 21, 2025).
[2] J. Elmore, "Heat Sinks: The Ultimate Guide to Choosing the Best Material," TheTechyLife, Feb. 27, 2025. https://thetechylife.com/what-is-the-best-material-for-a-heatsink/ (accessed May 21, 2025).
[3] AZO materials, "Aluminium - Specifications, Properties, Classifications and Classes," azom.com, May 17, 2005. https://www.azom.com/article.aspx?ArticleID=2863 (accessed May 21, 2025)
[4] "What is Acrylic: Properties, Processing, and Applications - HDC," Hdcmfg.com, Oct. 21, 2024. https://hdcmfg.com/resources/blog/what-is-acrylic-properties-processing-and-applications/ (accessed May 21, 2025)

Software Used

We used https://www.remove.bg/ to remove the background from our photograph of the completed Jellyfish. We also used https://canva.com/ to create several graphics for this technical documentation, including the SID and cover page.

Google Drive and its various editing tools were heavily utilized for team collaboration on technical documentation and general coordination.

Discord provided us a platform for discussion and remote work.

Git was used for version control, with GitHub and GitHub Projects being utilized for collaboration on the project management and programming.

We used the following libraries and APIs for our code:

- JavaScript APIs:
  - Gamepad API: https://developer.mozilla.org/en-US/docs/Web/API/Gamepad_API/Using_the_Gamepad_API
  - Websockets API: https://developer.mozilla.org/en-US/docs/Web/API/WebSockets_API
- Python modules and libraries:
  - Threading: https://docs.python.org/3/library/threading.html
  - Flask: https://flask.palletsprojects.com/en/stable/
  - Configparser: https://docs.python.org/3/library/configparser.html
  - pySerial: https://pyserial.readthedocs.io/en/latest/pyserial.html
  - Time: https://docs.python.org/3/library/time.html
  - RPi.GPIO: https://pypi.org/project/RPi.GPIO/
  - Opencv-python: https://pypi.org/project/opencv-python/
  - JSON: https://docs.python.org/3/library/json.html
  - Asyncio: https://docs.python.org/3/library/asyncio.html

- CSS Frameworks:
  - TailwindCSS: https://tailwindcss.com/

Our full codebase can be found at https://github.com/TritonTechROV/ROV2025.

Other Resources

As mentioned in our design rationale, we reused the thrusters from Triton Tech ROV's 2024 model. Last year's team used the following free model, with a slight adjustment, to print our thruster guards: https://www.thingiverse.com/thing:2854024