2026 Technical Documentation

Sequoia Marine Solutions (SMS)

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Fresno, CA, United States



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Abstract

Sequoia Marine Solutions (SMS) is a MATE ROV company at California State University, Fresno, consisting of undergraduate students who are designing, constructing, and marketing an ROV & vertical profiling float to compete in the 2026 MATE ROV World Championship in St. Johns, Canada. SMS is proud to present ROSIE (Remotely Operated Submersible for Innovation and Exploration), an ROV designed to complete all of the designated tasks this year, including species collection, servicing subsea observatories, and oil platform maintenance. ROSIE is modular, lightweight, and has a small profile, making it well-suited to complete these tasks. This document provides an overview of our design and development processes, as well as our safety standards, costs, company reflection, and more.

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Project Management

Company & Personnel Overview

Sequoia Marine Solutions is a first-year company that has a C-Suite Executive team that works closely with the seven subsystem team leads, who in turn work with our general employees. SMS' seven subsystems are staffed with appropriate combinations of Mechanical Engineers and Computer/Electrical Engineers.

Table 1: SMS Roles and Responsibilities

Role	Responsibility
CEO	Establishes company direction, long-term goals, external relationships, and final priorities.
COO	Coordinates day-to-day operations and keeps leadership decisions moving into team execution.
CPO	Oversees planning, personnel coordination, marketing, finance, and operations support.
CTO / CDO	Set technical and design standards, guide design reviews, and support integration between technical leads.
CSO	Oversees team safety procedures, and documentation, safe operating practices during building, testing, and competition.
Leads / Directors	Guide subsystem work for development of the ROV and float, as well as company interests.
Deck Management	Coordinates surface setup, tether handling, operational readiness, and testing/competition logistics.
Employees	Work on interdisciplinary projects, support subsystem development, assist with testing, and consult leads for guidance.

Schedule

As a new company, SMS is still working to develop a year-round schedule. To the right is our projected schedule, with December to May being accurate to this year's timeline. The goal is to onboard and train new members throughout the competition process. The Fall semester is spent learning from past experiences to identify overarching company goals. Winter break is focused around research, brainstorming, and developing of the company's planned solutions for given MATE tasks. Then, the Spring semester is the time for manufacturing, testing, and finalization.



Figure 1: Year-Round Schedule

Organizational Structure

An important factor to every company is the official structure. Due to the team size and the newly established nature of the host club, SMS decided to establish a C-Suite, while having individual leads for different subsystems. This allows clearer communication, and a fuller picture for each employee. The rigid structure (see Fig. 2) was established early on, and influenced design processes as well as purchasing and other administrative duties.

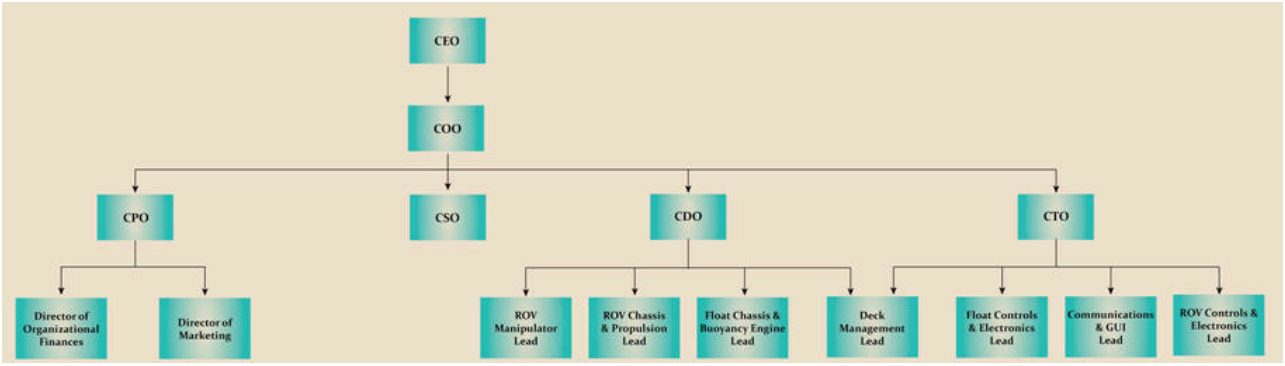


Figure 2: Sequoia Marine Solutions' Organization Chart.

ROV Design Overview

ROSIE

ROSIE (Remotely Operated Submersible for Innovation and Exploration) was designed for modularity, compactness, lightweightness, and strength. The design for ROSIE surrounded the Blue Robotics pressure hull that MATE had provided.

Initially, 1-in PVC pipe was used to make the chassis around the pressure hull. Aluminum t-slot rail was used in the second iteration to increase the modularity of the build while remaining lightweight. PETG was used as the main filament for 3D printed parts because it does not warp if left unprotected in the Central Valley heat (the way that PLA does) and because it is more durable in saltwater. Most external components of the ROV were 3D printed because it was cost effective and supported the modularity of the piece. To maintain strength, each print was infilled at 35% with five walls around the print.

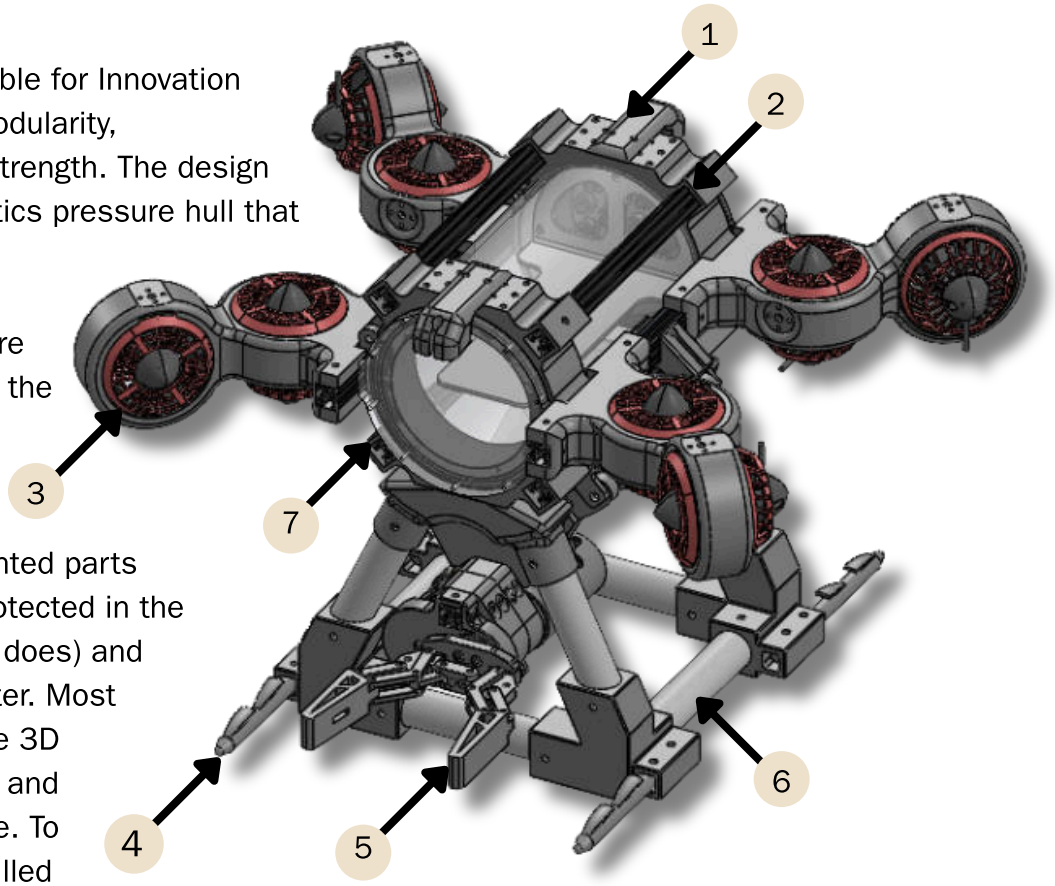


Figure 3: ROSIE the ROV fitted with all components

The team opted not to waterproof the 3D prints because when water filled the prints it added ballast, as well as ensuring that the ROV remained below the 18 kg weight threshhold.

The rotating manipulator claw was a late addition to the design that increased the dexterity of ROSIE and made completing the tasks easier. Stacked thruster mounts provide stability in currents and prevent thruster wash. The four harpoons allow ROSIE to pick-and-pull samples and wires throughout the tasks. Due to their print orientation they are also strong enough to lift a lobster pot without assistance from the primary manipulator (although the primary manipulator is also capable to lifting the lobster pot on its own as well). Cameras and sensors were the last elements to be added on, with a front, rear, and underside-facing camera available to the pilots for ease of maneuverability, as well as for use in the photogrammetry and crab identification tasks. Additionally, an IMU was added for additional stability while operating the ROV in currents of variable intensity.

Design Components

1. Camera mounts on front, back, and bottom for ease of piloting
2. T-slot rail for modularity
3. Stacked thruster mount to prevent thruster wash
4. Harpoon for rigid manipulation
5. Rotating manipulator
6. PVC pipe legs for stability
7. Blue Robotics waterproof pressure hull to protect electronics

Design Rationale

Planning and Design Process

Research: Nothing is ever born from a vacuum, so the team's brainstorming process included researching previous designs both related to the competition and unrelated components which may have proved useful, comparing them to the resources freely available to the team, and then analyzing the feasibility of each component. The thruster mounts and layout were a particularly tricky piece of the puzzle to research, requiring a knowledge of fluid dynamics to effectively design.

Identifying problems and constraints: The thruster mounts were originally designed to be at the four corners of the pressure hull as well as at the cross-sections, completely surrounding the pressure hull. This mathematically made sense and would have been very maneuverable. However, this was unfeasible because that would severely limit the team's access to the front and back caps.

Finding solutions: The thruster mounts were redesigned to be stacked horizontally on each other to prevent thruster wash and to allow for six degrees of freedom.

Prototype and Testing: The original stacked design had the screws holding the T-200s hidden within the mounts, but that was quickly adjusted for the sake of maintenanceability. The trade-off was that the T-200s would be more susceptible to vibrations, however this did not seem like something that would be a major issue.

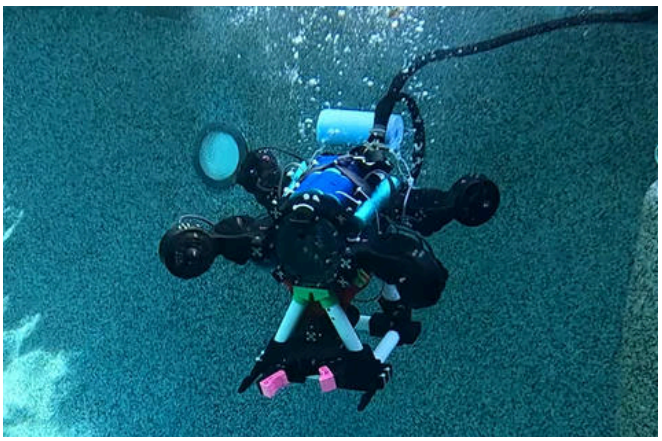


Figure 4: ROSIE operating underwater

Systems Approach

ROSIE's system design approach focused on **subsystem integration and iteration**, meaning, all the subsystems worked together at the same time to organically develop the entire system while emphasizing the team members individual passions for different aspects of the project.

Subsystems: Before assigning team members to their subsystems they were given the chance to try all different systems pertaining to their career emphasis. Mechanical engineering majors were spread out amongst the ROV Chassis, Float Chassis, and Manipulator teams. Electrical engineering majors were spread out to the ROV Controls and Electronics, Float Controls and Electronics, and GUI teams. All other majors got to choose where they went.

Communication: There were weekly meetings and check-ins to ensure that every subsystem was on the same page in terms of design. As designs would develop, the leads would contact each other and discuss the feasibility of the changes.

CAD software like Solidworks was invaluable for evaluating how components fit together and for designing the parts alongside each other. The files were organized using a spreadsheet and numbering system that allowed the mechanical team to organize their CAD files per subsystem and easily communicate with each other.

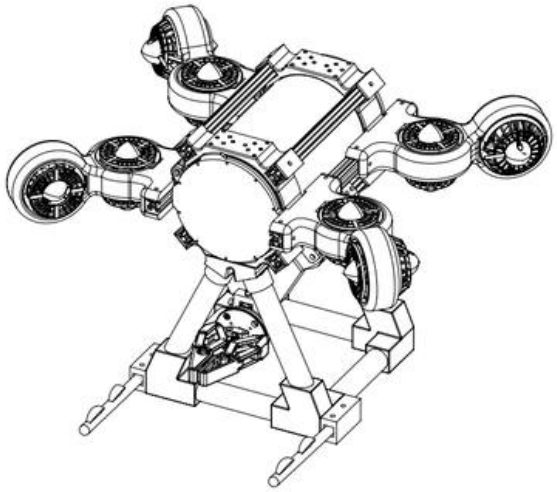


Figure 5: A prototype blueprint of ROSIE

Vehicle Structure

The overall vehicle size was kept as **compact** as possible to improve maneuverability and reduce drag underwater while still leaving enough room for all major subsystems. Thrusters were spread out to avoid thruster wash and to increase stability in currents. **Weight** was also considered throughout the design process, so reinforcement was only added where necessary instead of overbuilding the structure. Throughout development, the team compared different materials and design options based on strength, weight, manufacturability, cost, and how well each component integrated with the rest of the vehicle. **Big priorities in the design** were: weight (must be less than 18kg) – for maximum bonus points and ease of transport and handling, low cost – being a first year team SMS had limited resources to bring the vision to life, and modularity – because setting a foundation of modularity sets the future of the company up for success.

PETG was selected as SMS's primary filament for reasons documented in Table 2. PETG is accessible to beginner 3D printers, and has acceptable tensile strength, toughness, water resistance, and heat resistance for SMS's applications. PLA was used in some prototyping by was prone to warping (especially if left in a car in the Central Valley heat). TPU was selected for flexible grip designs for its ability to conform to the shape of objects grasped by the manipulator. **Black** was selected as the primary filament color of the ROV because it has the highest strength of standard color blends.

When submitted for printing, SMS parts were assigned to one of two continuously-refined setting groups: **air test or water test** and a PDF was sent to the printer for each component (see Figure X). Air test prints used 15% infill and 2-3 walls, allowing for maximum filament saving and quick initial fit tests. Water tests used 35-50% infill and 5 walls and shells, allowing for optimized strength and minimized mass absorption underwater. That being said, the 3D printed parts do absorb water and this was used to add ballast to the system and prevent the legs from swinging up towards the surface of the water.

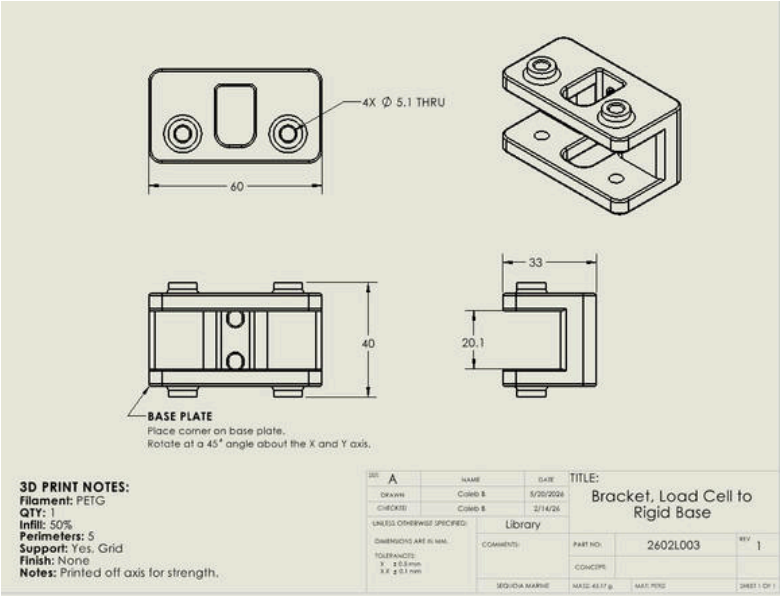


Figure 6: Sample of a drawing intended for 3D printing

Filament	Printability	Tensile Strength	Toughness	Water Resistance	Heat Resistance
PETG	High	Moderate	High	High	Moderate
TPU	Low	Low	Very High (Flexible)	High	Low
ASA	Low	High	High (Brittle)	High	High
PP	Unacceptable	Moderate	Moderate	Very High	High
PLA	Very High	High	Moderate (Brittle)	Moderate	Unacceptable
Nylon	Unacceptable	Very High	Very High	Unacceptable	High

Table 2: Decision Matrix for filament types

Innovations

A significant paint point identified early in the season was the **installation of T-nuts** into the T-slot rail. One would think they would be easy to install, since they are made to be used together. However, the team quickly noticed the T-nuts sliding around in the rail channels and falling out and otherwise being an enormous pain to deal with. The solution was a set of thin **jigs** that slid into the channels and held the T-nuts in position so they could be easily screwed into. Two versions were created, the thruster mount jig (Figure X) which would be printed in sets of four, and the general jig (Figure X) which was used to mount the rotating manipulator and its motors.



Figure 7: General jig

Previous to making the jigs, the rough set-up time was about 2 hours to attach the thruster mounts and manipulator onto the chassis. After the jigs, maintenancing time for ROSIE was reduced to **30 minutes** for removal and reattachment of the thruster mounts and the manipulator (assuming the manipulator didn't need any other work done).

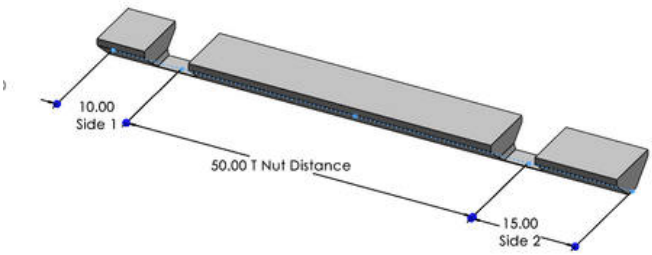


Figure 8: Thruster Mount jig

Another innovation the team made was the **harpoons**. While harpoons in and of themselves are not revolutionary, they absolutely changed the game for SMS. The original purpose of the harpoons were simply to efficiently drive-by grab the basket stars, thereby reducing trips to the surface. However, they proved useful for a mulltiude of tasks such as replacing the eDNA sensor, carrying spools, picking up the lobster pot, etc.



Figure 9: Harpoon

With **curved fins** that allow smooth grabbing and retention of the basket stars, a lip that prevents objects from accidental dropping, the harpoons proved just as versatile as the rotating manipulator. On the qualification run of ROSIE, the basket star, eDNA sensor, cap, and coral sample were all able to be brought to the surface **simultaneously**. An additional two harpoons were added to the back of the ROV that can be seen by the back camera so the pilots can back into samples that may move away from ROSIE in the current.

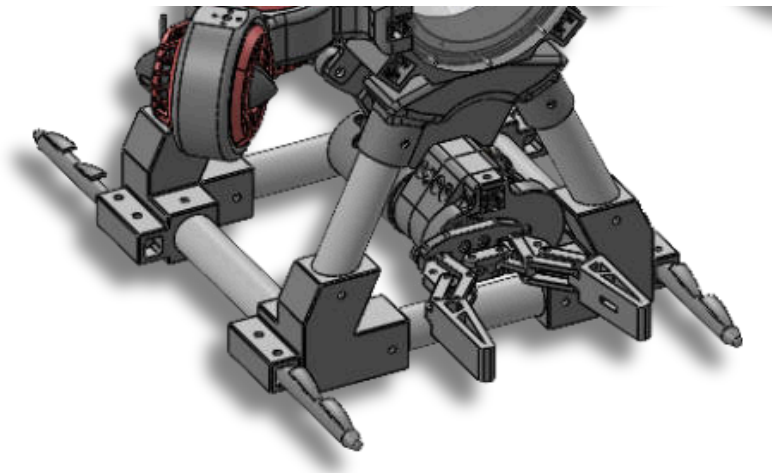


Figure 10: All four harpoons mounted to the chassis

Vehicle Systems

For the propulsion system, **T-200** thrusters were selected for their compact size, reliability, and high thrust output for the cost. A layout of eight thrusters was selected to achieve all six degrees of freedom and maintain stability in a current.



Figure 11: Thruster Mount with T-200 propellers

The manipulator rotates smoothly and easily with the help of plastic bushings. These were made of a plastic blend that offers low friction, self-kubrication, and moisture resistance.

The **plastic material won't rust** like most metal bearings and was chosen over stainless steel or ceramic bearings that would have been more expensive. The bushings were also thinner than bearings, allowing for stronger/wider rotation shaft.

Design Evolution

The first version of the manipulator's rotation mechanism functioned by spinning the entire t-slot that the manipulator parts are mounted to. The second rotation motor would have been directly attached to one end of the t-slot so that it could directly rotate the t-slot. This idea was quickly abandoned as it appeared to have many issues. One major one is that since the **leadscrew** motor was mounted to the rotating t-slot, if the t-slot rotated too much in one direction the motor wires would bind up, preventing further rotation and potentially damaging the wires. The design was also not very rigid or stable. The rotation motor would need to turn the entire weight of the manipulator, increasing needed torque. The rotating T-slot is a cantilever beam holding the weight of the motors, claw, and any collected object. Due to this we needed a way to support the T-slot while allowing it to spin, increasing the overall width. Furthermore, since the motors were in-line with each other, this greatly increased the overall length needed. Our second version of the rotation mechanism used gears to achieve rotation. In this design both the rotation and leadscrew motor are nearly side by side. Mounted to the back of the baseplate of the claw is the driven gear, this gear is concentric with the leadscrew, the leadscrew passes through this gear. A shaft on the driven gear then slots into a shaft mount with bearings. The rotation gear drives the driven gear ,turning the entire claw. The rotation gear was directly powered by the rotation motor. Since both motors are rigidly mounted side by side, the overall size was decreased and the issue of wires binding up was solved. However this design still had a few important issues. Most **metal bearings will corrode underwater**, ceramic and stainless steel bearings were expensive and hard to source. Furthermore bearings are somewhat thick, this thickness would require us to decide between a large shaft mount or a smaller/weaker drive gear shaft. The rotation motor was also too fast for our needs and didn't offer the desired torque. The weight of an object could also backdrive our motor. Our final rotation design functions very similarly to the second version except with a few changes to account for the issues with the previous design. The most major change was the addition of 2 4:1 planetary gearboxes for the rotation motor. This achieves a 16:1 ratio greatly increasing torque and reducing rotation speed. The gearbox also prevents backdriving of the rotaion motor. **Plastic bushings** were also used in place of bearings as they are thinner allowing room for a thicker shaft. Bushings are also longer allowing an increase to the length of the shaft and shaft mount increasing the claws stability. Both motor mounts were combined into one mount and the gearbox and shaft mount were also combined into one housing to help increase the compactness and reduce the number of parts to assemble/disassemble. Additionally, A ring shaped cap that is slightly larger in diameter than the shaft mounting hole is to the end of the shaft so that it cannot slide out of the shaft hole, while still allowing the shaft to rotate.

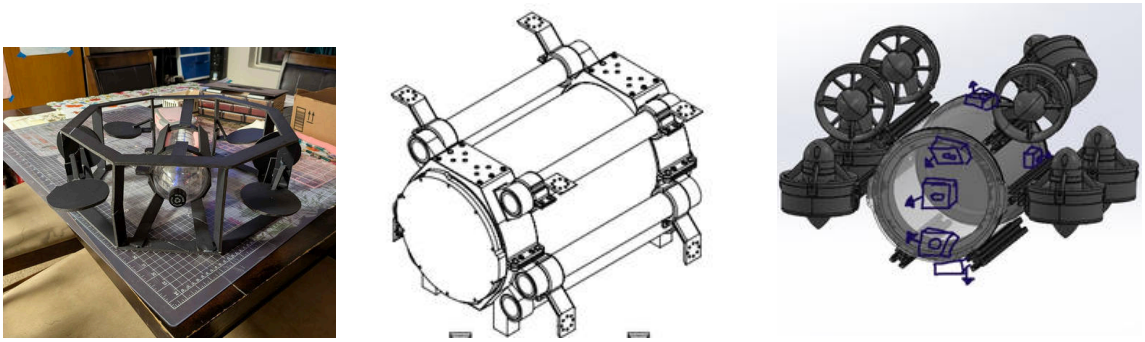


Figure 12: Versions 0, 1, and 2 from left to right

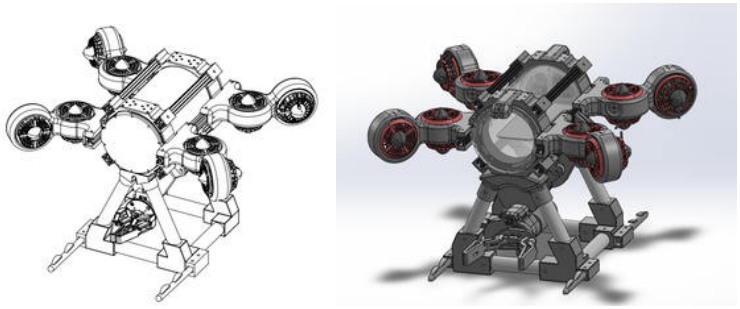


Figure 13: Versions 3 and 4 from left to right

ROSIE's propulsion design went through five distinct iterations, shown in the figures above. Each design prioritized obtaining 6 degrees of freedom to maximize our ability to approach and acquire mission props.

Version 0 was a foamboard mockup of an octagon shaped chassis, employing four vertical thrusters and two horizontal thrusters. Each foamboard panel represented an aluminum T-slot rail. SMS shifted away from this design because of the high density of the T-slot rail and the tolerancing complexity of the 32 required 45° angle cuts into the rails.

V**ersion 1** implemented a set of two enclosure clamps and six 1-in diameter PVC pipes running axially along the chassis tube. The PVC pipes enabled SMS to test the layout prior to cutting into any T-slot rail. The PVC pipes were used as potential mounting locations for other components to the chassis, such as cameras, thruster brackets, manipulator connectors, and leg adapters. Once fit tested and the concept verified, the PVC was replaced for T-slot rails. Version 2 also included a 4 DOF robotic arm, which was not fully implemented in the final design due to its complexity.

Version 2's thruster orientation was determined via an analysis of MATE's top ten product demonstration teams. SMS observed that 80% of the top ten teams used a thruster orientation with four vertical thrusters and four horizontal thrusters oriented at a 45° angle. SMS then adopted a similar orientation, which provided 6 degrees of freedom.

Version 3 introduced enclosure clamps capable of rotating open to provide easy removal of the chassis tube. PVC pipe legs were introduced, providing protection and space to mount the manipulator below the chassis tube. In this design iteration, the manipulator was capable of opening and closing, and was rigidly mounted to a T-slot rail below the chassis. Harpoons were introduced to aid easy pick-up of the basket stars.

Version 4 added rotation to the manipulator, significantly improving our ability to perform tasks such as installing the power connector or removing biofouling. Two additional cameras were added to improve the pilots' field of view, introduced alongside a custom 21-holed anodized aluminum backplate with additional holes to accommodate them. Legs were given a wider stance for additional stability and shortened to locate the manipulator closer to the ground. Bolt locations in the thruster mounts were repositioned to allow easy individual removal of each thruster, increasing the ease of maintenance. Strain relief transitioned from a double-layered polyethylene strap to a steel plate rigidly mounted to the frame of the ROV. Side straps were implemented for ease of handling, allowing the deck team to efficiently remove the ROV from the water. Harpoons were refined to allow pick-up of all rope-based props, extending their functionality beyond the basket-stars.

Electronic Design & Cabling

The inner chassis of the ROV is separated by a base plate to enable more mounting space for electronics. To ensure complete electrical isolation of power electronics, the base plate is wrapped in electrical tape to ensure non-conductivity, preventing electrical mishaps before they occur. The layout of connectors on the back plate is strategically placed so that power **electronics are compartmentalized** into the bottom of the chassis for ease of maintenance, while more sensitive electronics are placed on the top for ease of visual confirmation of functionality. The power-carrying connections are routed through the bottom of the back plate to attach to the 48V-12V buck converter. From there, 12V power is sent to the power distribution network, powering all ESCs, automotive back-up cameras, and the 12V-5V buck converter. On the top half of the chassis, all ESCs are taped together via electrical and cloth tape to aid in ease of component and cable management. Fitting the bulky ESC cables in the chassis is accomplished by routing them through the top section of the chassis rather than into the bottom, avoiding downward strain on joints. Alongside the ESCs, 12V power is stepped down to 5V via a 12V-5V buck converter to feed the Raspberry Pi 4B using a USB-C cable. From the **Raspberry Pi 4B**, the absolute orientation IMU and PWM expansion board sit on each side of the Raspberry Pi. All three of these boards are secured with robust double sided tape, which is more serviceable and less cumbersome than fastening screws each time to secure components. Short jumper wires were chosen to reduce excess cable space, reducing risk of accidentally pulling a cable out of socket, while also utilizing limited internal space more efficiently.

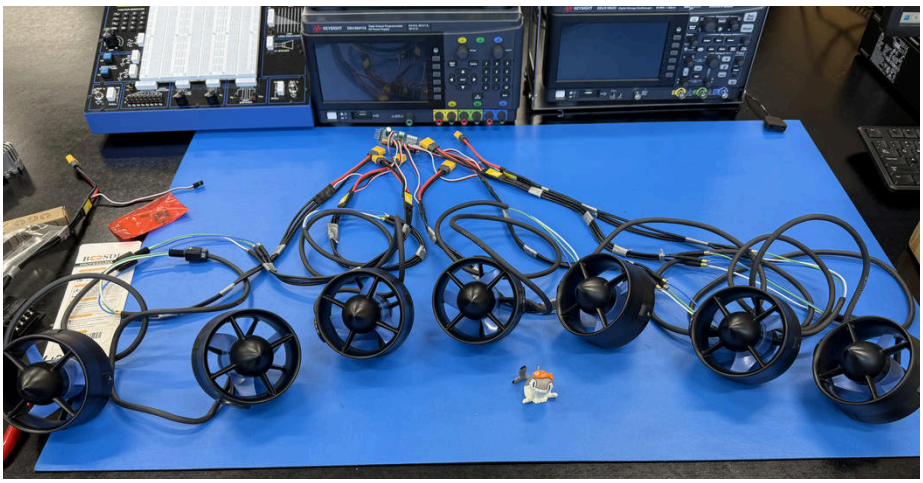


Figure 14: Eight thrusters and ESCs connected to the PWM Expansion Board

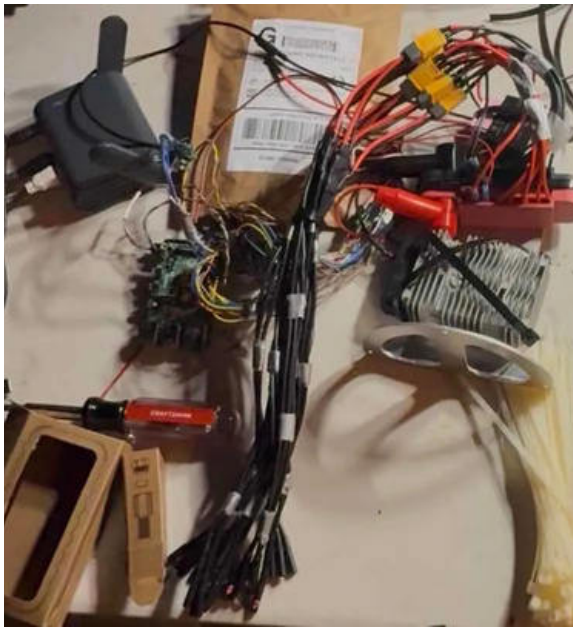


Figure 15: The internal electronics of the ROV connected to the WiFi router

Control System Software

The control system design that is in place allows for quick implementation for new items that need to be added to the ROV. To control the ROV, the surface side computer sends data packets of the current state of each controller. Based on those packets the Raspberry Pi 4B receives from the surface side computer, the inputs will be run through a controller class that maps all inputs to different thrusters and function of the ROV. The control system requirements were planned out by using a **UML class diagram** that displays all of the areas that are needed to be covered. Each table of the UML class diagram has its own subsections that go more in depth on how the code will be structured. SMS' Auto Leveling System (ALS) is utilized to stabilize the ROV in a pilot-defined, custom orientation. This system frees up the pilots mentally and physically to focus on the core aspects of each task. During implementation, the code was maintained in separate branches in GitHub to separate different versions of each function.

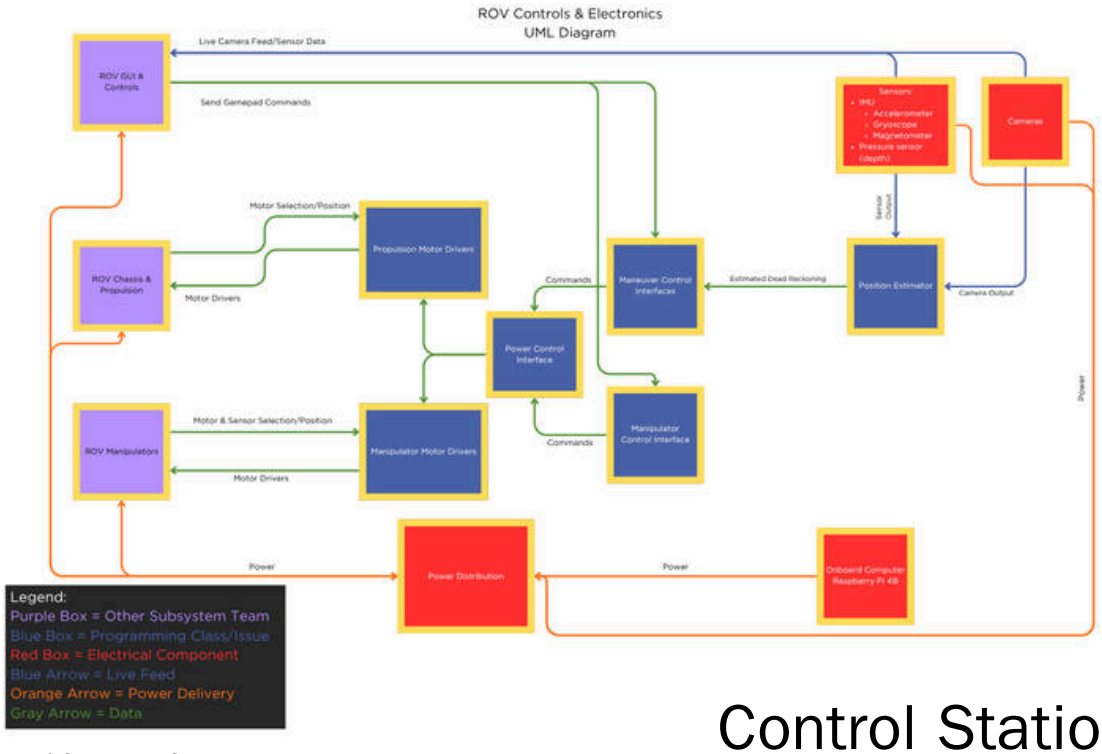


Figure 16: UML Class Diagram overview that shows each subsection of the control system design

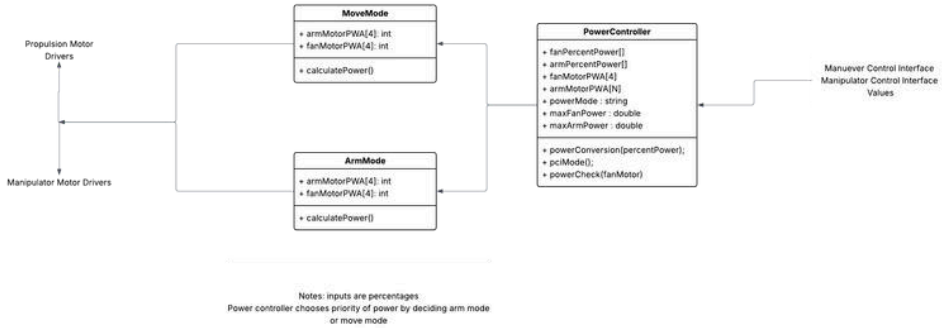


Figure 17: UML Class Diagram for the Power Control Interface subsection

Software Development Process

For the software development process, GitHub and Jira were utilized. Jira is a ticket system that can help manage code quality and progression. The process is to have a team member submit their code for **review in Jira**. Next, a team lead goes in for review, and checks for any issues in the script. If one is found, the script is rejected, and returned to the team member with notes on issues to correct. If the script is approved, it is sent to another team lead for a secondary review. Once the script passes the second check, it will be uploaded to the proper branch in GitHub. After a branch has reached its final version, it's added and merged with the code in the main branch. This process upholds a cleanliness standard for all code uploaded to the ROV.

Control Station

The control station set up was designed based on what the company observed during the MATE Regional Qualifier in Watsonville, CA. The team was able to devise that having two surface side computers would be the most effective option during our runs so that pilots wouldn't need to be disturbed between tasks to process anything. For ROV controls, SOL-R 2 HOSAS SPACE SIM DUO **ThrustMaster controllers** are used to provide precise maneuverability to the pilot, and an Xbox One controller for the co-pilot to allow quick and efficient control of different ROV peripherals. For communications, a WiFi router takes the ethernet cable from the tether, and allow the surface side computers to connect via LAN or WiFi connection to the router. To power the ROV, a 48V DC power supply will be utilized to provide the optimal amount of power to the ROV from the surface. There is an easy access kill switch that will shut off all power to the ROV in the case something goes wrong.

ROV Chassis and Propulsion

Buoyancy & Ballast

The ROV pressure hull was naturally buoyant. This was countered by the weight of all of the components both inside and out. The team then added some polyethylene foam ballast to be able to get closer to neutral buoyancy. This resulted in a slightly positive buoyancy.

Propulsion

The propulsion system used eight Blue Robotics T-200 thrusters, each of which is capable of producing approximately 50 N of forward thrust. To provide stable vertical control, horizontal translation, and rotational motion, four horizontal thruster were mounted around the mid-section of the pressure hull using custom angled mounts positioned at 135° from the chassis faces. Since the ROV was intentionally designed to be slightly positively buoyant, the vertical thrusters were oriented so the stronger forward thrust direction of the T200 opposed the buoyant force, improving depth control efficiency and reducing continuous motor strain. The eight thruster configuration was selected to provide greater stability, control authority, and payload handling capability during mission tasks, and although using additional thrusters increased power consumption, system weight, and overall cost, the improved maneuverability and vehicle stability were considered necessary for the tasks requirements.

Payload and Tools

VOX CAM7s, which are traditionally automotive back-up cameras, were used for the front, back, and bottom cameras. The AUTO VOX CAM7 cameras received a water proof rating of IP69K, so they are able to perform well under water without sustaining water damage. When these cameras were tested with the 3DF Zephyr, the photogrammetry software being utilized, the 3D models would not come out looking like the desired object. To solve this issue, a DeepWater Exploration exploreHD USB Camera from Blue Robotics was used to provide a clear, clean video

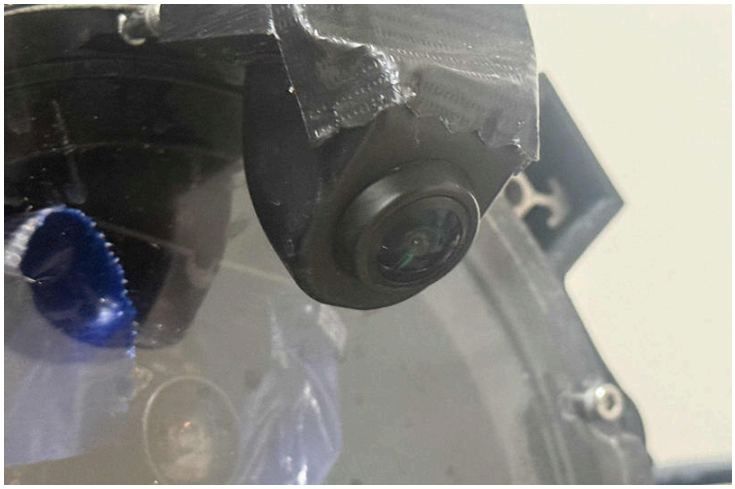


Figure 18: AUTO VOX CAM7 on the ROV

feed to achieve the photogrammetry and crab analysis tasks. Initially cameras were designed and connected through use of USB connection from computer to ROV. However, in order to reduce costs the team decided to utilize a streaming protocol starting with MediaMTX. Sending video packets over a network using TCP packets. This resulted in video but at a large latency of nearly 5 seconds, looking into other options the team moved to ffmpeg and got the latency down to around a second after many setting changes. There were many issues with ffmpeg on top of the minor latency, and the team struggled to establish connection and difficulty integrating it into the GUI. Later on, the switch was made to using Gstreamer to see if we can achieve better results with it than MediaMTX. Upon receiving the feed from the cameras, the results showed that there was a latency of 0.1 seconds, which is vastly superior to the latency from MediaMTX. The process to start up the cameras was much quicker due to its pipeline commands being easily readable. Gstreamer is also very compatible with QT, making the process to join the two more convenient.

The sensors that were selected were the Adafruit BNO085 9-DOF IMU and the Blue Robotics Bar02 Depth Sensor. The IMU helped with on the spot level correction, and keeps the ROV perfectly oriented when doing autonomous movement. The Bar02 Depth Sensor performs the measurements in the water, and outputs the depth in water.

Manipulators

To complete the mission tasks, ROSIE uses a primary 2 DOF manipulator and secondary static end effectors.

Claw Design: Uses a four-bar linkage system with the links in such a way that the opening/closing of the claw is powered by linear motion and achieves parallel motion when nearing full closure. To achieve this motion a leadscrew is mounted to a brushless motor. As the leadscrew rotates inside a heat set insert, the connector piece moves back and forwards moving the links in a way that opens and closes them.

Harpoon: Rigid manipulator that contains no moving parts. This manipulator is shaped like a harpoon with smooth fins inspired by the barbs of a harpoon. It was specifically designed for the task of picking up the basket stars. Due to its harpoon shape it can easily spear a basket star and use its barbs to hook it. Although it was made to pick up basket stars, testing has found that it can also easily hook the rope handles of the eDNA sensor. The harpoons are strong enough so that we can use 2 of them to pick up the lobster pot if needed.

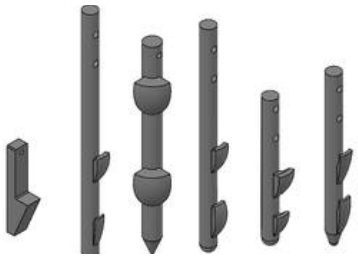


Figure 19: Iterations of harpoon (left to right)

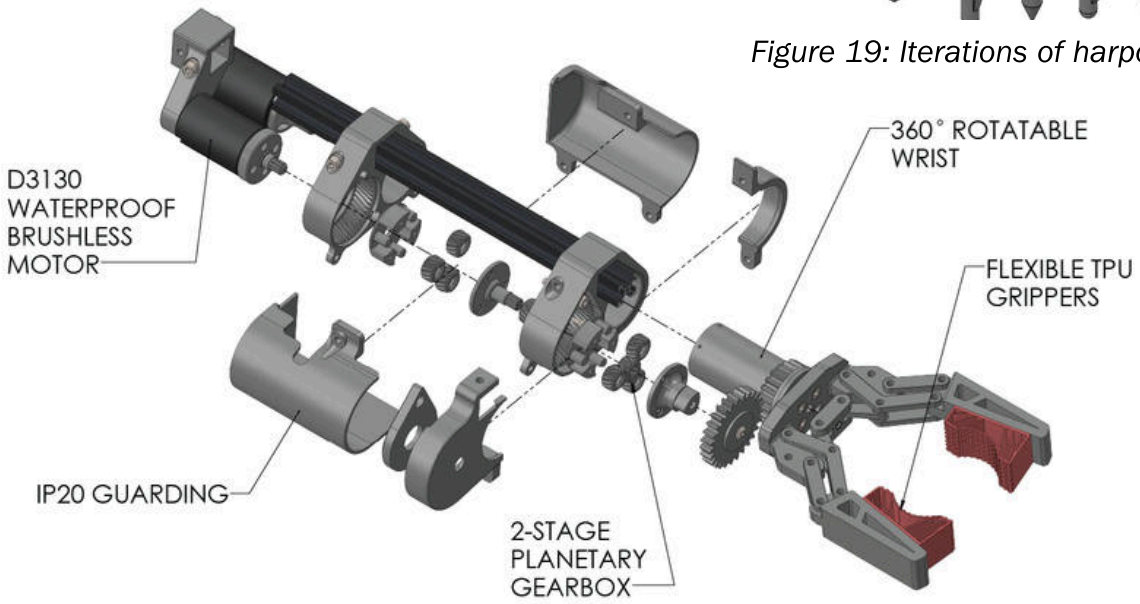


Figure 20: Explode view of SMS's 2 DOF Manipulator

Rotation Design: The rotation ability of the manipulator is useful as it allows greater ability to pick up and manipulate objects, some tasks become impossible without this ability such as removing the biofouling. Uses a 2-gear drive. The driven gear is mounted concentrically with the leadscrew and is mounted to the back of the baseplate of the claw. The housing of the driven gear shaft also includes two pressfit bushings. The rotation gear is powered by a DD 3130 waterproof brushless motor and placed at the output of the two 1:4 gearboxes. These gearboxes help reduce the speed of rotation while increasing torque to the rotation gear giving precise control to the pilots to **complete tasks more effectively** and **eliminates the need to make complex maneuvers** that can damage props. The bushings and gearboxes are mounted to the t-slot rail in two stacked housing parts placed in front of the motors. The driven gear shaft slides into the bushings and a cap is attached with wire to the end of the shaft, thus mounting the gear and claw to the housing while still allowing it to rotate. Since both motors are rigidly mounted to the t-slot behind the rotation mechanism, the claw can be rotated indefinitely without worry of any motor wires binding up.

Manipulators

3D Printed Gearbox: We used a free public design from a cad file sharing website and modified it to fit our purpose. The gearbox is a stackable planetary gearbox which offers a 1:4 ratio. The gearbox was resized to 70% its original size and input/output shafts were changed to better fit out needs. The input shaft was changed to mount directly to the rotation motor and the output shaft was made into a polygon. The polygon shape distributes stress much better than the traditional spline, increasing the shaft's max strength, torque, and lifespan. The gearbox housing was merged with the bushing mount and lid was changed to fit the modified output shaft.

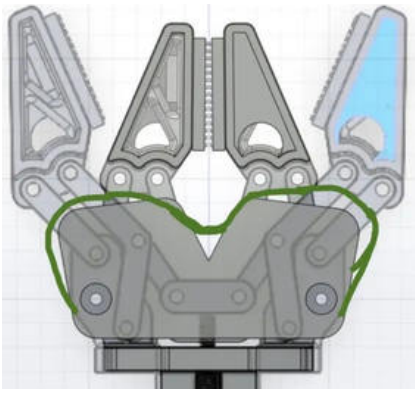


Figure 21: Linkage guard iteration

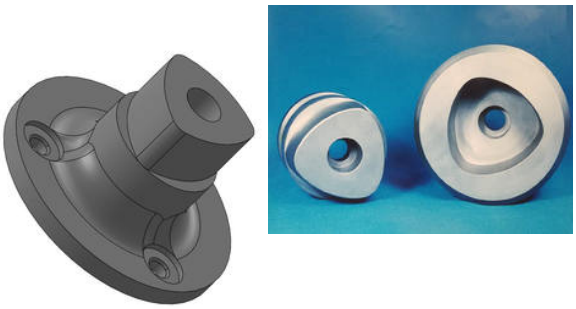


Figure 22: Polygon shaft for output torque

Protective Safety Guards: Uses custom 3D printed guards to completely cover the rotation gears, claw linkages, both motors, and leadscrew to IP20 standards.Motor guards completely protect the motor and leadscrew. Gear guards completely protect the 2 gears used for rotation. Claw guards protect linkage pinch points from the top and bottom as well as sides. Each mount can easily be taken off for maintenance or replacement by removing only 2 bolts; all of them come off easily without having to remove any other components.

Power Choice: For our manipulator we needed a way to move the connector piece for linear motion and a way to power the rotation. We decided to use brushless motors and a lead screw to achieve our needs. Using pneumatics for our linear motion would have been expensive, and requires pneumatic tubes to be run to the surface. Additionally no member of SMS has experience using pneumatics. unlike brushless motors, this is also one of the reasons for choosing brushless over servo or stepper motors for rotation of the claw. Waterproof servos were expensive and cheaper alternatives were too difficult to waterproof; stepper motors are also prone to corrode underwater. Therefore, two HobbyWater DD3130 brushless motors were purchased at a good price, providing a low kv for better torque, and are waterproof up to 300m. They are fast enough to turn our leadscrew quickly and offer 0.7Nm of torque which is enough grip onto objects and rotate the claw when using TPU grips and gearboxes.



Figure 23: Potting inexpensive motor



Figure 24: JB Welding DD3130 motor

Comparisons helped determine the direction of end-effector design to meet task requirements:

End-effector Type	Pros	Cons
Four-bar (selected)	Parallel motion improves grip stability	Linkages require accurate alignment during assembly
	Modularity for different grips to optimize for different objects	
	Less dependent on ROV's precise alignment	Higher part count compared to other designs
Clamping	Easy to assembly, minimal printing	Objects prone to slipping
Rigid (harpoons)	Simple, easy mounting to chassis	Designed only for a specific task
	No moving parts, less slop	Relies on precise positioning of the ROV
	Multiple can be mounted on the ROV, allowing multiple objects to be picked up before surfacing	String can easily get caught on the harpoon and can be difficult to unhook

Prototyping and Testing

Extensive focus was placed on optimizing the manipulator to securely grasp mission props, primarily by reducing the play in the gripper links. Slop in the link was corrected by tightening tolerances, loosening in the lead screw by adding a heat set insert mount, and introducing a guide bushing, and misalignment in the wrist by adding a second dry running bearing.

Additionally, 9 TPU grip designs were developed over the season to increase flexibility. A ray-fin design was adopted to conform around curved shapes, and bumps were added to reduce the lubrication effects of the water surrounding the surface of each prop.



Figure 25: Dry running bearing for wrist shaft

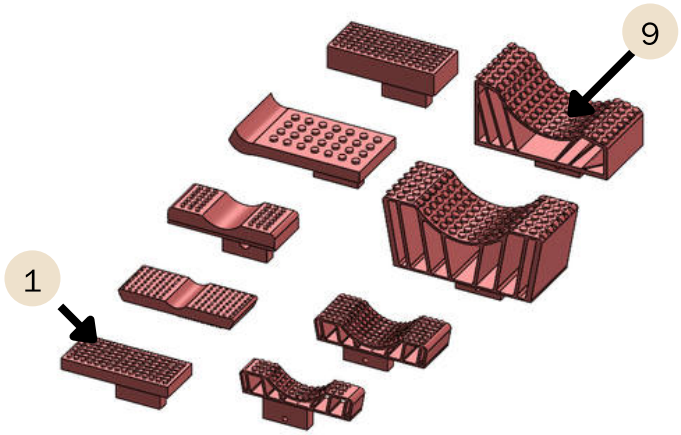


Figure 26: TPU grip iterations over time

Float

This year, Sequoia Marine Solutions has designed the Aquatic Data probe for Autonomous Monitoring (A.D.A.M.). A.D.A.M. utilizes a peristaltic pump as a buoyancy engine, to facilitate vertical profiling by changing the density of the float with water intake and output to descend and ascend respectively. Extensive testing of the peristaltic pump determined that while the flow rate had a higher variance in colder temperatures, the flow rate remained relatively constant over time regardless, including cold-start and kink-tube scenarios.





Figure 27: Sheet metal rails, shelves, ballast (left)
Figure 28: Machined endcap holes & NPT threads (right)

A.D.A.M. utilizes a Raspberry Pi Pico 2 microcontroller, which communicates with peripheral devices and processes all data collected during each vertical profile. The Pi Pico 2 connects to a pressure/depth sensor via one of two built in I2C buses, and uses this data to calculate subsurface position prior to wireless transmission. A.D.A.M. is designed to execute a PID loop, in which it repeatedly performs a vertical profile while also following a stabilization algorithm to calculate the required pump input or output to account for buoyancy changes and depth corrections. All data collected during vertical profiling is transmitted via LoRA using 915 MHz frequencies and an internal antenna, offering a secure and power efficient method for wireless communications underwater due to lower signal absorption. Power is supplied by a 2000 mA/hr NiMH AA rechargeable battery pack, ensuring sufficient power for ~1hr underwater operation, alongside a 2A blade fuse providing sufficient overcurrent protection for the 1.65A FLA.

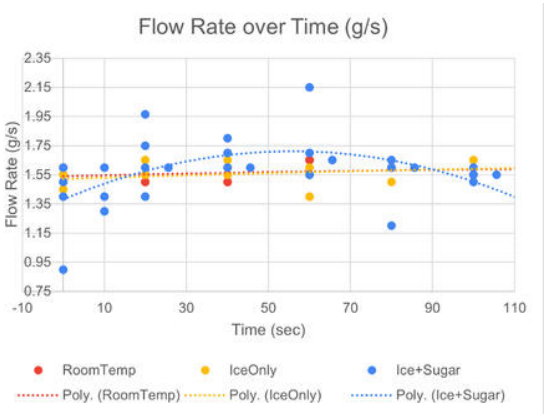




Figure 29: Flow Rate vs Time Graph (left)
Figure 30: Assembled Float (right)

In addition, A.D.A.M. features a stainless steel internal rail system that allows the internal electronics to be easily removed from the float chassis. Two side rails and two shelves (one vertical, one horizontal) have been custom machined in-house from stainless steel to fit the float's storage needs and are attached to the topmost endcap for ease of access and removal as well as safety (so that the weight of the railing system does not push out the bottom endcap). Customized ballast plates (also machined in-house from stainless steel) allow for adjustments in increments of ~ 4%, 2%, and 0.5% of the overall mass when necessary. The top endcap was additionally machined to hold an NPT-threaded hole for water intake and a pressure release.

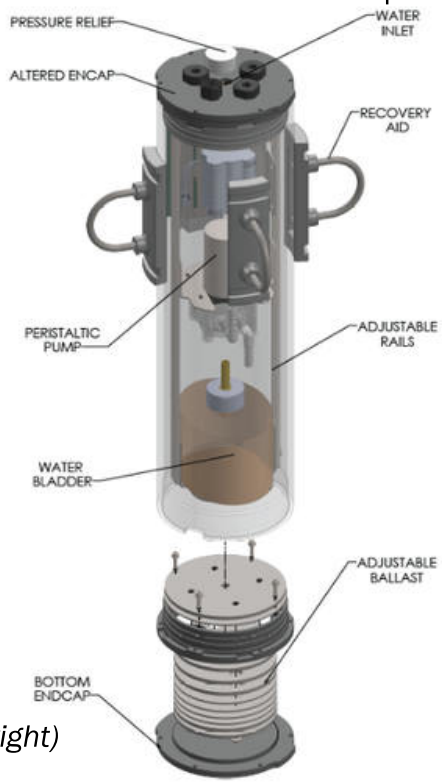


Figure 31: Solidworks CAD assembly design (right)

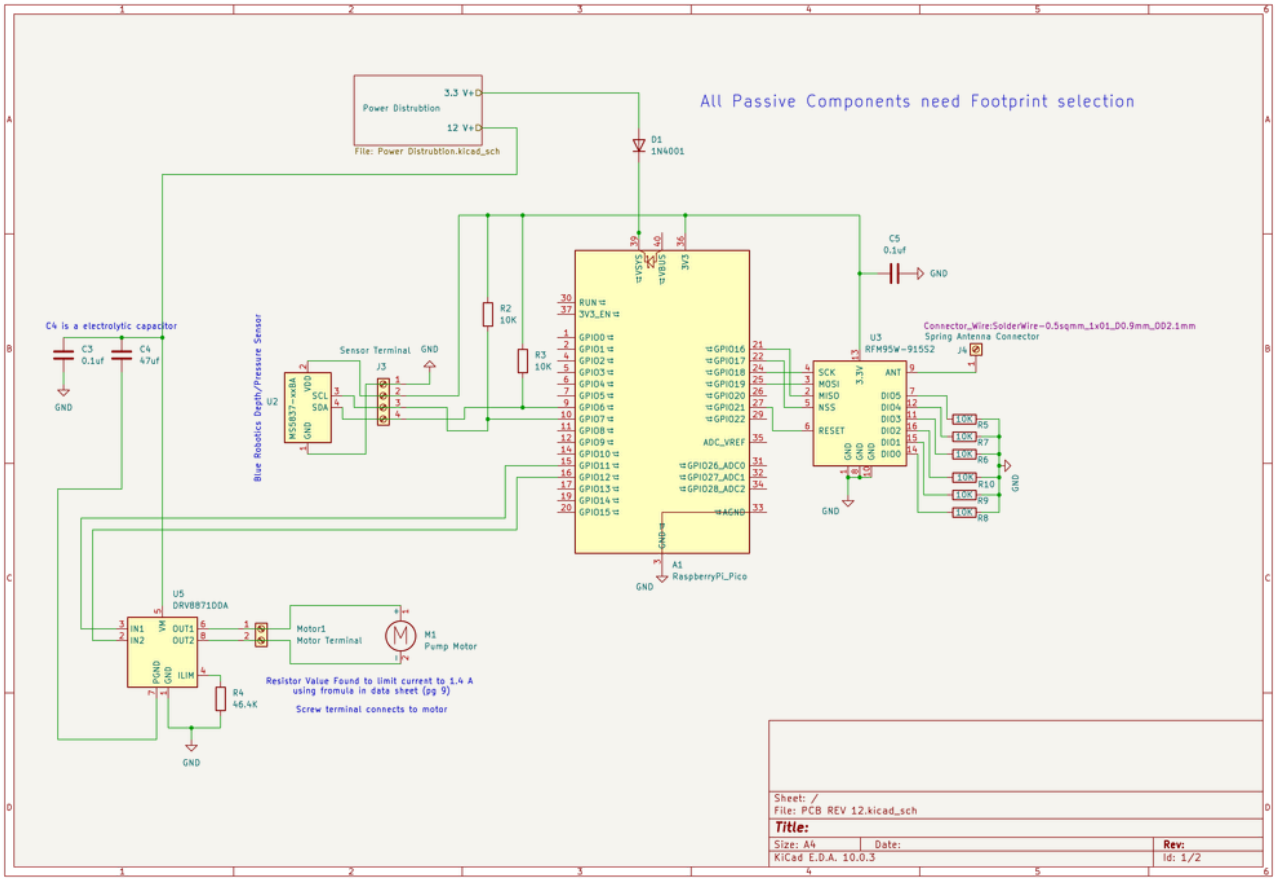


Figure 33: Detailed PCB schematic

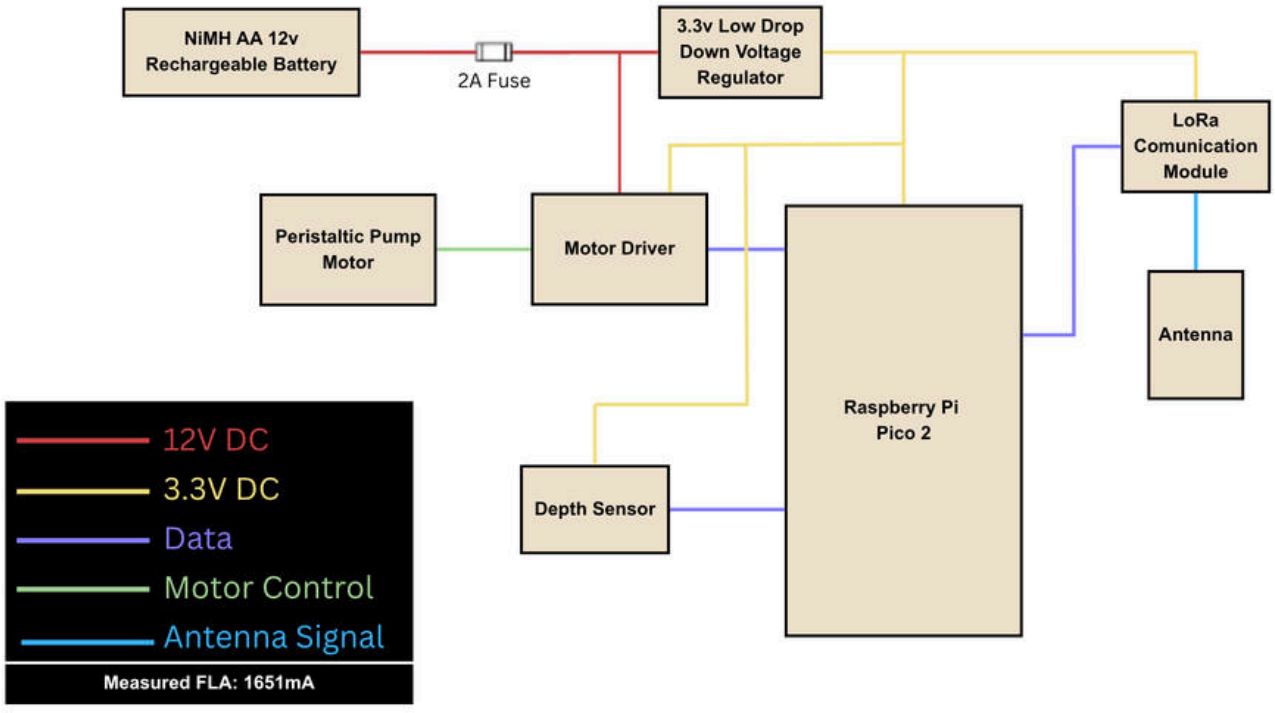


Figure 33: Float SID

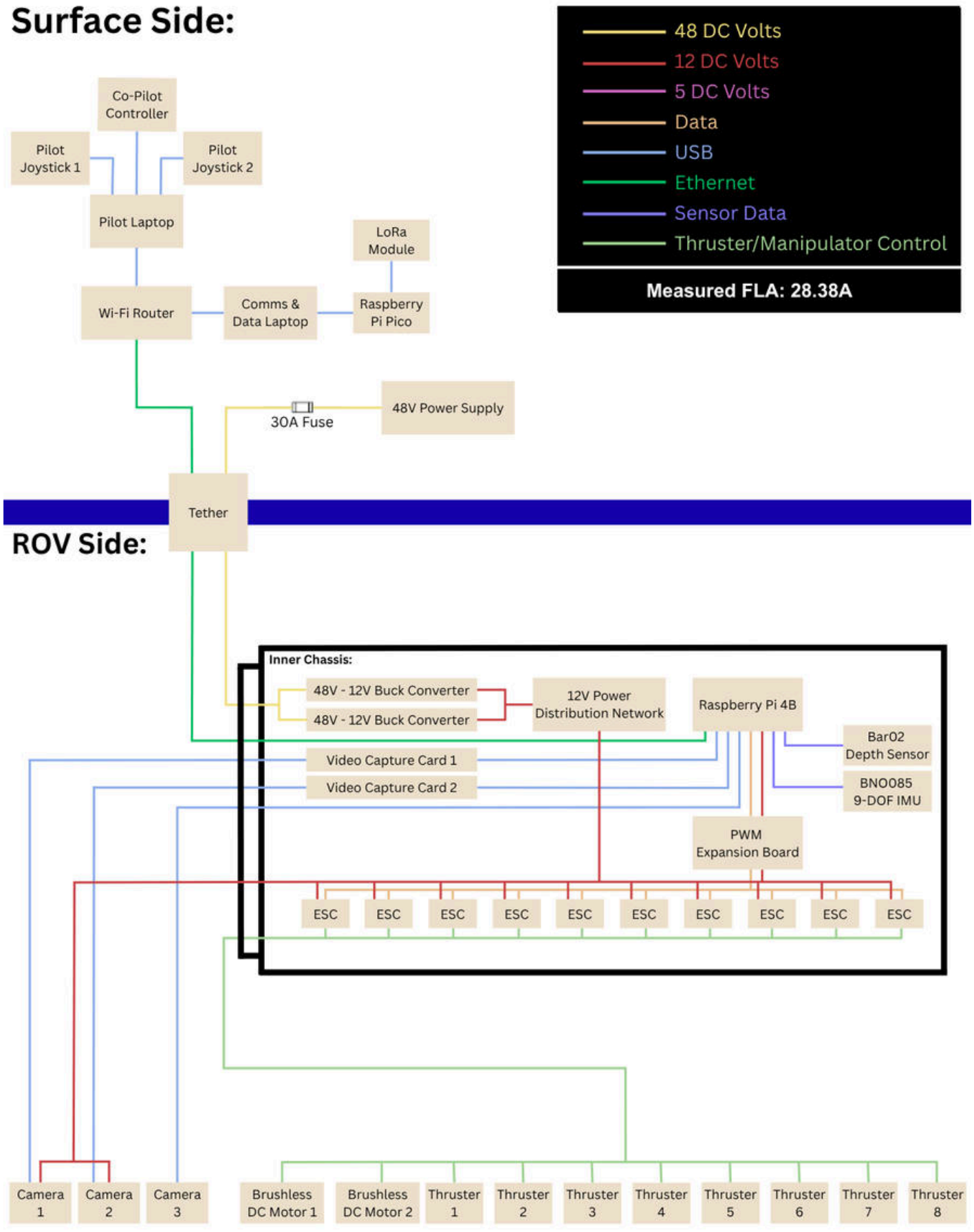


Figure 34: Simplified SID diagram

Safety

At Sequoia Marine Solutions, safety is considered a core component of the engineering process. Safety is integrated into every stage of development, whether it's fabrication, testing, or operational procedures. The team prioritizes the protection of personnel, equipment, and the surrounding environment during the development of the ROV. Safety considerations are integrated into the design and development of the ROV to ensure it operates reliably while minimizing any electrical or mechanical hazards. With routine inspections, preventative maintenance, and proper PPE, Sequoia Marine Solutions is able to maintain a safety-focused engineering environment.

Personnel Safety

The safety rationale developed by Sequoia Marine Solutions is designed to protect all personnel involved in the creation of the ROV. All personnel working on the creation of the ROV are required to complete a **lab safety training** as well as a **tool safety training** to ensure proper handling of equipment. Sequoia Marine Solutions encourages all personnel to complete OSHA 10 training to strengthen overall workplace safety; however, the safety lead is expected to obtain certification in order to oversee that operations are meeting all safety standards. In addition, proper personal protective equipment (PPE) is needed whenever working on the ROV. The PPE consists of safety glasses, gloves, closed-toed shoes, and masks. Proper PPE is required when working with power tools or any equipment that can cause airborne fumes. When personnel are seen not to be using proper PPE, the **Stop Work Authority Policy** will kick in and halt all work until members who are in violation wear proper PPE. In addition, a warning will be issued to personnel, and repetitive offenses will lead to personnel not being able to work on ROV.

Equipment Safety

Sequoia Marine Solutions incorporates multiple safety features and inspection procedures to protect the ROV and any associated equipment. Electrical systems are protected through fuse protection, insulated wires, waterproof enclosures, and strain relief on tether and electrical components in the chassis. Thrust guards are installed to reduce accidental contact when propellers are in use during deployment and recovery of the ROV. In addition, bolts, fasteners, and structural components are inspected to ensure they're secure during the operation of the ROV in the water. Most importantly, a safety check-off list is conducted before and after all operations to ensure the overall safety of the ROV. This helps minimize equipment damage and improves reliability.



Figure 35: CSO wearing proper PPE

Operational Safety

To ensure the safety of equipment and personnel a **Jobsite Safety and Environment Analysis (JSEA**) is conducted alongside a check off list to avoid any potential hazards to personnel, equipment, and environment. In addition, other safety measures like the Stop Work Authority are used as an additional safeguard for personnel and equipment. The Stop Work Authority is used whenever any Sequoia Marine Solutions personnel identifies an unsafe condition, hazardous action, or equipment failure. Operations will remain suspended until hazard has been implemented, and safety lead approves continuation of operation after corrective action has been completed. Sequoia Marine Solutions prioritizes safety, equipment protection, and mission success.

Build vs. Buy

At the time of our writing, over 50% of the **500+ designed parts** in this year's S.M.S CAD library are in-house 3D prints. These **265 unique 3D printed parts** embody our team's commitment to personally designing and fabricating as many of our components as possible. ROSIE also features a variety of outsourced materials, each selected for their essential role in completing this year's mission requirements. The tables below detail the selection procedures for key built versus bought parts. Note that because we are a first-year team, we did not re-use any components from a previous ROV.

Built/In-House

System	Justification
Chassis 3D Printed Frame	Customizable, lower cost than machining/sheet metal, encouraged rapid prototyping and testing, widely accessible by team members.
Chassis Custom Backplate	Machined from 6061-T6 aluminum to seat the 7 extra Wetlink penetrators needed for our cameras and motors; access to CNC mill and hard black anodized provided through local robotics mentors.
Float Sheet Metal Inner Chassis	Additional weight from stainless steel necessary to achieve neutral buoyancy, increase stability, and complete vertical profiles.

Bought/Outsourced

System	Justification
DD3130 Brushless Motors for Manipulator	High risk of complications with in-house motor epoxying, meets torque requirements (with custom gearbox) for all MATE tasks, reduced corrosion risk v. non-waterproofed alternatives.
Auto Vox Cam7	Automotive back up cameras that are severely inexpensive compared to the higher end options. Provides a 1080p resolution, rated at an IP69K for waterproofness, key for photogrammetry.
ThrustMaster Flight Sticks	Give the main pilot more precise mobility with 6 axes of movement. Come with 44 programmable buttons, increasing flexibility in competition runs.

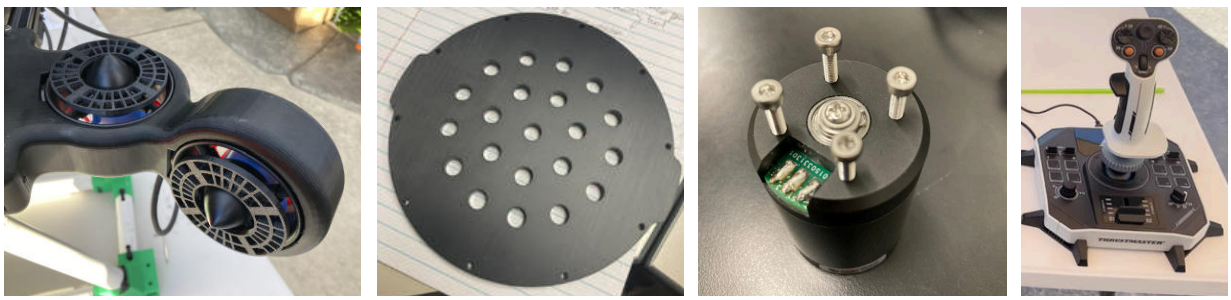


Figure 36: Thruster mounts, backplate, DD3130 motor, flight stick

Critical Analysis

To make key design decisions, SMS conducted **controlled feasibility tests**. For example, prior to water testing the aluminum T-slot rails on our ROV's chassis, SMS completed a one-week **accelerated corrosion test**. T-slot rails were placed in continuously aerated salt water, then removed at timed intervals throughout the week. Nickel-plated and stainless steel T-nuts were secured to each rail using stainless steel bolts, tightened with increasing torque.

At the conclusion of the week, the nickel-plated T-slot nuts displayed visible discoloration, and white aluminum oxide was observed in the highest concentrations around the overtightened bolts. In response, SMS exclusively adopted stainless T-nuts and established a **standard bolt size and material thickness** for all T-slot connections to limit corrosion from overtorqued bolts.

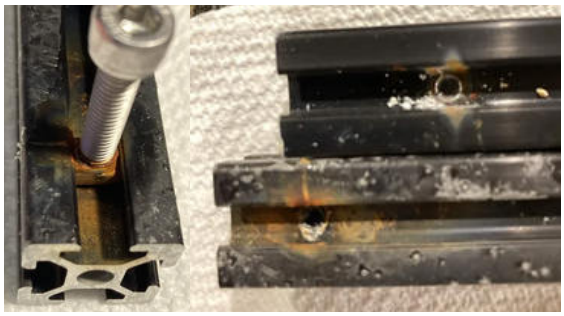


Figure 37: Corrosion testing, salt v. freshwater test

The float peristaltic pump was feasibility **tested in a sugar-ice water solution** to simulate the conditions in the ice tank to verify that its flow rate remained acceptable even under poor conditions.



Figure 38: Peristaltic pump feasibility testing

To evaluate the performance of our thruster shrouds, **load cell thrust testing** was performed. An 18% reduction in thrust was observed in initial iterations of t he thruster shrouds in comparison to an unshrouded thruster. In response, the thruster shrouds thickness was reduced and guarding holes were slightly opened, while still adhering to IP-20 standards.

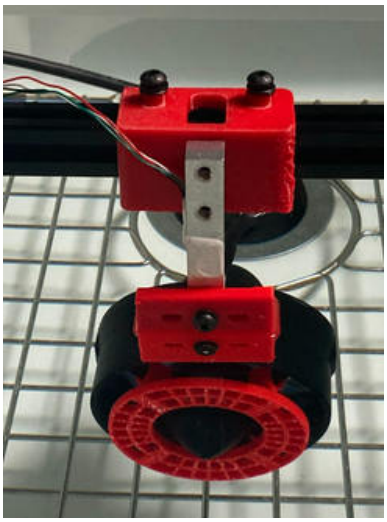


Figure 39: Load cell thrust testing of shrouds

Troubleshooting

A week before qualifying, SMS swapped the backplate to a new anodized one with custom holes. SMS also added 3 new cameras, and filled the extra holes with Wetlink blanks, which introduced **leakage** problems. A **compressed sponge** was used to detect water leaks within the pressure hull when submerged. Before submersion, a test was done with a **vacuum pump** to see if the pressure hull would hold pressure, which was partially successful. After **visual inspection** the pressure hull was placed in the shallow end of the pool for a duration of 20 seconds. No water penetrated through to the sponges initially, so it was submerged for an additional two minutes in the shallow end. However, during the **two minute test** water entered the pressure hull.

This leak location was identified by swelling in the sponge mesh, allowing for efficient correction. The culprit was a damaged o-ring on a Wetlink blank. The use of an incremental process expedited the identification of the root cause, exhibiting the successful application of water testing system to troubleshoot.

Accounting

Budget Category	Example Items	Budgeted	Total Value*	2026 Spending / Projected
Admin & Registration	501(c)(3) filing, CA DOJ registration, Canva, MATE registration	$850.00	$877.15	$877.15
Team Operations	Club shirts made in-house, tablecloth, food, booth materials, general supplies	$1,500.00	$1,327.47	$1,327.47
Vintage Days / Fundraising	Food inventory, booth fee, trays, cups, film, gloves, aprons, serving supplies	$1,900.00	$2,405.17	$2,405.17
ROV Manipulators	Waterproof motors, 650KV motor, servo, lead screw hardware, bushings, TPU/PETG prototypes	$350.00	$450.03	$450.03
ROV Controls + Electronics	T200 thrusters, ESCs, converters, sensors, cameras, tether/surface station support	$7,600.00	$7,452.09	$2,630.51
ROV Chassis	T-slot frame, fasteners, pressure hull, backplate, WetLinks, stoppers, filament, mounts, PETG prototype parts	$1,400.00	$1,471.64	$1,271.64
Float Chassis	Blue Robotics enclosure, end caps, O-rings, vent plug, pump/tubing, custom sheet metal	$800.00	$871.32	$671.32
Float C&E	Raspberry Pi 5, LoRa communication unit, float control electronics	$300.00	$200.00	$200.00
Competition Logistics	LAX parking and small travel logistics buffer	$350.00	$300.00	$300.00
Competition Travel Estimate	13 roundtrip flights; LAX to YYT (cheaper than local flight by over $3,000) 6 nights x 5 rooms @ The Capital Hotel in St. John's NL, Canada	$22,000.00	$18,869.00	$18,869.00
Totals:		**$37,050.00**	**$34,223.87**	**$29,002.29**

**Total Value includes the value of all ROV, float, travel, and operations costs, including reused, provided, projected, and manufactured items.*

Table 3: Budgeting spreadsheet

As the season progressed, our budget shifted based on **actual funding and design needs**. Early on, we had to be **conservative** with purchases while waiting for **sponsorships, grants, MESA volunteering funds, university support, and fundraising revenue** to come in. Once funding became more certain, we were able to move forward with larger purchases for the ROV, float, travel, and competition logistics. This is largely in part due to the financial team's persistence utilizing the SMS proprietary CRM tool for **sponsorship acquisition**, as well as **leveraging connections with local business owners** throughout the state.

Overall, SMS is **projected to remain under its 2026 budget** while still completing the ROV, float, and competition travel plan. More importantly, this first season gave the team **real financial data** that can be used to create **stronger, more accurate budgets** in future years.

Appendix A: Safety Checklists

ROV Construction

Disassembly:

- Disconnect all power sources before opening chassis
- Inspect wiring, connectors and tether incase of any damages
- Inspect the chassis, hardware, and 3D printed parts for wear and tear
- Inspect O-rings, penetrators, and seals for damage
- Check chassis for condensation or any other water intrusion

Before closing:

- Verify that all electrical wiring are secured and insulated
- Ensure correct fuse is installed
- Lubricate the O-ring
- Verify camera, manipulator and buoyancy components are secured

While closing:

- Ensure no wires are pinched during closure
- Tighten all hardware on the ROV
- Verify that pressure cap and strain relief are secured

After closing:

- Verify no energized components using multimeter
- Perform vacuum test on chassis
- Verify trusters, manipulators, and cameras

ROV Operation

Pre-Deployment:

- Verify all team members know their duties and responsibilities
- Ensure team members are wearing proper PPE
- Ensure deployment area is clear
- Inspect tether for any damage
- Verify communication between deck management and operators
- Ensure thruster guards are secure
- Tether strain relief attached to surface station and ROV
- Surface station laptop is working properly

During Operation:

- Monitor ROV for any abnormal behavior
- Abort mission immediately if smoke in the chassis, overheating or water intrusion. Ensure to power off the ROV before recovering the ROV.
- Monitor any abnormal draw or power supply temperature changes
- Verify proper thruster and manipulator operation
- Tether manager ensuring enough tether is out for ROV and entanglement prevention

Post-Deployment:

- Shut off all power to the ROV
- Dry off ROV
- Inspect ROV in case of any damages

Appendix B: Lab Safety Policy

1. Food and Drinks not allowed in the lab
2. If hair longer than shoulder length, ensure to tie it back
3. Avoid wearing any loose clothing or clothing that exposes the skin
4. Closed toed shoes are only allowed in the lab
5. Only authorized people who have completed lab safety quiz allowed in the lab
6. When working in the lab ensure that the door remains open, when the lab is not being used make sure that the door is always closed and locked
7. Report any equipment that has been damaged or not working properly to safety lead or subsystem lead
8. Ensure to always have a clean work station and clean up after yourself
9. When using power tools or any equipment that can cause airborne particles ensure to wear proper PPE like, safety glasses, gloves, face mask, and etc.

Appendix C: Cost Accounting

Income Total			
Funding Category	**Type**	**Source(s) / Notes**	**Amount (USD)**
Sponsorship	Company Sponsorships	Corporate Sponsors (see Acknowledgments)	$11,900.00
Sponsorship	GoFundMe Sponsor Payouts	Sponsor/community payouts received through GoFundMe, net of fees	$970.40
Grant	MESA Program Funding	MESA @ Fresno State volunteer/program support	$4,100.00
Grant	University Support	IEEE Nationals, CSUF President, LCOE	$9,500.00
Crowdfunding / Fundraising	Vintage Days Pop-up Restaurant	Cash and Square revenue from Vintage Days food and drink sales	$3,936.74
Crowdfunding / Fundraising	Panda Express Fundraiser	Panda Express fundraiser payouts received into checking and savings	$509.70
Crowdfunding / Fundraising	Community	General GoFundMe contributions and Pi Day Run booth award	$317.37
Self-Funded	Member Contributions / Initial Deposit	Member voluntary contributions and initial account opening deposit	$330.00
		Total Raised:	**$31,564.77**

Budget Category	Comparable Team Estimate*	2026 Budgeted	2026 Value / Projected	Notes
Lab Safety	$300	$400	$300	Lower due to shared university/member supplies.
Tooling & Equipment	$775	$1,250	$1,300	Tools provided by members
Research & Prototyping	$1,700	$2,000	$1,500	High first-year iteration needs, but reusing CAD/prints helped.
ROV Chassis	$500	$800	$675	Slight over due to backplate/waterproofing.
ROV Controls + Electronics	$3,500	$7,600	$7,450	Largest build category; lots provided however
ROV Manipulators	$450	$600	$350	Kept concise by prioritizing the end effector and rotation.
Float Chassis	$350	$500	$400	Enclosure and custom sheet metal drive most cost.
Float C&E	$400	$450	$425	Successful budgeting
Team Operations	$800	$1,500	$1,325	Near budget due to fundraising/event operations.
Vintage Days / Fundraising	$1,500	$2,200	$2,405	Intentional overspend because booth generated revenue.
Competition Fees	$550	$550	$550	Based on MATE registration and similar team reports.
Competition Logistics	$500	$600	$375	LAX departure kept costs lower than Fresno flights.
Competition Travel	$17,000	$20,000	$19,100	Prices rose as season went on
Total:	**$28,325**	**$38,450**	**$36,155**	
Projected under / (over) 2026 budget:			**$2,295**	**Positive value = below budget.**

ROV Total Cost			
Budget Category	**Type**	**Item(s)**	**Est. Value (USD)**
ROV Manipulators	Purchased	Motors (2x waterproof, 1x 650KV, 1x IP68 servo)	$300.17
ROV Manipulators	Purchased	Manipulator drivetrain hardware (lead screw hardware, bushings, heat set inserts, pipe tap)	$61.96
ROV Manipulators	Purchased	Motor waterproofing/potting and small tool supplies	$45.98
ROV Manipulators	Purchased	Rigid end effector / harpoon prototype supplies	$41.92
ROV Controls + Electronics	4x Purchased, 4x Provided	Blue Robotics T200 Thrusters x8	$2443.16
ROV Controls + Electronics	Purchased	ESCs / speed controllers for propulsion	$461.41
ROV Controls + Electronics	Purchased	Power electronics and sensors (buck converters, depth sensor, fuses, IMU/PWM/motor-driver testing components)	$535.87
ROV Controls + Electronics	Purchased	Camera and video capture system (AUTO-VOX cameras, capture cards, RCA adapters)	$360.78
ROV Controls + Electronics	Purchased	Wiring and soldering supplies (heat shrink, jumper wires, solder)	$50.87
ROV Controls + Electronics	Provided	Surface station and tether support (laptop, joysticks, tether components, exploreHD camera)	$3,600.00
ROV Chassis	Purchased	Frame, mounts, stand, fasteners and Blue Robotics chassis supplies	$661.23
ROV Chassis	Purchased	Waterproofing/enclosure hardware (WetLink penetrators/blanks, rubber stoppers)	$278.82
ROV Chassis	Purchased	Custom aluminum backplate (fabricated by Colin Warnes, anodized by BW Packaging)	$200.00
ROV Chassis	Purchased	PETG filament for 3D printed chassis/manipulator parts	$102.39
ROV Chassis	Purchased	Labels, anti-seize, and miscellaneous build supplies	$29.19
ROV Chassis	Provided / Reused	Cast acrylic pressure hull	$200.00
		Total Value:	**$9,373.76**

Float Total Cost			
Budget Category	**Type**	**Item(s)**	**Est. Value (USD)**
Float Chassis	Purchased	Blue Robotics 100 mm (4 in) cast acrylic enclosure tube, 400 mm, with tariff	$433.84
Float Chassis	Purchased	Drilled aluminum end cap with 4x M14 holes and 1x M10 hole, with tariff	$44.80
Float Chassis	Purchased	Blank aluminum end cap for 100 mm enclosure	$38.08
Float Chassis	Purchased	O-ring sealing flanges x2 for 100 mm enclosure	$112.00
Float Chassis	Purchased	M10 enclosure vent and plug, with tariff	$13.44
Float Chassis	Purchased	Peristaltic pump and silicone tubing for float buoyancy engine testing	$29.87
Float Chassis	Provided / Fabricated	Custom float sheet metal/internal mounting plates, fabricated & anodized	$250.00
Float C&E	Purchased	Raspberry Pi Pico for float control computer, LoRa unit	$50
		Total Value:	**$641.32**