Sugar Hill, Georgia, USA

COMPANY MEMBERS: 9th-11th Grade

orange name indicates a returning member/mentor

- Makenna Reilly: CEO, CFO, Lead Mechanical Engineer, Lead Electrical Engineer, Lead Programmer
- Violet Brockmann: Lead Manufacturer, Lead Tether Manager, Mechanical Engineer
- Eliss Palacios: Lead Prop Manager, Mechanical Engineer, Pilot
- Sarah Redstrom: Lead Graphic Designer, Mechanical Engineer, Assistant Tether Manager
- Ciana Lee: Programmer, Mechanical Engineer, Copilot
- Dr. Mick West: Mentor
- Michael Reilly: Mentor

INTRODUCTION

ABSTRACT

SeaCow Robotics is a five-person company of girls with access to a large makerspace allowing in-house prototyping and manufacturing of almost all parts of the robot. Our mission is to both produce a unique and successful product while creating a safe space for girls to explore and develop their STEM passions at a high level.

LegenDairy is SeaCow Robotics' third underwater Remotely Operated Vehicle (ROV), and is designed to contribute to achieving four of the 17 UN Sustainable Development Goals as part of the UN Decade of the Ocean. These goals include creating and maintaining clean energy solutions in the water, protecting plant and animal life that supports marine ecosystems, establishing responsible consumption and production practices, and understanding the effects of climate change on our oceans to better reverse its effects and prevent further harm.

To accomplish these goals with maximum efficiency, LegenDairy uses its wide range of tools and subsystems, minimizing the amount of times the ROV must surface. This document describes the process used to design, prototype, manufacture, and test LegenDairy and the solutions that it provides to contribute to various UN Sustainable Development Goals.

Fig 1: 2023 SeaCow Robotics employees - Jessica Mambo

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DESIGN RATIONALE

DESIGN EVOLUTION

LegenDairy (Cow) is the third ROV produced by SeaCow Robotics and utilizes concepts from both previous years. This robot further develops the successful components of previous robots such as the vectored thruster orientation and linearly actuated claw, and strives to eliminate past weaknesses such as inefficient piloting.

All employees in the 2023 season have had some background in robotics, whether that be through past participation in SeaCow Robotics, FIRST Lego League, or FIRST Robotics Competition. This provided the opportunity to advance the timeline of our design and build process so that we could get in the water and start testing our subsystems as soon as possible. This extra time in the water greatly aided in revealing problems, inspiring improved designs, and understanding the competition at a deeper level.

One of the main goals in designing LegenDairy was to eliminate the need to return to the surface between each task. To accomplish this we designed many tools for simultaneous use. This allowed multiple tasks to be completed quickly without surfacing as we previously did.

Fig 2: Various tools with LegenDairy - Makenna Reilly

Another way efficiency was increased was through adopting the Ardusub system for robot control. This system refines the basic driving controls of LegenDairy to increase accuracy and speed during travel between tasks and the surface. In addition, this software helped increase the autonomous capabilities of LegenDairy and encouraged employees to learn more about how autonomous underwater vehicles operate in the real world.

While SeaCow Robotics aimed to make many improvements over the 2023 season, safety continued to be in mind during design, manufacturing, assembly, and testing. While this was difficult to balance with our other goal of providing new members more autonomy, it was achieved through clear safety checklists and requirements for certain dangerous tasks.

MECHANICAL DESIGN AND MANUFACTURING PROCESS

SeaCow Robotics made the decision to design a new ROV for the 2023 competition and used principles and techniques discovered in the creation of previous robots rather than reusing major components of these robots. By using methods and systems that were similar to those that we previously utilized, employees could design quickly and with confidence.

The mechanical design phase began in June, following the Appalachian Highlands Regional Event. A team of SeaCow Robotics mechanical and control systems engineers met to decide on the major components that would make up LegenDairy with the goal of creating an easily modifiable and versatile base to build on later. This team found that a larger electronics enclosure was necessary to accommodate plans for a more advanced control system, so this was prioritized.

The first iterations of the design also prioritized thruster placement for pitching, but this ended up getting in the way of a camera inside the enclosure. After some deliberations, it was decided that pitching was not needed as long as the camera inside the enclosure could pitch.

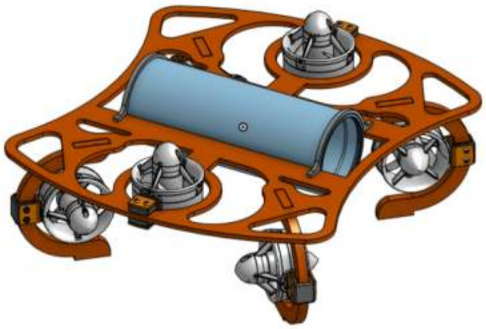


Fig 3: Isometric view of early iteration of LegenDairy

The design of LegenDairy was done in the computer aided design (CAD) software OnShape, which allowed employees to collaborate with each other and edit designs from anywhere with internet access. Many iterations of the main frame design were made, but the final design prioritized resolving issues experienced in 2022 including lack of customizability after manufacturing, an excessively small electronics enclosure, and more.

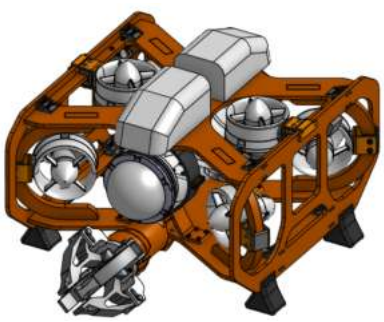


Fig 4: Isometric view of CAD of LegenDairy

LegenDairy's frame is made of HDPE due to its ease of design/manufacturing and natural buoyancy. HDPE sheets were cut by employees on a CNC router, allowing complete control of the design and tolerances of the frame pieces as well as providing the opportunity to train new employees in manufacturing. Many of our other parts on the frame are 3D printed using Stratasys 3D printers. This allows the fabrication of more abstract custom parts for various needs including thruster mounts, most parts of the claw, and more.

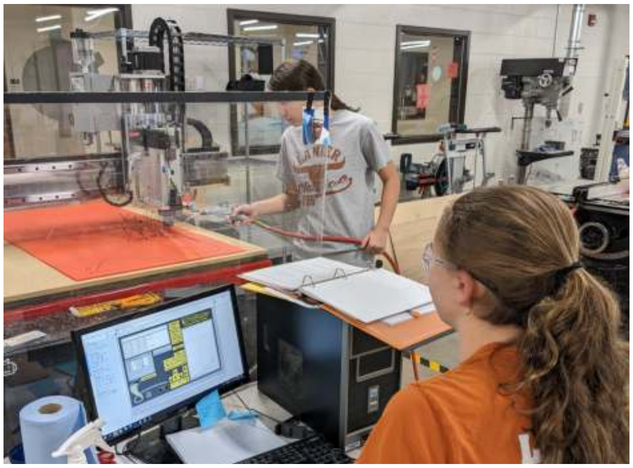


Fig 5: Parts being cut on CNC Router - Michael Reilly

MECHANICAL COMPONENTS

FRAME

Continuing to use custom HDPE sheets for the frame of our ROV provided complete control over the shape of LegenDairy, integrated buoyancy, and complete confidence in the tolerances designed for connecting the parts. Previous frames made by SeaCow Robotics included extruded aluminum and steel components, making them much less buoyant than the 2023 frame.

The side plate designs are meant to provide enough open area for the current produced by the horizontal thrusters to flow efficiently while also protecting the thrusters from direct interaction with the props and structures in the pool. This design also provides many opportunities to mount various tools to minimize surfacing, along with handles to ensure the safety of SeaCow Robotics employees when handling LegenDairy.

The electronics enclosure is located in the center of the frame which allows the main camera to achieve a clear view of the claw, objects in front of the ROV, and the surface. The mounts for the electronics enclosure and claw form supports as shown in Fig. 6 that stabilize the center of the ROV.

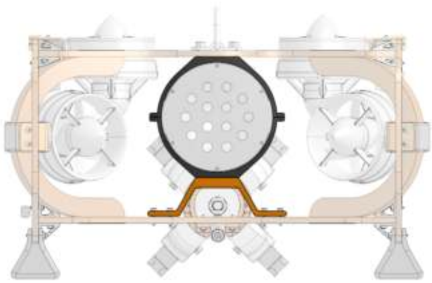


Fig. 6: Integrated supports isolated on CAD of LegenDairy

Thrusters are mounted at 30° angles on HDPE arcs that are used both to protect the T200s during travel and use, as well as provide structural support to the edges of the frame. This angle was chosen over 45° angles because it increases the forward thrust of LegenDairy by up to 25% at the sacrifice of strafe thrust.

Buoyancy foam is mounted at the top of the frame to raise the center of buoyancy, adding more stability to the ROV. The stability that the arcs provide to the thrusters ensure that their weight is always distributed evenly and that the center of mass is not disturbed even under strong currents.

UNDERWATER ELECTRONICS ENCLOSURE

LegenDairy's underwater electronics enclosure is a 4" Blue Robotics acrylic tube. It is outfitted with an acrylic dome and a 14 hole end cap. The dome was chosen to accommodate the Raspberry PiCam and its view at all achievable angles. The 14 hole end cap was chosen to accommodate all of the penetrators including six T200 wires, two power supply wires, one signal wire, one LED wire, one depth sensor, one vent plug, and two blanks.

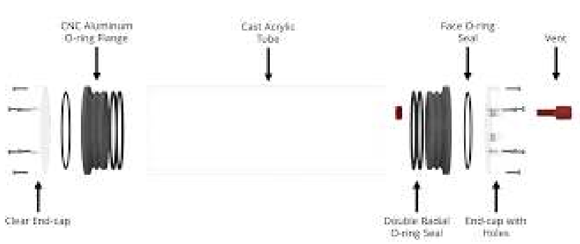


Fig. 7: Electronics housing assembly - Blue Robotics

The use of easily detachable waterproof penetrators was considered due to the fact that Bulgin, a popular supplier of these connectors, is known to donate them to MATE ROV Competition teams. This detachable feature would allow easier storage and transportation of the robot, but would require a custom bulkhead to be milled and increase the risk of flooding the enclosure. For these reasons, we used penetrators sold by the same company that made the enclosure.

THRUSTERS

LegenDairy is equipped with six T200 thrusters in a vectored orientation. The four horizontal thrusters in this orientation allow all horizontal degrees of freedom. This allows the pilot maximum freedom in movement, increasing efficiency.

Vertical thrusters are mounted on the left and right side of the robot, which allows a larger electronics enclosure at the sacrifice of pitching. As mentioned previously, pitching was deemed unnecessary due to the main camera servo.

Since the Ardusub system is used on LegenDairy, it was also important to choose a thruster orientation that was able to work with this software. The vectored thruster orientation used on LegenDairy matches a default thruster orientation in the piloting software used which made it easy to get the thrusters up and running quickly.

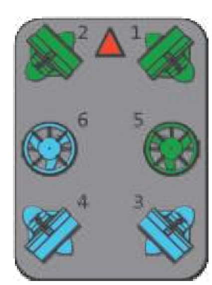


Fig. 8: Vectored ROV configuration - Ardusub Gitbook

While these six thrusters provide speed, they also draw a large amount of current. This current, in addition to being limited by the main 25A fuse, is limited through the Ardusub software. With the RC3_MAX, RC3_MIN, and RC3_TRIM parameters, we are able to limit the current drawn by all of the thrusters by limiting the maximum and minimum PWM values. These values limit the current draw per thruster to 2A, providing an extra layer of safety in compliance with MATE ROV Competition regulations.

RC3_MAX	1684 PWM	RC max PWM
RC3_MIN	1316 PWM	RC min PWM
RC3_REVERSED	Normal	RC reversed
RC3_TRIM	1316 PWM	RC trim PWM

Fig. 9: Current-limiting parameters in QGroundControl

CAMERAS

There are three cameras on LegenDairy including one "smart camera" which is inside the underwater electronics enclosure and two "dummy cameras" which are mounted on the bottom and left side of the robot. The "smart camera" is used for manipulation involving the claw and most vision-based tasks while the "dummy cameras" are used for navigation and tasks using side-mounted manipulators.

The "smart camera" is a Raspberry PiCam mounted on a servo assembly inside the underwater electronics enclosure. This camera is high resolution, which can aid in completing tasks such as *2.6 Inspect the buoy ropes for damage* where a clear view is necessary.

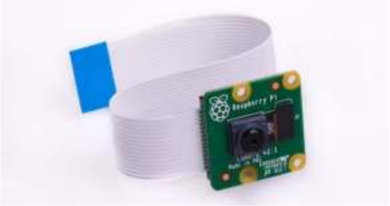


Fig. 10: Raspberry Pi Camera 2 - Raspberry Pi

The two "dummy cameras" are car backup cameras from Natika, chosen for their IP69K rating. This rating requires minimal waterproofing needed before these cameras could be implemented on LegenDairy, which aided in getting the robot into the testing phase quickly. One of these cameras is used to view the manipulators mounted on the side panels of the robot such as the water sampler used for task *2.2 Collect a water sample from above the coral head*. By having manipulators and cameras on the sides of the robot, LegenDairy can complete many different tasks before surfacing, increasing its efficiency.

The other "dummy camera" is mounted underneath the claw, which allows better navigation ability when a large object is being carried inside the claw, blocking the Raspberry Pi Camera. An example of the use of this camera is in task *1.1 Moor the panel array to three anchor points*. In this task, the PVC holding the carabiner is very large, and it fully blocks the camera inside the enclosure.

BUOYANCY/BALLAST

Archimedes' principle was used in a custom Google Sheet to get a basis for the buoyancy of LegenDairy, disregarding the pressurized air inside the pneumatic cylinder and tubing. This allowed us to arrange the proper amount of buoyancy and ballast before getting LegenDairy in the water and minimize necessary changes during the first dive.

Volume (cm^3)	Mass (kg)	Buoyant Force (N)	Weight (N)	Net Buoyant Force (N)
5691.395551	6.03	55.7756764	59.11753	-3.341853596
217.216	0.37870821	2.1287168	3.711340458	-1.582623658
302.830262	0.45889813	2.967736568	4.497201674	-1.529465106
1376.102	0.39631702	13.4857996	3.883906796	9.601892804
696.692018	0.81	6.827581776	7.938	-1.110418224

Fig. 11: Buoyancy calculations chart

The values for volume and mass that are used in the chart were taken from the CAD of the robot after assigning material values for each part.

Since the buoyancy calculations are done assuming that the robot is fully submerged, as it is for most of the missions, these values could be used without extensive in-water testing.

The buoyancy material used on LegenDairy is syntactic foam, which does not compress at depth, keeping the buoyancy consistent within the entire mission zone. The ballast material used on LegenDairy is laser cut .375” 316 Stainless Steel in 200g circles, and is mounted within the claw assembly to compensate for the added buoyancy from the compressed air. This steel was cut through the Send-Cut-Send company after being designed by SeaCow Robotics’ mechanical engineers.

ELECTRICAL SYSTEMS

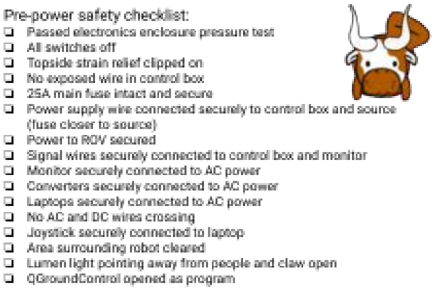
TOPSIDE CONTROL SYSTEMS

Although most computing for LegenDairy is done either in the underwater enclosure or on a laptop, an extra-large case was chosen for the control box to prioritize safety and spread out components. The electrical components inside the topside control box include: a double bus bar, one main power switch, one pneumatic switch, one fry container switch, two RCA-HDMI converters, an Arduino MKR WAN 1310. All switches are mounted on a laser cut acrylic sheet placed over all of the components. The clear acrylic allows easy visibility of all topside electronic components while providing a barrier both to protect the electronics and employees.

Fig. 12: Control box overhead view - Makenna Reilly

The penetrators into the topside control box include: one 9-pin receptacle, three quick-disconnect pneumatic fittings, one ethernet receptacle, two HDMI receptacles, one Anderson powerpole receptacle, two RCA video receptacles, two camera power receptacles, one ROV power receptacle, and three USB receptacles. The 9-pin receptacle is used for signal to the ROV and is mounted on the same side of the topside control box as two of the pneumatic connectors, the power to ROV connector, and the video connectors, making all lines to the ROV exit on the same size minimizing the tripping risk. The Anderson powerpole, HDMI, and ethernet penetrators are mounted on the back of the topside control box and connect the topside control box to the monitor, laptop, and power source.

The main laptop receives power from the provided AC power supply to minimize the risk of signal loss during use. It also sends an ethernet signal to the topside control box which controls the thrusters, light, camera servo, and more. Other uses of AC power in the topside control system include the two RCA-HDMI converters and the video monitor. The video monitor is located outside of the control box, so AC wires are separated from the rest of the system. Inside the control box, the AC power wires leading to the converters are marked with yellow tape to notify users of possible danger and tied down to keep them separate from other wires.



Pre-power safety checklist:
- ❏ Passed electronics enclosure pressure test
- ❏ All switches off
- ❏ Topside strain relief clipped on
- ❏ No exposed wire in control box
- ❏ 25A main fuse intact and secure
- ❏ Power supply wire connected securely to control box and source (fuse closer to source)
- ❏ Power to ROV secured
- ❏ Signal wires securely connected to control box and monitor
- ❏ Monitor securely connected to AC power
- ❏ Converters securely connected to AC power
- ❏ Laptops securely connected to AC power
- ❏ No AC and DC wires crossing
- ❏ Joystick securely connected to laptop
- ❏ Area surrounding robot cleared
- ❏ Lumen light pointing away from people and claw open
- ❏ QGroundControl opened as program

Fig. 13: Pre-power safety checklist

Safety was a priority in designing the topside control system, and it can be seen in many features of this setup. One safety feature is a strain relief integrated into the topside of the tether in the form of a carabiner that clips onto the side of the control box, preventing pulling of any wires coming from the tether. Another safety feature is our pre-power checklist which is permanently mounted on the lid of the topside control box, which is shown in Fig. 13. This checklist minimizes the risk of powering the robot before fully set up which can damage the system and/or cause harm to employees.

TETHER

The tether is made up of one signal wire, two power wires, two pneumatic tubes, and two camera wires. All of these wires are surrounded by a split tether loom that holds them together in an organized and safe fashion. This loom is then surrounded by pool noodle sections covered in duct tape which adds buoyancy to the tether and minimizes tether influence on ROV motion.

The main signal wire is a Blue Robotics Fathom X tether, which was chosen due to its compatibility with Blue Robotics penetrators. Since the underwater enclosure used on LegenDairy is produced by the same company, extra time does not have to be used to waterproof it. This wire is also neutrally buoyant, which minimizes the buoyancy calculations needed to be done for the tether.

The two main power wires are 8 AWG silicone wires in red and black. These wires, although negatively buoyant, are extremely flexible and provide maximum range of motion for the tether which makes piloting much easier. The penetrators for these wires are potted, which means that they have an epoxy seal instead of a compression seal. These penetrators are reused from SeaCow Robotics' 2022 robot, and utilize a semi-flexible epoxy which allows the extremely flexible silicone to bond to it more securely when properly prepped. Prepping the silicone wires included intensely sanding them and cleaning them with abrasive alcohol. This was vital in ensuring a secure and long-lasting seal that we can be confident in.

Fig. 14: Enclosure penetrators - Violet Brockmann

The two pneumatic tubes are polyurethane, ¼" OD, 0.156" ID tubes which are filled with pressurized air regulated to 40 PSI. The pressurized air inside these tubes makes them buoyant, which helps to offset the negative buoyancy provided by the heavy silicone power wires previously described. These tubes connect to pneumatic fittings inside the claw providing the air necessary to operate the pneumatic actuator.

The "dummy camera" wires are RCA video cables. Since the cameras chosen are completely potted with epoxy already, the only waterproofing needed to be done was with the RCA connectors on the robot side. These were waterproofed by encasing the connectors in epoxy, fully protecting them from water at the expense of greater weight. These cables are only slightly negatively buoyant, which means that less buoyancy must be added to bring the tether to neutral buoyancy.

The strain relief on the robot side of the tether is provided by a carabiner attached to a dynamic mount on the top and center of LegenDairy. This placement ensures that the slightly positively buoyant tether rises straight up from the ROV when submerged, minimizing the tether's effect on the motion and ease of driving of the ROV. The carabiner used for strain relief on the robot also provides a secure grab-point for employees to safely lift the robot out of the water without risk of back injury. The strain relief on the topside control box is done similarly with a carabiner that is attached to the tether loom and a built-in hole on the control box.

Fig. 15: Strain relief on the robot-side - Violet Brockmann

BOTTOMSIDE ELECTRONICS

The interior of the underwater electronics enclosure includes a 3D printed electronics tray fastened to the o-ring flange on the penetrator side with hexagonal shafts. On this electronics tray, there is one Raspberry Pi 3B, one Pixhawk 1, two bus bars, two terminal blocks, one power sensing module, one 12V to 5V converter, six ESCs, and various connectors.

Previously, SeaCow Robotics used the National Instruments RoboRio computer for main control of the robot, which was donated from FIRST Robotics Competition team 4509. The new control systems electronics used in the 2023 underwater enclosure were more expensive, but they also allowed us to use Ardusub which made piloting and main ROV control much easier and faster to implement. The old computer was also very large and could not be housed on the ROV unless a very large underwater enclosure was used, which would prevent our intentionally vertically compact design of LegenDairy from being utilized. On the other hand, both our Raspberry Pi and Pixhawk are each smaller than a deck of cards, allowing us to use a 4" enclosure and keep our design vertically compact.

Since the T200 thrusters are capable of drawing an extremely large amount of current, the ESCs are coded to limit this draw for the safety of the electronics, SeaCow Robotics employees, and others in the pool area. See the Thrusters section for more information on how this is done. There is a main fuse in case of too much current being drawn, but this is on the surface side of the pool near the power supply. Fuse calculations including overcurrent protection can be seen in the SID in Fig. 17. Power is also monitored by the power sensing module inside the electronics enclosure. Power passes through this module before being distributed on the two bus bars, which sends a signal to the topside computer reporting the current being drawn and the voltage.

The terminal blocks carrying the ESC signal wires are fully insulated which minimizes the risk of accidental connection between signal wires and power wires. Most connections in this enclosure are made with some variation of a screw-down connector, which provides greater security than the popular lever-lock connectors that SeaCow Robotics has used in the past.

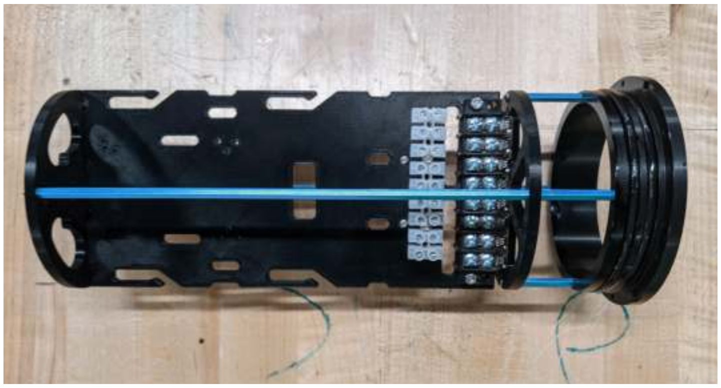


Fig. 16: Screw-down terminal blocks - Makenna Reilly

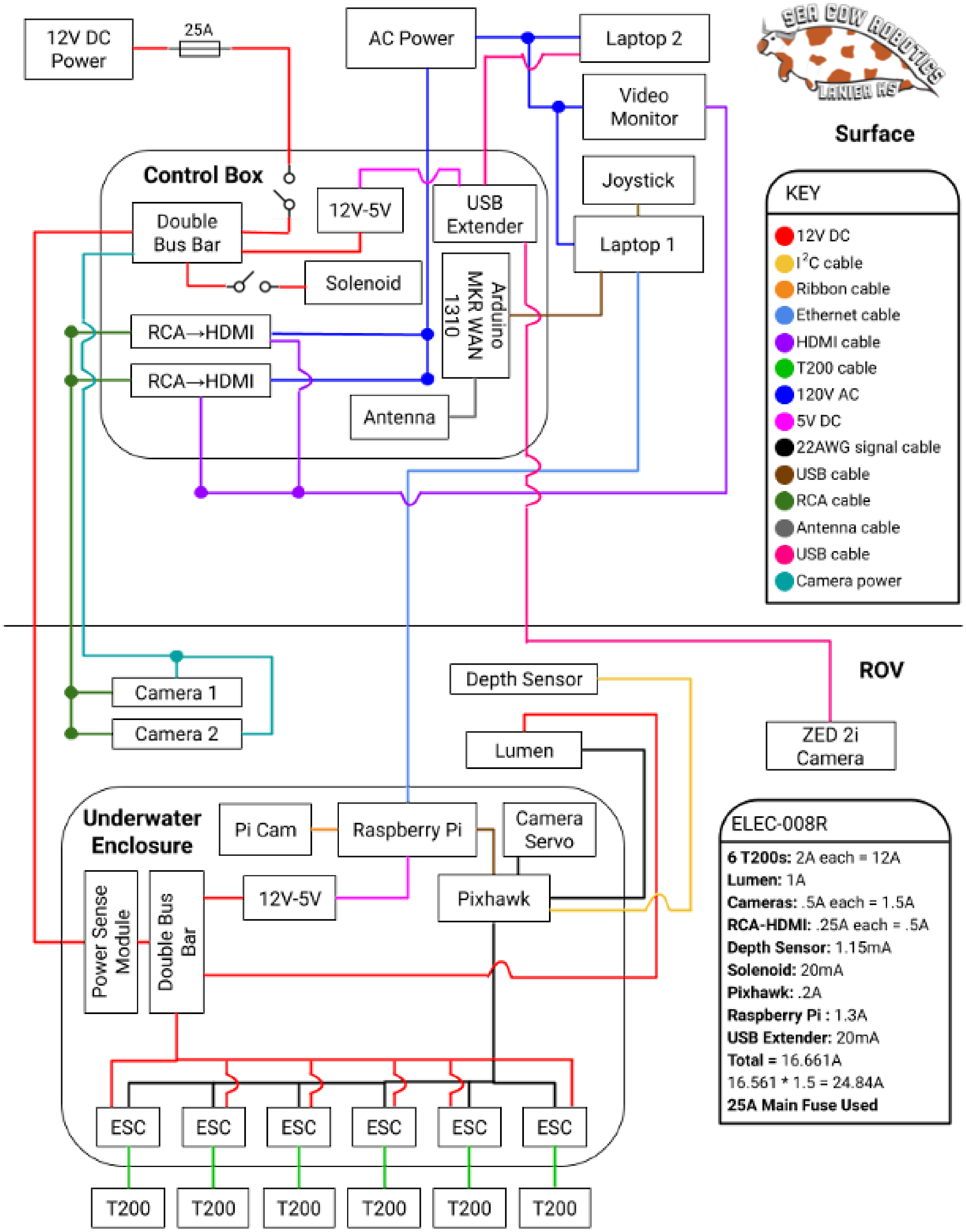


Fig. 17: Electrical SID

PNEUMATICS

The only pneumatics used on LegenDairy is for the control of the claw mounted on the front of the robot. The system consists of a connection to the MATE provided air supply, a pressure relief valve, a regulator with gauge set to 40 psi, a solenoid valve, and a double action pneumatic actuator. All components in the system are rated to 100 psi or greater in compliance with the MATE regulations. The solenoid receives power from the double bus bar inside our topside control box which is controlled by a switch in the laser cut acrylic panel. This switch allows our copilot to quickly actuate the claw when needed.

The pressure relief valve, regulator, and solenoid are housed in the topside control unit but are separated from the electrical wires. All of these components are either secured through attachment to the acrylic top plate or industrial strength velcro to the bottom of the case. The pressure relief valve is kept accessible, so that any employee may access it for safety at any time.

Although having two pneumatic lines going down to the robot does make the tether heavier and less flexible, it also counteracts the negative buoyancy in the tether provided by the two 8AWG silicone power wires, making the tether neutrally buoyant. The pressurized air inside the cylinder controlling the claw has a significant effect on the total buoyancy and center of buoyancy of the robot, so the claw is ballasted by two 200g steel weights.

All symbols used in the SID are ANSI symbols. This SID is shown in Fig. 18, and does not assume that there is a relief valve and regulator on the compressor even though most do have these features. This allows us to connect to most air supplies rather than relying on having to move around our own compressor, especially when demonstrating far away from our school.

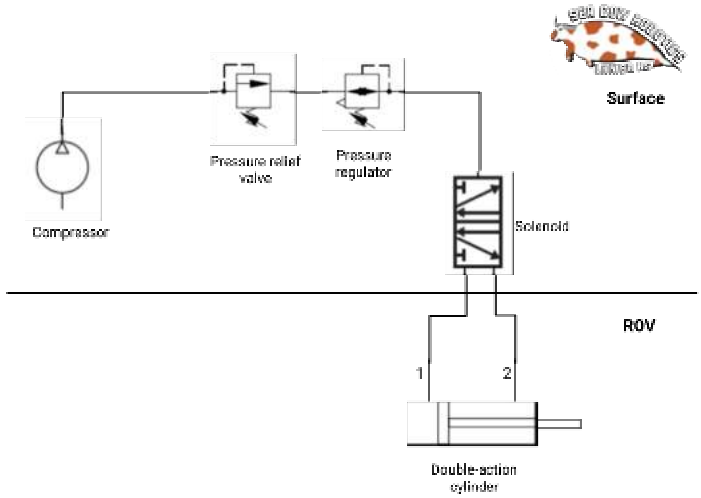


Fig. 18: Pneumatics SID

SOFTWARE

LegenDairy Cow uses the QGroundControl system for the majority of robot control and driving. This program is compatible with the Raspberry Pi and the Pixhawk 1 inside the underwater enclosure, making integration with our robot quick and easy. While this software allows piloting the robot to be relatively plug-and-play, we did have to edit parameters and tweak some of the program to optimize robot control for MATE-specific tasks.

Some of the tweaks that we made were to add deadbands to prevent accidental movement due to “sticky” joysticks, set PWM limits on our ESCs to prevent excessive current draw while maintaining speed, and correct gyroscope bias around the horizontal axis. Due to the simplicity of this program, many of these fixes were able to be done without directly editing the code. Some personalization such as widget choice had to be made in the code which is done in C++, but this was minimal.

The majority of hands-on coding that was done for LegenDairy was done for non-ROV systems. The two non-ROV systems that required more intense coding were the profiling float for task *3 MATE Floats!* and the ZED 2i camera for task *2.1 Create a 3D Model of a coral head.* The profiling float includes an Arduino Nano which controls the buoyancy engine and an Arduino MKR WAN 1310 which communicates with another board in the topside control box, both of which are coded in Arduino's custom language, which is based on C++. The ZED 2i camera is coded in C++ and uses spatial mapping capabilities to create a mesh of the bottom of the pool. This code is on a separate laptop from the one running QGroundControl to minimize pilot distraction and because a NVIDIA graphics card is required to use the full capabilities of the ZED camera.

PROFILING FLOAT

The profiling float is one of our non-ROV devices that works in conjunction with LegenDairy to complete task *3 MATE Floats!*. Information on the design and electrical elements of this device can be found in the Tooling section of this document. The Arduino Nano is used to control a servo which operates the syringe inside the float. It uses a limit switch to stop the servo when the lead screw has reached its maximum/minimum and a timer to control how long the syringe holds each position. This allows the float to be successfully operated with minimal code and calibration necessary, since it does not require a depth sensor for operation.

Communication between the float and the surface is done using an Arduino MKR WAN 1310 which has LoRa capabilities. To minimize space used inside the enclosure for the profiling float, the time is calibrated manually then uploaded to the onboard Arduino each time it is used. Currently, the # symbol is used in place of the team number, but this can easily be changed along with the time calibration when needed. Once the Arduino is turned on, the time is automatically updated and sent to the receiver board inside of the topside control box.

The code is relatively simple and uses both the LoRa and Time libraries made by Arduino to minimize code needed. There is a one-second delay between each time the on-board Arduino sends data to not overwhelm the user on the receiving end while still providing an accurate time.

```
//send packet
LoRa.beginPacket();
LoRa.print("time: ");
LoRa.print(hour());
LoRa.print(":");
LoRa.print(minute());
LoRa.print(":");
LoRa.print(second());
LoRa.print("  team number: #");
LoRa.endPacket();

counter++;

delay(1000);
```

Fig. 19: Excerpt from LoRa sender code

The code for the receiver is more compact and consists of a check to make sure that it is receiving the correct size and type of packet, printing the information it receives from the sender, and adding a personalized tag for SeaCow Robotics. The information received is displayed in the serial monitor the Arduino IDE of the laptop connected to the topside control box which can easily be read without pilot distraction.

```
void loop() {
  int packetSize = LoRa.parsePacket();
  if (packetSize) {

  while(LoRa.available()) {
    Serial.print((char)LoRa.read());
  }
  Serial.println("       blub blub MOO!");
  }
```

Fig. 20: Excerpt from LoRa receiver code

ZED CAMERA

The code for the ZED 2i camera is based off of the Spatial Mapping example code provided by Stereolabs and is much more complex than the code used for robot control or profiling float communications. All of the code for the ZED camera was done in C++ which made our system much more cohesive, with this being the main language used for all of our programmed systems. The ZED camera Spatial Mapping feature is most often used to model large spaces on land, which meant that most of our modification in the code was to make it compatible with modeling small objects like the bowl used in task 2.1. This was done by changing the camera settings to ULTRA which activated the settings needed for close-up modeling. In addition, we calibrated the ZED camera inside the underwater enclosure so that our calculations in creating the model accounted for the refraction of light caused by the acrylic tube.

```
// Configure Spatial Mapping parameters
spatial_mapping_parameters.resolution_meter = 0.01;
spatial_mapping_parameters.use_chunk_only = true;
spatial_mapping_parameters.save_texture = true;
spatial_mapping_parameters.range_meter = 2;
```

Fig. 21: Settings chosen for ZED underwater use

A positional tracking system is used to create an accurate model of the underwater terrain with measurements within 1 cm accuracy. This allows us to calculate the measurements of the coral head accurately without having to use another measurement system outside of the camera.

TOOLING

PNEUMATIC CLAW

The pneumatic claw is the main manipulator used on LegenDairy and is the only pneumatic device on the robot. For more information on the pneumatic system, see the previous Pneumatics section. A four-finger design was chosen for the claw for its versatility and ability to grab a wide range of objects. Pneumatics were chosen as the actuation method for this claw because of their simplicity in creating linear motion as compared to popular servo motors.

In previous SeaCow Robotics ROVs, the smaller size of the main manipulator limited the robot's overall efficiency because the pilot was required to drive more accurately and slowly to correctly position the manipulator. This problem was solved in LegenDairy's claw by designing it to open 19 cm maximum width. This significantly minimizes driving time needed to acquire an object such as the carabiners in task *1.1 Moor the panel array to three anchor points*.

Fig. 22: Claw fully opened - Violet Brockmann

Another advantage of LegenDairy's claw is its strength. The double-action pneumatic cylinder is used at the MATE maximum 40 psi, which secures an object tightly without breaking the 3D printed claw or crushing the object inside. This increases the robot's efficiency by virtually eliminating scenarios where an object is dropped after it is acquired, requiring the pilot to go back for it a second time. Previously, SeaCow Robotics claws had the issue of ropes becoming tangled inside and not being able to drop them. This claw also eliminates this issue by creating a flat surface when the claw is fully opened.

The decision to make the claw a fully 3D printed assembly instead of using steel pins was difficult, but it ended up reducing the cost, weight, and complexity of the system significantly. Pins that fit this application are extremely expensive and would have made the claw approximately $200 if used. By making a fully 3D printed assembly, some strength is lost, but the claw only costs approximately $50 including the pneumatic actuator. It also allows much faster swapping of claws if any breakage occurs.

Extensive testing was done to ensure that this system would be reliable since it was so new to SeaCow Robotics. These tests were done to determine the ideal tolerance between pins and slots, radius of fillets needed to minimize pin breakage, and wall thickness needed to minimize assembly breakage. Many of these tests were done by applying stress from different directions and in different environments (wet, completely dry, saturated, etc.). After these early tests were done, their discoveries were implemented in the claw.

Fig. 23: Claw prototype 1 - Makenna Reilly

FISH FRY CONTAINER

The fish fry container is one of our non-ROV devices and is used to complete task *2.5 Release the fry*. It utilizes a simple electromagnet and a 3D printed case to hold the fry and control when they are released. The case is made of two pieces: a bottom funnel for the fry to slide out of, and a top dome to hold them in while they are transported and are acclimating. The bottom has washers to hold the electromagnet when it is on and is negatively buoyant. The top holds the electromagnet and is slightly positively buoyant.

A string is loosely thread through both of these parts for transportation purposes and to hold both parts together when the electromagnet is released to avoid leaving debris. The electromagnet is tethered to the surface through one polycord and two silicone power wires, with both the string and a hot glued section acting as strain relief. The two power wires are ideally connected to a separate power supply, but can be connected to main ROV power if necessary. A 3A fuse is between the connection and the electromagnet at the surface side of the pool, which provides significant overcurrent protection. Power is on for transportation and the acclimation period, and is turned off after the acclimation period is over. When power is turned off, the positively buoyant top floats while the negatively buoyant bottom stays on the pool floor, releasing the fish. Once the ROV cameras confirm the fry have been successfully released, the container can be pulled up by hand. More information on the container can be found in the non-ROV device design sheet.

PROFILING FLOAT

Our profiling float used in task *3 MATE Floats!* uses an extremely simple buoyancy engine consisting of a syringe, a lead screw connected to a servo, and a bladder. When in use, water is contained in the bladder-syringe system and shifts between the two to change the buoyancy of the float. When the majority of the water is inside the syringe which is inside the main body of the float, the float sinks. When the majority of the water is in the bladder, the float rises.

As previously mentioned, the main computers inside the profiling float are an Arduino Nano and an Arduino MKR WAN 1310. These computers use a limit switch, servo, and antenna to control the buoyancy of the float and transmit data back to the surface side of the pool. Information on this code can be found in the Software section. The electronics are intentionally simple to save space inside the enclosure and minimize current draw, as seen in the fuse calculations.

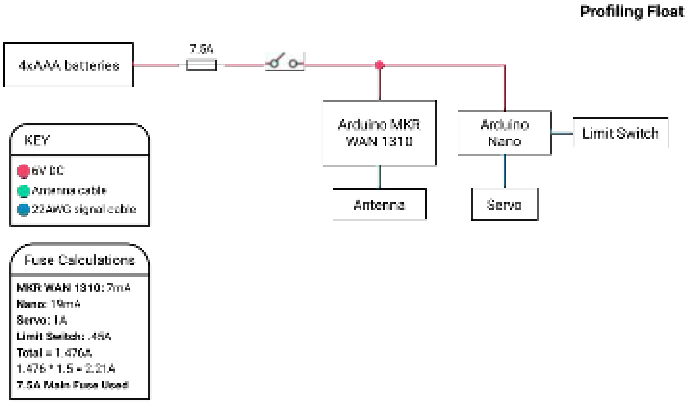


Fig. 24: Profiling float SID

A 3” blue robotics tube is used for the body of the profiling float due to its small but adequate size to fit all of the components safely in addition to its availability since it was used by SeaCow Robotics in 2022. The 4 AAA batteries are secured in their own container which is then wrapped in electrical tape to prevent any batteries getting loose from vibrations in transportation. All other electronics are also wrapped in electrical tape to prevent any wires from becoming loose inside the container and causing a danger to the electronics and SeaCow Robotics employees. The antenna for LoRa communications is held out of the main body of the float in a repurposed makeup tube that is epoxied to the end cap of the float. This minimizes interference and allows the most reliable communication with the topside computer. More information on the float can be found in the non-ROV Design Document.

ZED CAMERA

The ZED camera is used for photogrammetry in task *2.1 Create a 3D Model of a coral head - autonomously* and is housed in a 3” Blue Robotics enclosure. It is carried in the claw of the robot with a custom mount and uses a custom Spatial Mapping app to create a 3D model of the pool area and simulated coral head. More information on the software of the ZED Camera can be found in the Software section.

The mount for the ZED camera is relatively simple and takes advantage of the ease and stability of which our claw can carry ½” PVC tees. It simply wraps around the ZED camera and connects to a PVC assembly which the claw then grabs and surveys the pool with. Stability for this tool was extremely important as the pilot must carefully view all angles around the bowl to create an accurate 3D model of the coral head.

Fig. 25: ZED camera in acrylic tube - Makenna Reilly

The ZED camera is a USB camera, so, per MATE regulations, it uses a powered USB extender in the topside control unit to ensure that it is powered by the regulated MATE supply. This does not affect the use of the ZED camera at all and is only for safety purposes. Since this camera is only used for one task, its USB cable is separated from the tether. However, it still has its own strain relief done in the same way as the main tether for safety purposes.

WATER SAMPLER

LegenDairy’s water sampler is used in task *2.2 Collect a water sample from above the coral* *head*. The water sampler uses a two-ended syringe system, with the motion of a syringe on the surface side of the pool controlling the motion of a syringe on the robot. The syringe on the robot is two-ended, so instead of a plunger on one side, it has another tube outlet. The o-ring inside of the bottomside syringe separates the water being sampled from the water connected to the topside syringe, controlling the movement of the o-ring.

When water is pulled up from the topside syringe, the o-ring moves up, making water move into the side of the syringe not connected to the manual hydraulic system. When this side of the water sampler is positioned inside the container of salt water, it takes a sample of water with a low level of contamination by pool water.

Since the area that water can be sampled from is so small, our water sampler utilizes a sliding funnel to make piloting the sampler into this space much faster and easier. This funnel aligns the syringe with the area covered by saran wrap, then contracts upward when the robot pushes downward. To puncture the saran wrap, we use a sharpened plastic straw that is epoxied to the bottom end of the water sampler. This tool has enough sharpness to cleanly break the plastic without much force needed, but does not have the ability to cut a user. The straw length was changed often to puncture the container deep enough without interfering with alignment.

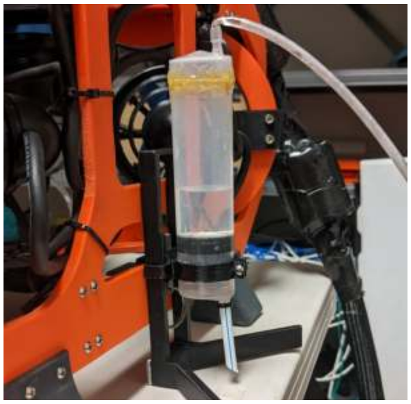


Fig. 26: Water sampler in slider mount - Violet Brockmann

The water sampler is mounted on the side of the robot with a pin, which makes it easily removable during a demonstration. This allows us to use both the water sampler and the claw without coming to the surface or leaving debris on the bottom of the pool, greatly increasing our efficiency. This mount type is also used for many other tools, minimizing the amount of mounts needed on the robot.

SIDE HOOK

The side hook is the simplest tool on the robot, and it stays true to its name. This hook is used to carry the fish fry container for task *2.5 Transport the fry to a safe release area*. Similarly to the water sampler, its location on the side of the robot allows it to be used even when the claw is also in use, making our system much more efficient. Since it does not have a strong grip like the claw does, it is only used to carry weighted objects on ropes. When the robot places the fry container in the safe area, it simply descends to release it and allow the fish fry to acclimate to conditions until they are released.

Fig. 27: Side hook - Violet Brockmann

LIFT BAG

To lift the heavy object in task *2.6 Lift the container* we chose to use a lift bag. We calculated the lift capacity of our robot with all current limits to be only 11N, which may not be enough to lift the heavy container in this task. A lift bag allows our robot to make this container buoyant so it can then push it back to the surface side of the pool.

The lift bag is another manipulator that includes its own unique line to the surface side of the pool. This lift bag consists of a 2.6 gallon drink bag, a pneumatic tube, a hook, and a PVC assembly. The PVC assembly mimics the PVC assembly that the carabiners are mounted on in task *1.1 Moor the panel array to three anchor points* as the claw secures this shape extremely well. The hook is attached to the PVC assembly that the robot grasps in the pneumatic claw, and holds the u-bolt attached to the container in task *2.6.* An ambient pressure pneumatic line runs from the bag to the surface where air is pumped through using a bike pump.

When attached to the u-bolt and the bag is inflated, the air accumulated inside the bag provides a buoyant force large enough to lift the 60N object from the bottom of the pool. After completing more challenges underwater while the bag is being inflated, the robot pushes the lift bag to a tether manager at the surface side of the pool.

Fig. 28: Lift bag - Sarah Redstrom

LIGHT-CONTROLLING TENT

To complete task *2.3 Irradiate the diseased area of coral with simulated UV light*, we use a side mounted tent. The side mounting mechanism is the same as the mechanism used for the water sampler. This tent has a tapered design that allows our pilot to place the manipulator in approximately the correct area and be corrected as they descend. The top of the tent is usually open, but when it is put on the robot, the lumen light is moved from its front-facing position to the tent where it is velcro strapped in. This blocks out external light when the lumen is not on, then provides an adequate amount of light to be detected by the photoresistor when turned on.

Fig. 29: Side tent without lumen mounted - Makenna Reilly

TENT BUOYANCY

The tent buoyancy foam may be our simplest manipulator, only consisting of a block of buoyancy foam attached to a long rope. This block of foam is used to counteract the massive negative buoyancy provided by the tent in task *2.3 Place a tent over the diseased area of coral* so that the only challenge our pilot must face when transporting this tent is the drag it creates. This tool is used by placing the tent in the pneumatic claw, then adding the buoyancy foam/rope to hold it in. Then, the claw grasps both items and proceeds to transport the tent to the coral head.

Fig. 30: Tent buoyancy tool - Makenna Reilly

TROUBLESHOOTING AND TESTING

Our thrusters and thruster arrangement were similar to that of past years, so this physical system didn't require much troubleshooting. This allowed us to spend more time troubleshooting newer and more complex tools. We used an entirely new software system for our ROV, so this was tested thoroughly both on land and in the pool. The system that required the most tuning was the ZED camera for photogrammetry, since this system was both completely new to employees of SeaCow Robotics and was used in an environment where light is heavily refracted.

Aside from preliminary stress testing of 3D printed systems such as the pneumatic claw, most tooling testing was done at the Swim Atlanta pool. Size verification and some identification of possible problems with tool/robot identification could be done at our school, but interaction with the water and difficulty of piloting for a specific task could not be determined at our workspace. For example, in task *2.3 Place a tent over the diseased area of coral,* we needed to understand how it felt to pilot the robot with a tent in the claw to determine how it affected the freedom of motion of the robot underwater. This testing even inspired a new tool, the Tent Buoyancy.

Our new software system, QGroundControl, made testing and tweaking our thruster, gyroscope, and depth sensor setting much easier. In the testing and fly view pages, we were able to see all of the options for each of these tools and change them when they weren't working properly by just selecting a different option or changing a few numbers. ZED testing and troubleshooting was also relatively easy to troubleshoot thanks to the clarity of the documentation put out by Stereolabs. While this troubleshooting was more complicated than with QGroundControl requiring employees to directly edit the code for all modifications, it could be done easily at our workspace or the pool.

In order to ensure that any issues we faced were due to unforeseen challenges and not setup issues, we created a Pre-Power checklist that is inside our control box to ensure that we set up the robot in the same way for each test. This checklist is used any time power is added to any part of the robot to make sure that all employees working with LegenDairy do so in a safe way. This checklist can be seen in the Electrical Systems section of this document.

SAFETY

COMPANY SAFETY PHILOSOPHY

Safety is the top priority of SeaCow Robotics. All employees are expected to follow MATE and SeaCow Robotics safety protocols at all times to ensure that they and the rest of the team can continue to learn and grow without the interruption of an accident. SeaCow Robotics is committed to giving women who are typically underrepresented in STEM fields an opportunity to develop and demonstrate their skills, and this cannot be done effectively without strict safety policies.

LAB PROTOCOLS

The most dangerous processes needed to manufacture and build LegenDairy were cutting HDPE on the CNC Router, epoxy-ing various components like the "dummy" camera wires, and soldering various electrical components. For all of these processes, employees were first trained by a more experienced employee and supervised by a mentor when completing a task.

When completing any of these tasks, employees consulted the JSA and safety instructions before beginning. On the CNC Router table, there is a CNC Router instructions and safety booklet written by a former SeaCow Robotics Manufacturing Lead and a local manufacturing teacher that includes checklists for using the CNC Router. This book allows employees to verify that they have completed all set-up tasks correctly and in order so that all employees stay safe. While the CNC Router is in use, all employees in the workspace are required to wear safety glasses, and two employees are required to stay at the CNC Router table. One of these employees is required to watch the material for any signs of issues such as the material lifting, melting, etc. The other employee is required to watch the CNC Routing program for any issues with cut depth, unexpected paths, etc. Both employees have access to an emergency stop button.

All of the epoxy-ing for LegenDairy is done in an isolated but well ventilated area to ensure that employees are safe while working and that the epoxy isn't disturbed during the curing process. Since many different epoxies are used for different purposes on LegenDairy, safety procedures vary for each job. As a general rule, all employees are required to read the safety instructions on the epoxy container and wear proper protective gear recommended by the specific epoxy.

Soldering is done in an open and well ventilated area of our workspace so that fumes from melted solder and flux are able to disperse quickly. Soldering is always done with at least one other employee supervising to make sure that the employee soldering is using the correct temperature for the material, taking frequent breaks to minimize fumes, and not allowing the solder to get too close to their exposed fingers.

TRAINING

SeaCow Robotics has created a student-led culture, where all employees are taught by other employees or students at Lanier High School. Mentors are used in the training process for any questions that employees can't answer or to offer advice that employees cannot provide. After a returning employee with previous experience in a certain area deems another employee capable, they are allowed to work independently with the exception of particularly dangerous tasks such as CNC routing or soldering.

Fig. 31: Employees being trained in soldering - Mike Reilly

VEHICLE SAFETY FEATURES

MATE ROV Competition safety requirements were considered in all aspects of designing, manufacturing, and building LegenDairy. Some of the elements on our robot that have the potential to be more dangerous are the underwater enclosure, the pneumatics, and sharp edges on the frame and all manipulators.

Danger caused by the underwater electronics enclosure is minimized by doing frequent vacuum checks and inspecting o-rings/epoxy seals before each dive. The vacuum check is done after any time the enclosure is opened and before the first submersion of the day. This check allows us to see the rate at which air enters the enclosure when brought to the vacuum pressure of 15 inHg, simulating submersion and water entering the enclosure. If the pressure goes down to below 13.5 inHG after 15 minutes, the enclosure is deemed not safe for use and requires maintenance.

Fig. 32: Vacuum test being performed - Makenna Reilly

Every employee is required to review and understand the Fluid Power information provided by MATE and work with another experienced SeaCow Robotics employee before working on any pneumatics. When pressurized, no employee is allowed to manipulate any pneumatic components with the exception of the pneumatic regulator to change the output pressure or the pressure relief valve to remove pressure from the system. All other pneumatic components are concealed in cases or enclosures to minimize this risk.

There are no sharp edges on our robot to minimize the risk of injury when manipulating it. All of the CNC routed frame pieces and 3D printed components have rounded edges and the sharpened straw on the water sampler easily bends when pressed.

Our robot also includes the required safety components including strain relief on the robot and topside control box, thruster guards fitting the IP20 standard, a fuse within 30 cm of the main power connection, a single connection to the main power supply, clearly separated AC and DC power lines, and more.

OPERATIONAL AND SAFETY CHECKLISTS

In all ROV operations, employees are required to follow all safety checklists and recommendations in Appendix 1, the safety checklist inside the control box which can be seen in the Topside Control Systems section, and the recommendations in the JSAs.

LOGISTICS

SCHEDULED PROJECT MANAGEMENT

Before the Request for Proposals (RFP) is released by MATE, the CEO creates a preliminary schedule for the design and manufacturing of the core robot and manipulator. With the assistance of the mechanical engineers, they analyze the most likely needs for the robot based on past RFPs and make a schedule based on the estimated length of each task.

After the 2023 RFP was released, SeaCow Robotics had an all-hands meeting to analyze the difficulty of each task and create an initial strategy for completing the maximum amount of tasks in 15 minutes. After this meeting, the CEO created a Gantt chart for the season from January to May including all tasks ranging from 3D CAD, manufacturing, assembly, electrical work, etc. This Gantt chart was then reviewed by the entire company to account for variance in employee schedules and the needs of the company overall. This Gantt chart was continuously updated by the CEO with the guidance of employees as schedules and project statuses change to create the best plan for success.

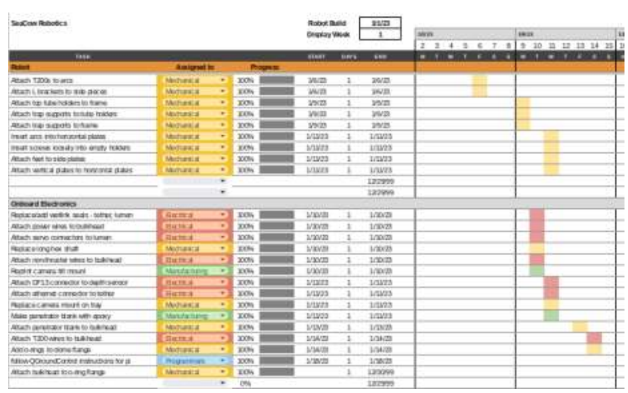


Fig. 33: Gantt chart initial build and electronics phase

COMPANY ORGANIZATION AND ASSIGNMENTS

SeaCow Robotics is divided into the following categories, with every member belonging in at least one: CAD, manufacturing, mechanical, electrical, and spirit. All team members are required to contribute to the documentation in areas that they are knowledgeable about. Leads of each of these categories worked with the CEO to develop a realistic yet rigorous schedule for tasks falling into their respective group. They also divided the work between other employees in their category with the help of the CEO when needed. These category and personal task assignments were frequently altered depending on the needs of group members and individuals.

Category leads made sure to assign new members tasks that would challenge them and make time in their own individual schedule to train them, or delegate the training to another returning employee. This way, new employees could learn while also contributing to the overall success of the organization and robot.

COLLABORATIVE WORKSPACE

All research, project management, and other documents are available to all employees in the shared Google Drive folder. This folder includes all documentation, research, planning, financing, etc. from past years and the current year for anyone to access freely. This allows employees to learn without directly being taught, increasing the speed of the training process. All 3D CAD was done in the online software OnShape, which allows complete collaboration in design. All employees have access to all designs and can freely view or edit current and past versions of designs.

Fig. 34: OnShape versioning for main robot document

Main communication outside of work time was done through the Discord app, which provided an organized way to communicate logistics information, set up in-person meetings, and discuss technical information/strategy. The organization and security that can be achieved with this app made it the ideal solution for SeaCow Robotics.

BUDGET AND PROJECT COSTING

At the beginning of the 2022-2023 school year, SeaCow Robotics makes a preliminary budget with the initial design of the robot in mind. This year, with many re-used/donated parts, it was much easier and faster to estimate costs that would go into the robot. Since one of the main goals of SeaCow Robotics is to provide opportunities for women who otherwise might not be interested in STEM, we strive to completely eliminate dues. This does make fundraising much harder, but the opportunity for all women to strive for success in robotics is worth it.

Most of our fundraising is done by selling products made in our workspace such as custom engraved water bottles, laser cut ornaments, yard signs, etc. Other fundraising is done through networking at water innovation events such as The Water Tower Innovation and Leadership Summit. While this does significantly contribute to our monetary freedom throughout the year, it also teaches employees important entrepreneurship skills that they can take with them to their next chapter. The budget and project costing documents can be found in Appendix 2.

CONCLUSION

CHALLENGES

Since SeaCow Robotics is in its third year, employees have a basis for most subsystems of a typical MATE ROV Competition ROV. This also means that some key members are moving on, and that systems must be put in place to ensure the long-term success of the company. Our biggest challenge this year was balancing this goal with striving for the success of our 2023 robot and growing the team to support a network of women in STEM for years to come. To address this challenge, we completely changed the roles of most of our employees, introduced a freshman to the team, and gave more autonomy to less experienced team members so they could more quickly gain confidence in the workspace. While this may have been slower than if experienced members guided new members through everything, it set up younger members for future success.

LESSONS LEARNED AND SKILLS GAINED

While manufacturing the main ROV in November made integrating tools once the RFP was released harder, it allowed us to get the robot driving in the water much sooner. This allowed us to diagnose issues that prevented us from completing demonstration tasks months before we needed to practice them. This made our water testing time in later months much more efficient, as basic driving practices did not need to be tested each time. It also allowed us to slow down the manufacturing process and train new members to be leaders in this subsystem, stepping towards our goal of establishing a long-lasting organization.

Since our ambitions this year were much higher in terms of outreach, community building, and ROV performance, we needed to raise extra funds to accomplish this. To fundraise, we focused on selling various custom products to other organizations as it helped integrate SeaCow Robotics with the community, teach employees entrepreneurship skills, and was very profitable. In the future, we will continue this practice for its several benefits.

FUTURE IMPROVEMENTS

While using the Raspberry Pi Cam as the main camera on the robot was a huge improvement from previous years, the rest of our camera system was still bulky and less efficient than it could have been. The other two cameras mounted permanently on the robot required connectors being encased in epoxy for waterproofing, which added unneeded ballast and got in the way of pneumatic tubing. In the future, using USB cameras strategically placed in smaller enclosures connected to the main 8 conductor tether would lower tether weight and diameter while also providing extra buoyancy instead of ballast.

Fig. 37: Camera connector epoxy - Violet Brockmann

With a large control box, one monitor, and two laptops, our ROV requires a large amount of space to be operated. This would prevent its use in many real-world applications, making it less effective in solving the problems presented in the UN Decade of Ocean Science and Sustainability. In the future, we plan to condense this system by using all digital cameras, integrating a monitor into the control box if needed, and minimizing the amount of connections needed topside.

ACKNOWLEDGEMENTS

MATE II for providing the opportunity to support women in STEM and demonstrate our passion and skills
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Swim Atlanta for allowing pool access
Gwinnett County Public Schools for funding the LHS makerspace
National Science Foundation for supporting MATE
The Water Tower for giving us a space to publicly display and demonstrate our mission/robots
The International Science and Engineering Fair for providing a space to display our mission/robots
Blue Trail Engineering for providing discounted products
Jesuit High School Rovotics for providing documentation format inspiration

REFERENCES

Argo and climate change. Argo. (n.d.). Retrieved April 11, 2023, from https://argo.ucsd.edu/science/argo-and-climate-change/

Bluerov2 Assembly (R3 version). Blue Robotics. (2023, March 2). Retrieved April 13, 2023, from https://bluerobotics.com/learn/bluerov2-assembly-r3-version

Environmental Protection Agency. (2022, August). *Sources of Greenhouse Gas Emissions* . EPA. Retrieved April 11, 2023, from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#electricity

Ocean Sciences and Exploration. ROPOS. (n.d.). Retrieved April 11, 2023, from https://www.ropos.com/index.php/services/ocean-science-and-exploration

Person, Male, Willard, & Balthazar. (2023, February 24). *ROVs in use for renewables*. Hydro International. Retrieved April 11, 2023, from https://www.hydro-international.com/content/article/rovs-in-use-for-renewables

APPENDIX

1. OPERATIONS AND SAFETY CHECKLIST

Pre-Pool Procedure

Visually inspect underwater electronics enclosure
Unscrew vent plug from end cap
Insert vacuum pump connection into penetrator
Bring underwater enclosure to 15inHg vacuum
Wait 15 minutes
Passed for pool if pressure is >13.5inHg

Power Up Procedure

Follow Pre-Power checklist
Turn power supply switch on
Turn main power switch on
Listen for two noise sequences on ESCs
If both sequences are not heard, power down
Wait for blue light on Pixhawk
Proceed with test

Pre-First Dive Systems Check

Complete power up procedure
Inspect penetrators and o-rings for damage
Press pneumatics switch and verify claw moves
Attempt rotating main camera
Attempt dimming and brightening light
Arm ROV
Test all thruster movements briefly (<10s per)
Disarm ROV
Proceed with dive

Launch Procedure

Submerge ROV and rotate
After rotation hold under and watch for bubbles
If any extra bubbles rise, execute leak procedure
If no extra bubbles rise, CEO calls ready
If ROV is in safe orientation, tether managers call ready
If QGroundControl is running without issues, pilot calls ready
Pilot arms ROV and begins task

Communication Loss Troubleshooting

Turn off main power switch
Turn of power supply switch
Wait 10 seconds
Complete Power Up Procedure
If communication is restored, continue test
If no communication, move ROV to safe area and begin continuity tests

In-water Leak Detection

Power down
Inspect enclosure for obvious damage/leaks
Observe color of leak detection packet
If packet is blue, there is no leak, continue with test
If packet is pink, there is a leak
Dry off exterior of ROV and move to its container
Remove vent plug and place in safe space
Disassemble demonstration station and move to workspace
Identify cause of leak

2. BUDGET AND PROJECT COSTING

Budget - SeaCow Robotics 2023

				Reporting Period
			From:	7/1/2022
			To:	5/1/2023
Income				
Source				**Amount**
State Farm Grant				$1,000.00
Yard Sign Fundraisers				$390.00
Ornament Fundraiser				$650.00
Water Bottle Fundraiser				$180.00
Nordson Grant				$1,000.00
Expenses				
Category	**Type**	**Description/Examples**	**Projected Cost**	**Budgeted Value**
Control Electronics	Purchased/Donated	pixhawk, raspberry pi, power sensor, bus bars	$680.00	$400.00
Electronic Enclosure	Purchased/Reused	4" acrylic tube, o-ring flanges, end caps, penetrators	$400.00	$300.00
Frame Materials	Purchased/Reused	HDPE, M3 fasteners, strain relief, 3D printed mounts	$150.00	$100.00
Tether	Purchased/Reused	signal wire, power wires, pneumatic tubing, sheath	$250.00	$150.00
Thrusters	Reused	6 T200 thrusters	$1,200.00	$0.00
Photogrammetry	Purchased/Donated	ZED 2i camera, powered USB extender, 3" enclosure	$600.00	$50.00
Manipulators	Purchased/Reused	claw 3D print, pneumatics, fasteners	$400.00	$350.00
Prop Building	Purchased/Reused	PVC connectors, carabiners, soft waterbottle	$500.00	$250.00
Regional Travel	Purchased	hotel, food, gas, etc. for Appalachian Highlands Regional	$1,000.00	$1,000.00
Championship Travel	Purchased	hotel, flights, food, robot shipping, etc. for World Championship	$6,000.00	$6,000.00
			Total Income:	$3,220.00
			Total Expenses:	$11,180.00
			Total Expenses - Reused/Donated:	$8,600.00
			Total Estimated Fundraising Needed:	$5,380.00

Project Costing - SeaCow Robotics 2023

					Reporting Period
				From:	7/1/2022
				To:	5/1/2023
Funds					
Category	**Type**	**Description/Examples**	**Value**	**Amount Spent**	**Running Balance**
Income	Cash Donated	State Farm grant, Nordson grant	$2,000.00	$0.00	$0.00
Income	Cash Donated	Product sales such as: ornament, engraved water bottles, etc.	$1,201.50	$0.00	$0.00
Control Electronics	Purchased/Donated	pixhawk, raspberry pi, power sensor, bus bars	$407.00	$372.00	$372.00
Electronics Enclosure	Purchased/Re-used	4" acrylic tube, o-ring flanges, end caps, penetrators	$393.00	$303.00	$675.00
Frame Materials	Purchased/Re-used	HDPE, M3 fasteners, strain relief, 3D printed mounts	$94.20	$74.20	$749.20
Tether	Purchased/Re-used	signal wire, power wires, pneumatic tubing, sheath	$238.00	$142.74	$891.94
Thrusters	Re-used	6 T200 Thrusters	$1,200.00	$0.00	$891.94
Photogrammetry	Purchased/Donated	ZED 2i camera, powered USB extender, 3" enclosure	$825.95	$39.95	$931.89
Manipulators	Purchased/Re-used	claw 3D print, pneumatics, fasteners	$571.02	$271.02	$1,202.91
Regional Travel	Purchased	hotel, food, gas, etc. for Appalachian Highlands Regional	$647.00	$647.00	$1,849.91
Championship Travel	Purchased	hotel, food, gas, etc. for World Championships	$6,200.00	$6,200.00	$8,049.91
Purchased - items purchased/new services paid for				Total Raised	$3,201.50
Re-used - items purchased in previous years				Total Spent	$8,049.91
Donated - equipment, material, and time donated				Final Balance	$4,848.41
Cash Donated - funds contributed to the company					
Negative final balance = more money raised than spent					