LINN-BENTON ROV

LINN-BENTON COMMUNITY COLLEGE | ALBANY, OR, USA

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Technical Documentation

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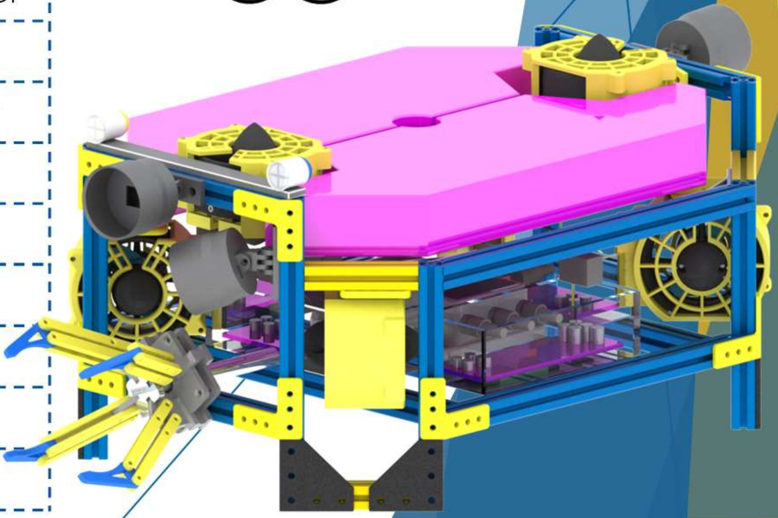
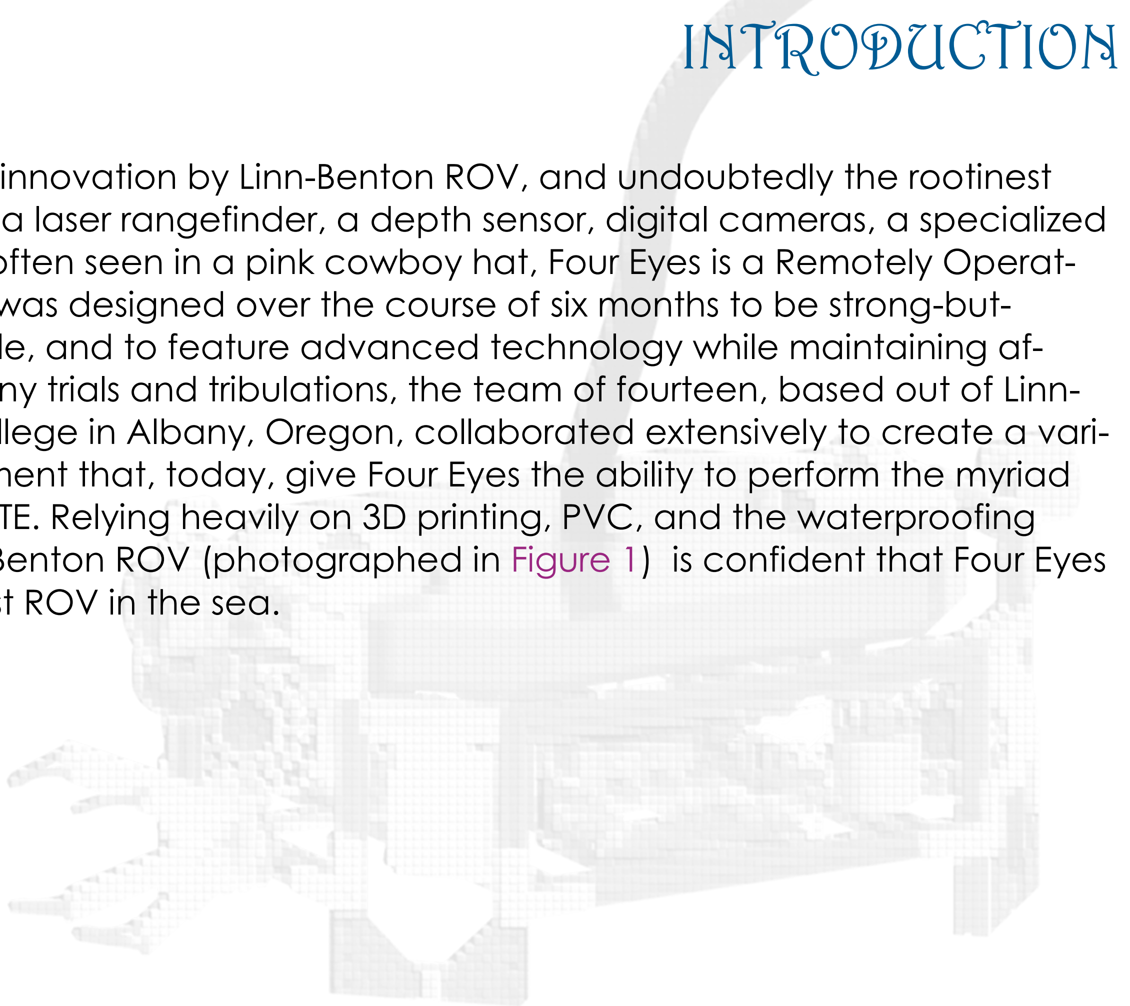
Rootin' Tootin'

Four Eyes

* * *





INTRODUCTION

ABSTRACT

Four Eyes is the newest innovation by Linn-Benton ROV, and undoubtedly the rootinest and tootinest. Sporting a laser rangefinder, a depth sensor, digital cameras, a specialized pneumatic claw, and often seen in a pink cowboy hat, Four Eyes is a Remotely Operated Vehicle (ROV) that was designed over the course of six months to be strong-but-delicate, quick-but-agile, and to feature advanced technology while maintaining affordability. Through many trials and tribulations, the team of fourteen, based out of Linn-Benton Community College in Albany, Oregon, collaborated extensively to create a variety of tools and equipment that, today, give Four Eyes the ability to perform the myriad of tasks set forth by MATE. Relying heavily on 3D printing, PVC, and the waterproofing powers of epoxy, Linn-Benton ROV (photographed in Figure 1) is confident that Four Eyes is the rootinest, tootinest ROV in the sea.

Figure 1: Linn-Benton ROV

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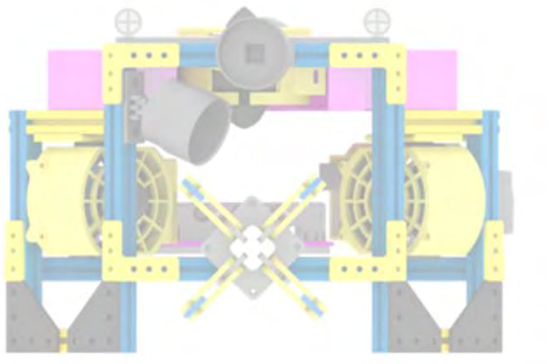
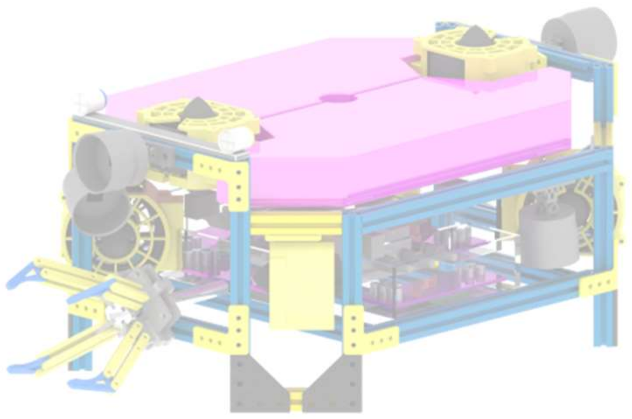
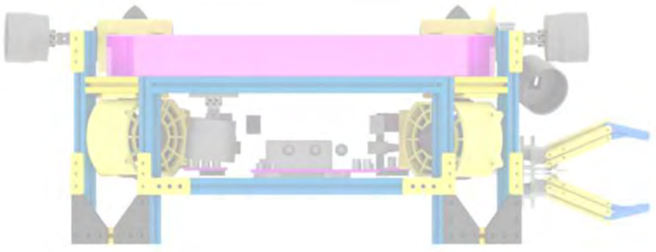






DESIGN RATIONALE

DESIGN PHILOSOPHY & OVERVIEW

At Linn-Benton ROV, we pride ourselves on designing remotely operated vehicles (ROVs) that are both adaptable and affordable. At the heart of our design philosophy is a mission to ensure that each component of the ROV can be added and removed from the vehicle with ease, allowing the team to adapt the vehicle for new or changing tasks without difficulty. Additionally, the design process at Linn-Benton ROV emphasizes affordability; any pieces that can be reused or homemade for less are favored over more costly options. This approach has led to the many components of our vehicle that are designed around polyvinyl chloride (PVC) pipes and/or 3D printed parts.

With limited time due to pandemic restrictions, a select few major components of the ROV were chosen to be upgraded, including the camera system, the manipulator, and the frame. Each of these components, while functional in past years, had noticeable room for improvement. Being reused without significant modification, however, are the vehicle's thrusters and power conversion boards. Furthermore, we have added a laser rangefinder and a depth sensor to the vehicle, as well as designed and built an autonomous vertical profiling float. A computer-aided design (CAD) model of the vehicle, whom we have nicknamed "Four Eyes," is shown in Figure 2.

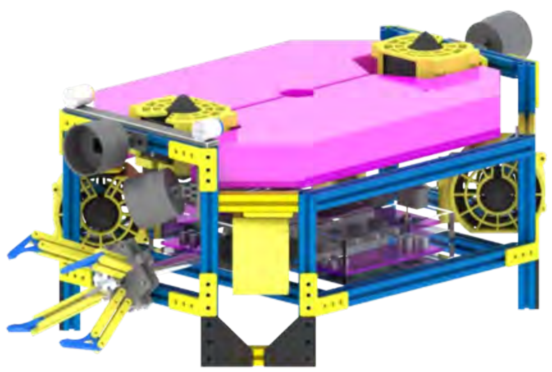


Figure 2: CAD model of Four Eyes

FRAME

Rather than reusing the aluminum frame from recent years, we made the decision to recreate the frame of our ROV to address a challenge faced by previous teams: air travel. In the past, Linn-Benton ROV has faced the task of taking apart the entire vehicle, including the frame, in order to transport it to and from MATE competitions. This process meant multiple hours of labor to disassemble and reassemble the ROV before departure and after arrival at each destination, all the while ensuring that small pieces do not get lost or left behind. Our new frame, measuring 53 × 40 × 25 centimeters, was designed to fit into an airline-approved travel tote so that it may be transported in one piece – no disassembly required.

This new frame (see Figure 3), is constructed of 20 mm x 20 mm extruded aluminum. Used in the construction of past frames by Linn-Benton ROV, aluminum serves as a lightweight, durable, and inexpensive building material that readily aids in our mission of modularity.

Aluminum pieces are secured via metal or 3D printed polylactic acid (PLA) brackets.

Metal brackets are used for all 90° connections, as well as four 135° connections, as they were readily available from commercial sources. Conversely, due to an unusual shape requirement, custom brackets were designed and produced by the team for most of the non-90° joints. Since PLA is not as strong as metal, these brackets introduced some challenges when it came to assembling a sturdy frame, and as a result, two brackets are used for each connection: one in a vertical orientation along the sides of the pieces, and another in a horizontal orientation along the top or bottom of each horizontal piece.

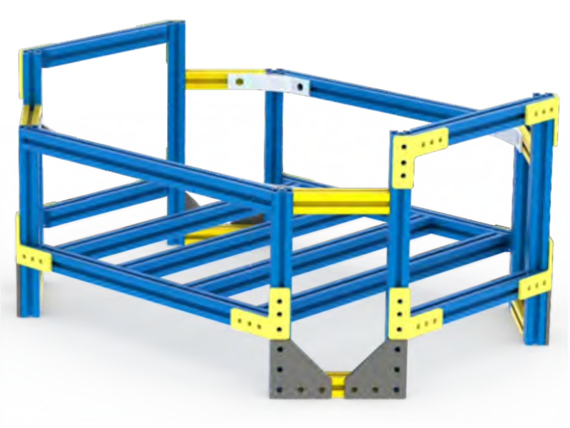


Figure 3: CAD model of frame

In addition to adhering to travel requirements, the frame's basket-like shape serves to house the many crucial tools and electronics that allow the vehicle to operate. Furthermore, the shape was designed with the removal of sharp edges in mind. To further integrate safety as well as beauty into the vehicle, all aluminum pieces are powder-coated for a smooth finish.

BUOYANCY

To achieve neutral buoyancy for the ROV, we determined that 4,500 cubic centimeters of air volume would be required to overcome its weight. Since enclosing large volumes of air allows for the possibility of leaks, it was decided that a lightweight solid buoyancy option would be preferable.

The bulk of our vehicle's buoyancy is in the form of R-3312 polyurethane foam,[1] cut to fit just inside the frame, as seen in Figure 4. This "elongated octagon" of foam is divided in half length-wise, with a hole cut in the center to allow the vehicle's tether to reach into the "basket" below, and cutouts on the front and back edges to allow space for the vertical thrusters to rest.

To further enable access to Four Eyes' electronics, the foam halves are attached to hinges on either side, allowing the buoyancy module to open while remaining secured to the ROV frame. The module is secured in the "closed" position during operation by two latching hooks.

For safety, there are no sharp edges on the foam pieces. The exposed edges of the foam are rounded to a smooth and gentle finish.

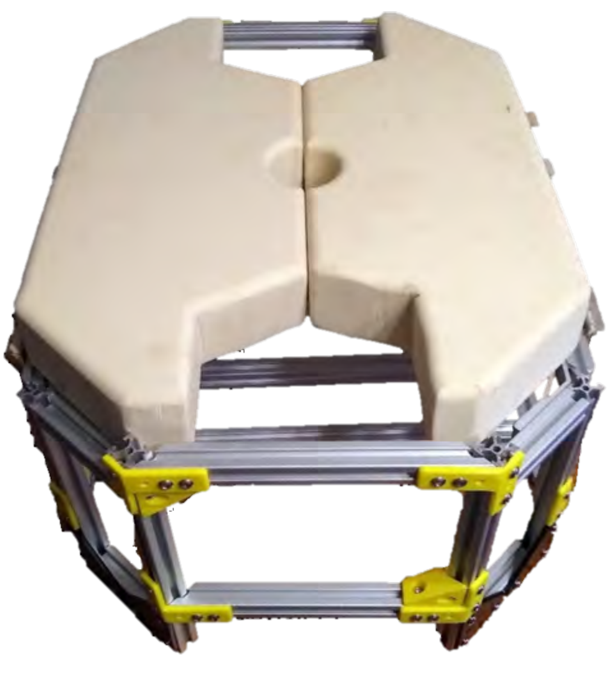


Figure 4: Buoyancy foam on new frame

To achieve neutral buoyancy, more than 4,500 cubic centimeters of foam is required. Each foam piece has a volume of about 2,500 cubic centimeters, which accounts for this additional requirement. Volume can be removed from the foam pieces by sanding, cutting, or drilling holes into the foam, as needed. Fine tuning the buoyancy with the addition or removal of various tools is more easily done by attaching polyethylene foam around the frame.

TETHER

Linn-Benton ROV designed the tether to be neutrally buoyant and detachable. The tether measures 12 meters and is composed of five wire cords, three air hoses, and a strip of polyethylene foam for buoyancy, all of which are contained in a wire sheathing. As shown in Figure 5, wires contained in the sheathing are:

- Ethernet for the camera signal
- Ethernet for the Arduino signal
- Two 18-gauge power wires for 48 VDC power
- Two pneumatic air hoses with a 148-psi rating for the claw
- Polyethylene foam for buoyancy

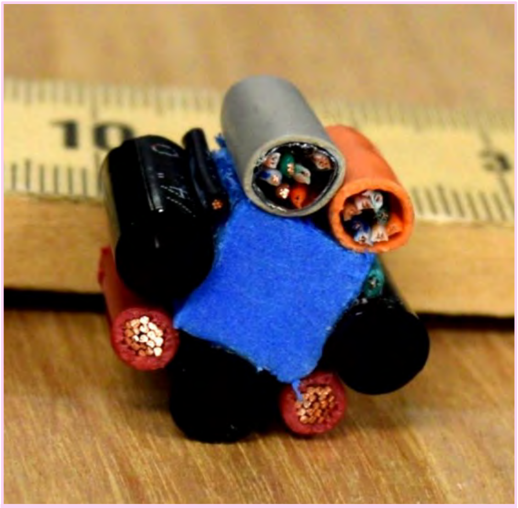


Figure 5: Unsheathed cross-section of tether

Also contained in the tether, as remnants of past vehicle components that are no longer in use, are a Swan visual signal cord and a pneumatic air hose with a 120-psi rating. These components are safely capped at both ends and are not used on the vehicle.

At the topside of the tether, there is a closed-mesh, single-eye strain that connects to a metal U-bolt on the control station. Coming from the strain, we have an orange Ethernet which connects to the Dry Arduino at the control station, a grey Ethernet which connects to the video control system, and two power wires entering an Anderson SBS50, which connects to our fused switch box. There are also two 148-psi air hoses coming from the strain, which connect to our pneumatic control station.

On the ROV-side of the tether, there is a closed-mesh, double-eye strain that connects to two metal U-bolts on the ROV. The connections from the tether wires come from the strain and connect to their specified places. The two 18-guage wires are divided into four 48 VDC power connections, which connect to the on-ROV power converters through SubConn® Low Profile two-contact connectors.[2] The two Ethernet cables have circular SubConn® eight-contact connectors;[2] the grey Ethernet connects to the camera system, and the orange Ethernet connects to the Wet Arduino. The two 148-psi air hoses connect to the pneumatic claw.

The tether was designed to be neutrally buoyant, however it proved to be marginally negatively buoyant, so there are rings of polyethylene on the bottom end of the tether near the ROV, so that the tether does not interfere with the ROV flight path.

SYSTEM POWER

A variety of our ROV components require electrical power to function. Shore power is provided to Four Eyes at 48 VDC and is converted to 12 VDC by four individual power conversion boards (PCBs). All devices onboard the ROV that require power must connect to one of these PCBs .

Figure 6: Completed PCB

The PCBs, shown in Figure 6, were designed by Linn-Benton ROV in 2019 to be small and easily replaceable. The circuit on the board is shown in Figure 7. Each board has one 48 VDC power input in the form of a SubConn® Low Profile two-contact connector, and three or four 12 VDC power outputs in the form of circular SubConn® two-contact connectors. The difference in connectors mitigates any risk of improper connections. To waterproof the boards, each PCB is epoxy-potted in an individual acrylic box. The bottom of this box is an aluminum plate, to which the PCB is attached via thermally conductive glue. This plate acts as a heat sink for the power conversion system.

During normal operation and testing, the power is supplied by four 12 VDC batteries, connected in series and accessed via an Anderson SBS50 connector, which is protected by a 30-amp fuse. Before connection to the ROV, this power supply is connected to a switch box, containing another 30-amp fuse and gauges for monitoring voltage and amperage. This switch box, with the switch in the *OFF* position, is then connected to the topside of the ROV tether. The switch is only moved to the *ON* position after all safety

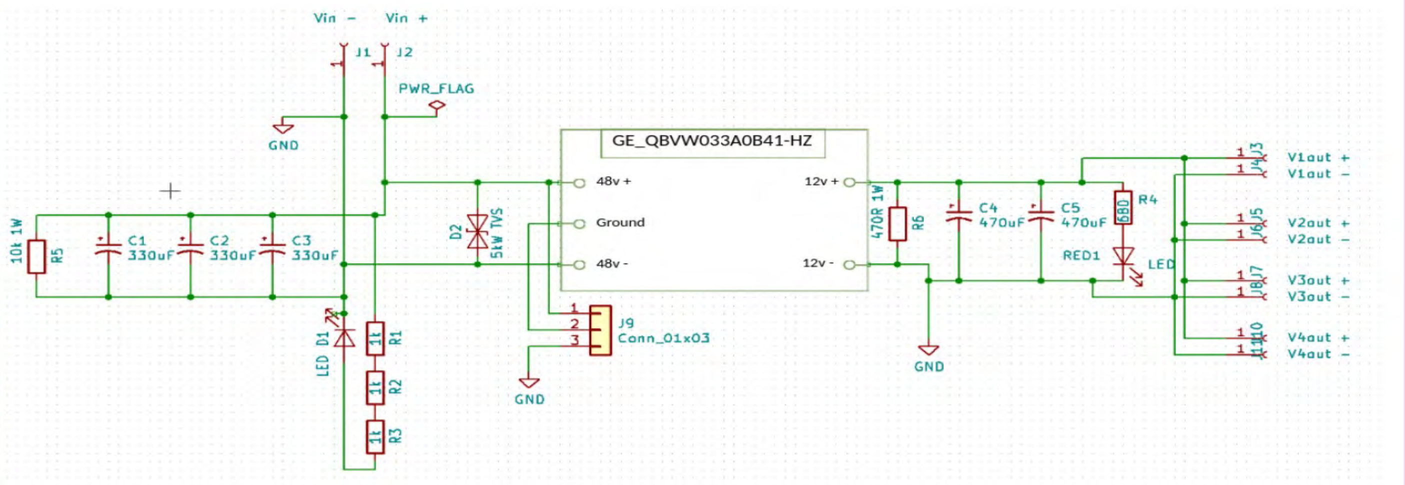


Figure 7: Circuit diagram of the power conversion boards

checks (see *Safety*) have been performed.

During the competition, power is supplied by the MATE power supply, to which the fused switch box connects, allowing the protocol above to be followed.

SYSTEM CONTROLS

Figure 8: PlayStation2 controller and Dry Arduino

Most movement and component controls on Four Eyes are accomplished through a PlayStation2 controller and two Arduino Uno boards: one on the topside, known as the Dry Arduino (see Figure 8), and one onboard the ROV, known as the Wet Arduino. The Arduinos communicate through the tether's orange Ethernet; the Dry Arduino passes input from the controller to the Wet Arduino to be relayed to thrusters and tools, while the Wet Arduino collects information from components and sensors on the ROV and passes them to the Dry Arduino to be displayed.

The PlayStation2 controller serves as an intuitive option for controlling the ROV, with two analog joysticks to control movement and a variety of digital buttons to toggle tools or movement modes or speeds. The D-pad buttons will increase or decrease the thruster speed in 10% increments and, in addition to linear and yaw movements, the ROV can enter "tilt" mode via the right trigger and change angle/pitch to aid in various tasks.

The only tool which is not controlled by the Arduino system is Four Eyes' manipulator claw. As the claw is pneumatic, it is controlled by a series of electrical air valves, which are controlled by a two-way switch that is separate from the controller.

THRUSTERS

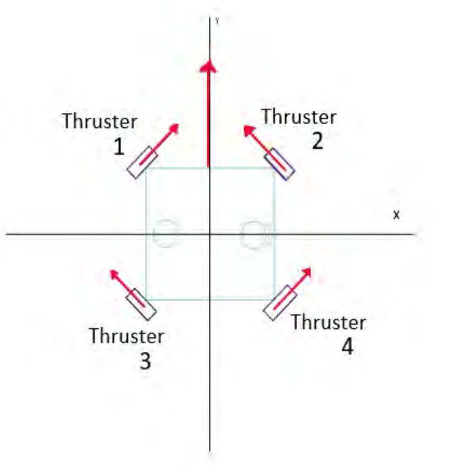


Figure 9: Thruster diagram

Four Eyes utilizes six BlueRobotics T100 thrusters,^{3} chosen for their reliability as proven in past Linn-Benton ROV builds. Four of these thrusters are mounted at a 90° offset from one another, one at each corner, and function in main directional movement. The remaining two thrusters are mounted on top of the ROV, positioned for up/down and tilt movements.

The main directional movement is accomplished via vector geometry. The decision to approach movement in this way comes at the cost of movement power, as half of each thruster's output is cancelled by another thruster when moving linearly. A top-down view of each thruster's movement in the "forward" direction can be seen in Figure 9. The benefit to this approach, however, is the ability to accomplish yaw movement to change the direction the ROV is facing, without compromising stability or using additional thrusters.

For safety, the thrusters are each shrouded in 3D printed cases, which prevent fingers or other objects from encountering moving propellers.

CAMERAS & COMPUTER VISION

This year, Linn-Benton ROV decided to upgrade from an analog vision system to a digital vision system. A digital system would allow for higher resolution, better quality, ability to program AI functions, and overall, more functionality. This conversion has undergone many challenges along the way, with some of the most significant being consistency and latency. While the analog cameras are relatively consistent, digital cameras require quite a bit of processing power to operate efficiently. We decided to utilize a Raspberry Pi to perform the hefty processing. The Raspberry Pi allowed for portability and convenience on our control station since it acts as a micro-computer. Through trial and error, the team recognized the digital camera setup that appeared to be the most efficient and successful.

Figure 10: Camera system

Rather than buying expensive pre-waterproofed cameras, we decided to design and waterproof our own camera system for both the learning experience and financial savings. This camera system, as shown in Figure 10, works by allowing four BlueRobotics USB cameras[4] to connect to a USB transmitter that is mounted on the ROV and multiplexed through an Ethernet cable in the tether to a USB receiver at the control station. The control station receiver is bridged to the Raspberry Pi, which processes the signal and displays it on a monitor at the control station.

As shown in Figure 11, the cameras are each placed in a 3D printed housing which fortifies the viewing dome from scratches, an improvement over the previous camera system. The housing is sealed with epoxy to ensure waterproofing in a way that still grants access to the camera. The housing additionally allows for two axes of rotation, allowing manipulation for desired camera angle. Two of the cameras are mounted in the front, with one looking forward and the other looking at the gripper. Another camera is mounted on the rear, and the last is facing down under the ROV.

The software used on the Raspberry Pi to process the images is called OpenCV,[5] which utilizes Python to manipulate and create user functions. The key function implemented allows the operator to view the four cameras and capture snapshots of any of the cameras at a given time.

Figure 11: USB camera in housing

While this code is still in the process of being perfected in hope of being ready for our upcoming competition, we also plan to produce a code ready to assist in measuring morts, autonomously following a red line, capturing images for a panorama, and mapping a shipwreck. Our current setback, however, is that the four digital cameras push the Raspberry Pi to its processing limit, leading to inconsistency. True to the Linn-Benton ROV Design Philosophy, the plan is to have the digital system be modular, including its own easily separable tether, so that the system could be easily removed from the ROV in case of malfunctions. In this case, the analog cameras may still serve as a direct source of video feedback.

MANIPULATOR

While we are reusing the pneumatic manipulator from Linn-Benton ROV's 2019 vehicle, several improvements have been made. In 2019, the claw was built using a four-fingered Robotpark X4M as the base, which was then scaled down to an efficient two-fingered tool.

Starting in January 2022 with a new pilot, the claw was discovered to be less than ideal for the given tasks, as it could not easily pick up horizontal PVC pipes and could not grasp the ghost net pin. As such, the team decided to return to a four-fingered model, so that the claw could interact with both vertical and horizontal pipes. The last six months have been spent fine-tuning the fingers of the claw to be adept at each of the missions required, from pulling a small pin to scooping a mort from the floor.

The improved fingers (see Figure 12) are 3D printed in Linn-Benton ROV colors, greatlyelongated, notched to hold 1-inch PVC, and feature hooks which can grab and retain pins with ease. High-friction pads have also been added to the inside of each finger to prevent objects from slipping.

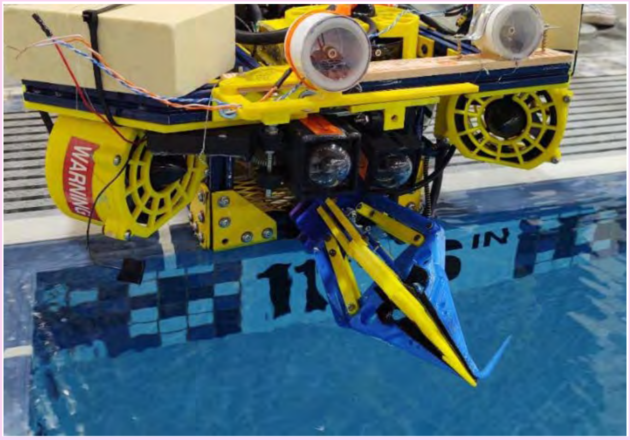


Figure 12: Improved manipulator

DEPTH SENSOR

Two important design considerations for Four Eyes were 1) ensuring that the pilots were able to reliably know the ROV's depth and 2) being able to measure the length of the wreck of Endurance. It was agreed upon that a depth/pressure sensor would be vital to accomplishing these goals.

The depth/pressure sensor is able to consistently and continuously measure and communicate the ROV's depth to the pilots during operation. Additionally, using the pressure sensor's reported depth in conjunction with the camera's field of view and a little trigonometry, the length of the Endurance's wreck can be determined. This scenario is illustrated in Figure 13.

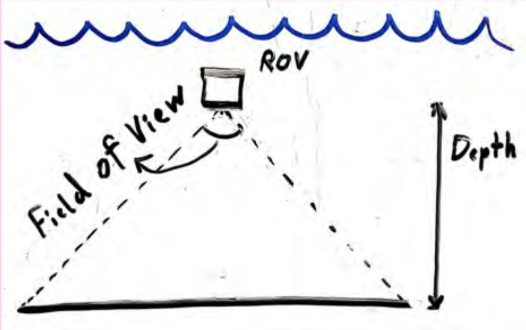


Figure 13: Depth sensor trigonometry

The Bar02 Depth and Pressure Sensor[6] from BlueRobotics, shown in Figure 14, was integrated into the ROV design to accomplish these two goals. The sensor is positioned such that it can collect depth pressure information from the surrounding water without sustaining water damage to its components.

The system requires an I2C logic level converter to convert the Arduino's 5 V logic to the sensor's required 3.3 V logic. The code operating the sensor uses the BlueRobotics MS5837 library[7] to convert the sensor's electrical readings into a depth reading. This depth reading is then sent from the Wet Arduino, through the tether, and finally to the Dry Arduino to be displayed on a four-digit digital display (see Figure 15). This digital display allows the pilot and copilot to keep track of the ROV's depth during the mission.

The pressure sensor was also determined to be of use to the vertical profiler. Its inclusion in the vertical profiler is discussed in the Vertical Profiler section of this document.

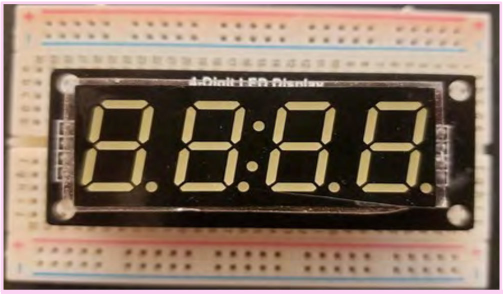


Figure 14: Four-digit digital display

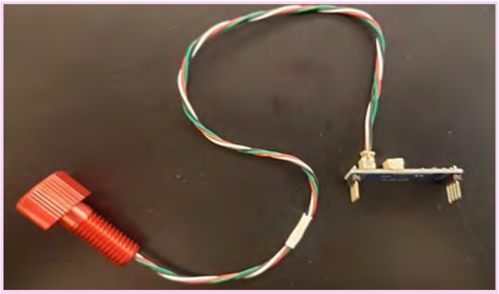


Figure 15: Bar02 pressure sensor

LASER RANGEFINDER

The purpose of integrating a laser measuring system into the ROV is to determine both the length of distant objects and their distance away from the vehicle. Not only are these details are important to some competition tasks, they also give the ROV control team spatial information to aid in performance during the competition.

The original design was based around the principle of time-of-flight, which is commonly incorporated into commercial laser rangefinders. Shortly after development began, it became apparent that building such a sophisticated rangefinder was far outside the scope of the project. To maintain a balance of affordability, reliability, and efficiency, the team decided to pivot to a system that would use trigonometry. The alternative option we chose is a system that forms a triangle using two lasers and a motor to measure a distant object. This design, diagramed in Figure 16, also allows the ROV to measure the length of objects parallel to itself, along with maintaining the original functionality of range finding.

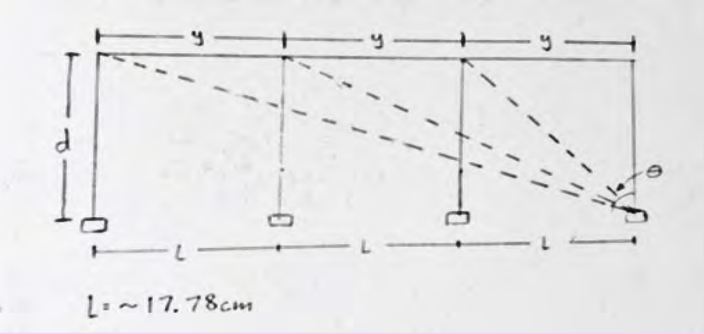


Figure 16: Laser rangefinder concept drawing

The laser system, seen in Figure 17 and Figure 18, is composed of several primary pieces, including the stationary laser cell, mobile laser cell, the processor, and the control station. The shells of each laser cell are constructed identically, made of a 3D printed PLA sleeve, 1" PVC piping, 1" PVC pipe cap, and a clear polycarbonate lens. The shell is assembled and sealed with plastic epoxy. Each PLA sleeve is designed to hold a single 5 mW, 650 nm laser diode, which is wired to an insulated cable that connects to a 12 VDC to 5 VDC power converter via a relay. This power converter connects to one of the PCBs onboard the ROV, while the relay is controlled by a power switch at the surface control station.

The stationary laser cell is attached to the frame of the ROV, and the mobile laser cell is connected to a sealed 5 VDC servo motor via a neodymium magnetic coupler. The servo motor, also attached to the frame of the ROV, connects to the Wet Arduino on the

Figure 17: First prototype of laser rangefinder

Figure 18: Second prototype of laser rangefinder, mounted on ROV.

ROV to provide angular position data on the mobile laser. The Wet Arduino transmits data to and from the control station, which contains a laser control unit that consists of a potentiometer and a display for reading the laser's angle.

VERTICAL PROFILER

A vertical profiling float is an autonomous vehicle that moves from the top of a body of water to the bottom, often taking measurements as it goes. For the MATE competition, the float is required to use a buoyancy engine to move itself through the water. A buoyancy engine works by moving a fluid, such as water or air, from a bladder inside the vehicle to a secondary bladder external to the vehicle. The movement from the internal bladder to the external bladder displaces a certain volume of water, which changes the density of the float. This allows the profiler to be more buoyant.

Figure 19: Vertical Profiler

Our buoyancy engine (see Figure 19 and Figure 20) consists of a 4-inch diameter piece of sewage pipe, a linear actuator, a flexible external bladder, and a series of 3D printed pieces, which can be seen in Figure 21. During operation, air will be moved from a reservoir inside the pipe to an external bladder to change the buoyancy of profiler. This causes the vertical profiler to rise from the bottom of the pool to the top. The air will be moved between the bladders by a 3D printed attachment on the top of a linear actuator, which creates a piston sealed by an O-ring to make it airtight and redundant.

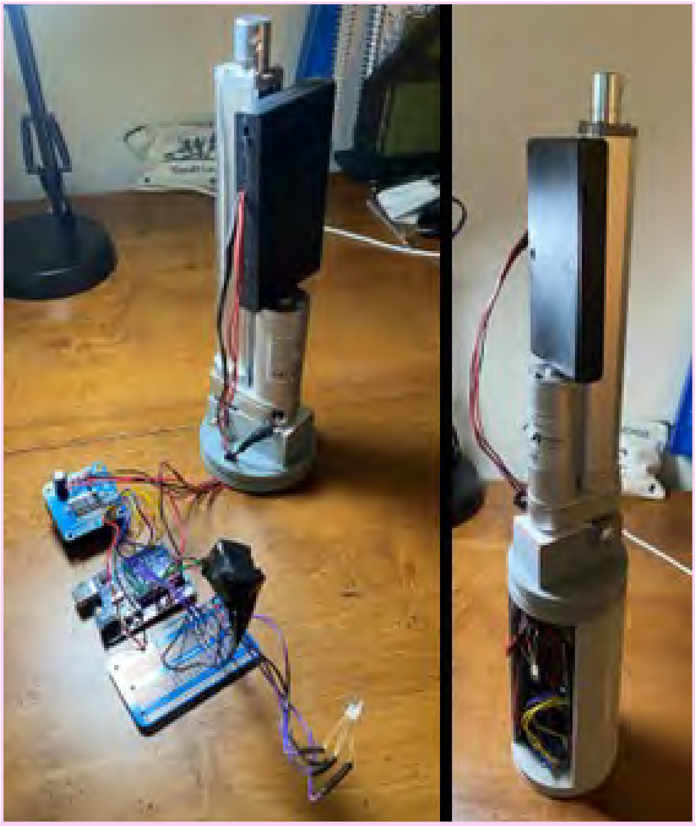


Figure 20: Buoyancy engine electronics

The external bladder is a pop-up, silicone bowl. The bowl is attached to a large, lightweight metal funnel to allow the air to enter. To waterproof the electronics and actuator, the bladder and funnel are made watertight with sealant, and the 3D printed pieces have O-rings running along the perimeter. The electronics are thus housed in a watertight compartment at the bottom of the sewage pipe, separated by a 3D printed piece

Figure 21: a. Tech shield base;
b. linear actuator base;
c. linear actuator connector

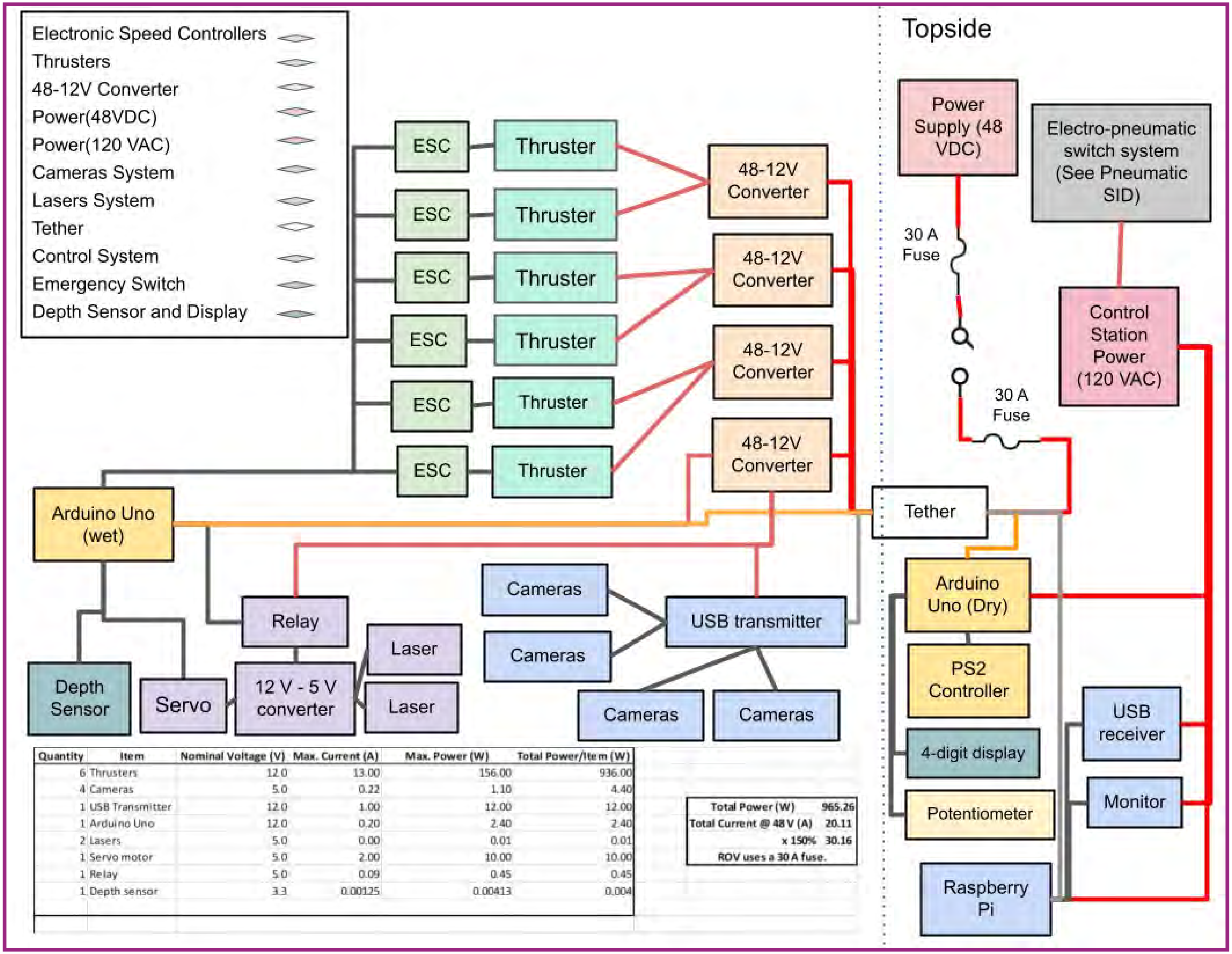
from the actuator’s chamber. The actuator’s chamber is then separated from the air chamber by the piston.

The buoyancy engine control system uses an Arduino Uno, a motor controller, and a linear actuator. The electronics are powered by a 12 VDC AA battery pack; as such, the sewage pipe contains an automatic pressure release valve as a safety measure, should excess pressure build inside the tube. The electronics are controlled by a switch on the outside of the tube, which controls power. Once the power is on, a timer dictates when the linear actuator is activated to expand the external bladder.

Before the competition, we would like to incorporate a pressure/depth sensor, mirroring the depth sensor system integrated onto the main vehicle. This depth sensor would replace the timer in dictating the action of the actuator.

SYSTEM INTEGRATION DIAGRAMS

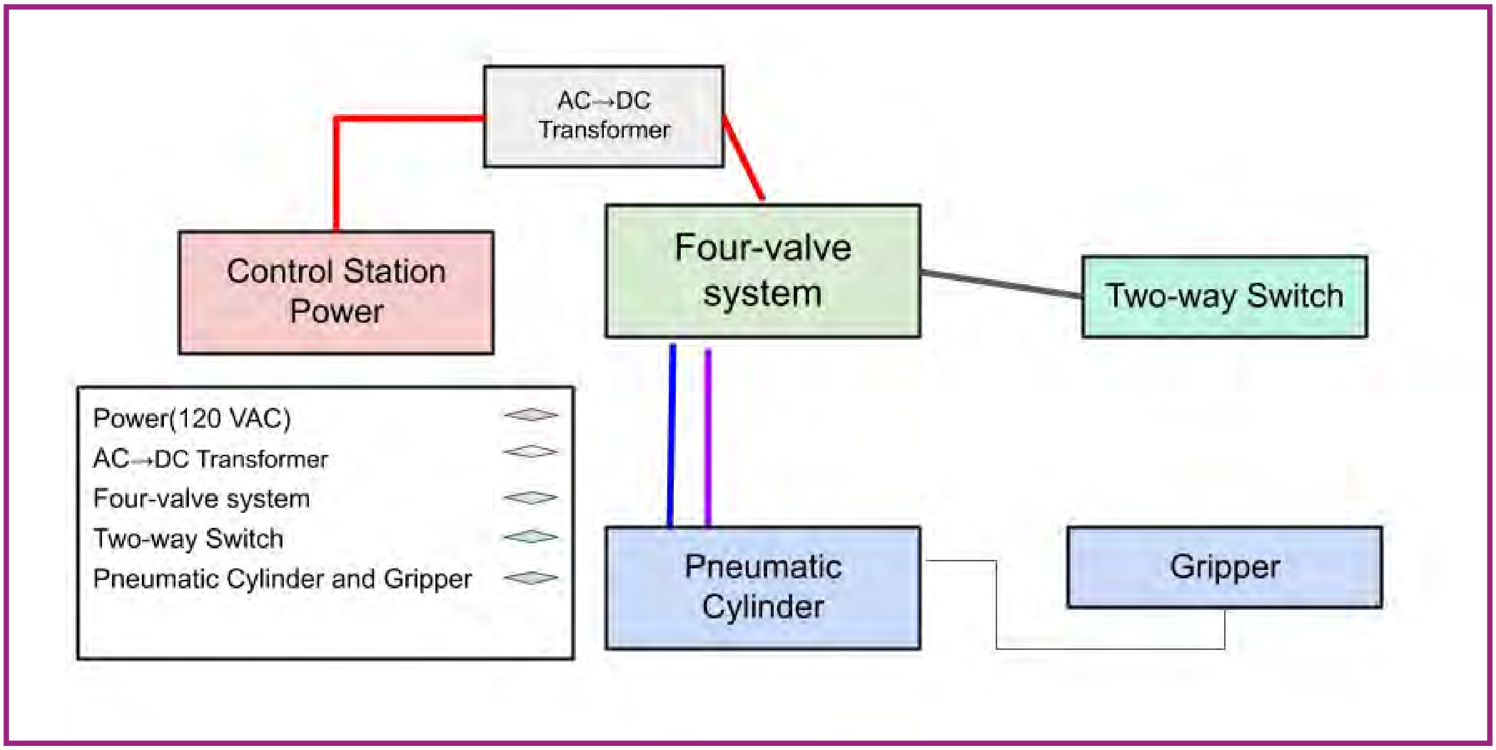
ROV — ELECTRICAL



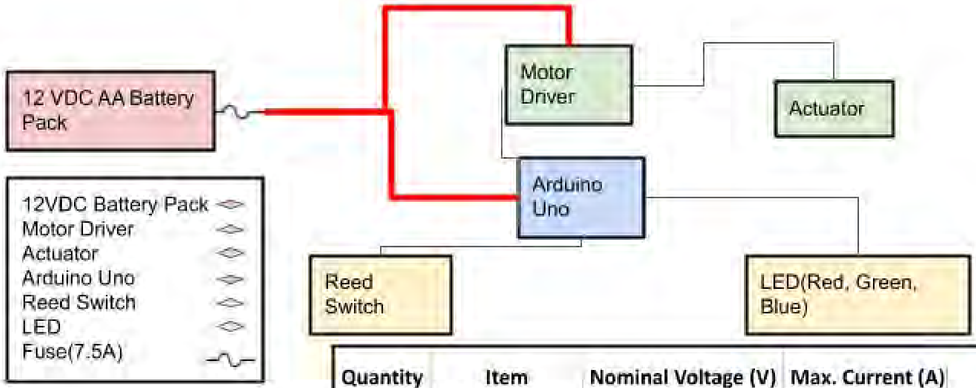
Quantity	Item	Nominal Voltage (V)	Max. Current (A)	Max. Power (W)	Total Power/Item (W)
6	Thrusters	12.0	13.00	156.00	936.00
4	Cameras	5.0	0.22	1.10	4.40
1	USB Transmitter	12.0	1.00	12.00	12.00
1	Arduino Uno	12.0	0.20	2.40	2.40
2	Lasers	5.0	0.00	0.01	0.01
1	Servo motor	5.0	2.00	10.00	10.00
1	Relay	5.0	0.09	0.45	0.45
1	Depth sensor	3.3	0.00125	0.00413	0.004

Total Power (W)	965.26
Total Current @ 48 V (A)	20.11
x 150%	30.16
ROV uses a 30 A fuse.	

ROV — PNEUMATIC



VERTICAL PROFILER — ELECTRICAL



Quantity	Item	Nominal Voltage (V)	Max. Current (A)	Max. Power (W)	Total Power/Item (W)
1	Actuator	12.0	5.00	60.00	60.00
1	Arduino Uno	12.0	0.20	2.40	2.40
				Total Power (W)	**62.40**
				Total Current @ 12 V (A)	**5.2**
				x 150%	**7.8**
				VP uses a 7.5 A fuse.	

TESTING & TROUBLESHOOTING

TESTING METHODOLOGY

We have a couple of different methods that we have been using to test and troubleshoot throughout the design process. Throughout the six months that we have been working together, we have been testing different parts of Four Eyes; from basic movement, control, and vision systems to the usability of the claw. Our development protocol typically consists of modeling/designing, followed by testing the model and deciding which steps to take next based on what worked well and what didn't. For most subteams, this happened to some extent on a weekly basis, whether it was testing in water or testing in a lab environment.

One example of our troubleshooting process comes from our manipulator sub-team, as they had to go through many variations of claws and testing to reach what we have today. The first model had many issues, including that it could not pick up the mort and had significant trouble in pulling the ghost net pin. To counteract this, the claw team modeled a new design in SolidWorks that had a four-finger, rather than two-finger, approach to get a better hold on the mort. The next step was to find an easier way to pull the ghost net pin, for which the team tested a version of the claw with a hook on the end of two of the fingers. This allowed the ROV pilot to hook the pin, rather than attempting to grab the pin with the claw itself.

Further testing revealed that the four-finger approach alone was not enough to grab the mort with ease. A series of changes to the shape of the claw led the team to its current design, including two flat fingers on the bottom to act as a shovel and grip tape covering each finger to improve traction and reduce slipping. Without this continuous testing, the manipulator sub-team would not have known which direction to go at each stage.

Another example of our testing and troubleshooting process comes from the vertical profiling float sub-team. The first series of tests that the float team conducted involved attempting to make the linear actuator work. To do this, the sub-team used an Arduino Uno, a bread board, two buttons, linear actuator, motor driver, battery pack, wiring and a USB cable that was connected to the laptop that had the computer program, written by the float team, to control the electronics. After directly following the manufacturer's recommendations for how to set up the circuitry for the actuator, the float team began to suspect that something within the system was faulty. It was eventually discovered that the motor driver was not the correct model. After acquiring the correct motor driver, the program made the linear actuator work perfectly.

The float team's first in-water testing consisted of seeing how long it would take for specific weights to sink to the bottom of a pool with a hollow tube; this field testing was intended to verify the accuracy of the Python model of the design's buoyancy. Further changes to both the Python model and the actual design were made as a result of this testing.

SAFETY

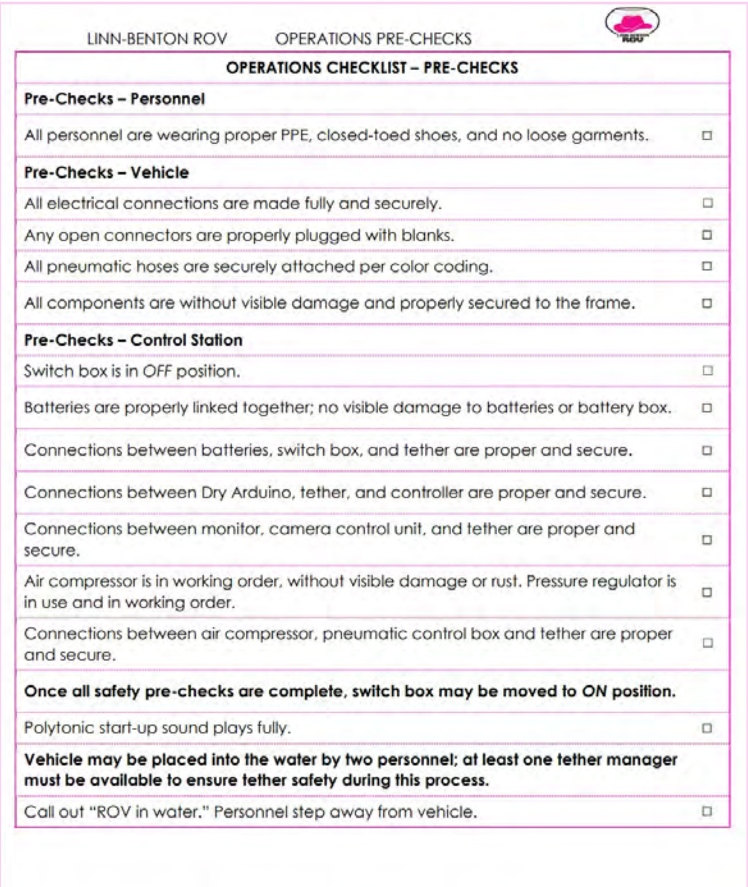
SAFETY PHILOSOPHY

Safety is very important to Linn-Benton ROV, and we take it very seriously. In order to maintain a supreme level of safety for our team and our ROV, we follow many safety procedures and protocols. These protocols span the use and operation of ROV and its design features, as well as personal safety for all team members.

COMPANY SAFETY PROTOCOLS

Safety protocols are strictly enforced. To ensure this, every team member has a designated job and a procedure for each job:

- Batteries are charged by Alex, who has worked with batteries in a professional environment and thus knows all proceedings to properly and safely charge the batteries, reducing the risk of electrocution and small fires.
- Vehicle safety checks (see Figure 22) are carried out by copilot Chloe and pilot Levi during set-up for operation. Specifically, Chloe performs the control station checks; while Levi performs the vehicle and personnel checks. In performing this inspection while keeping the vehicle away from the water, we reduce the risk of electrocution and harm to personnel, in addition to reducing the risk of shortages and damage to both the control station and the ROV.
- During operation, we always have two people in charge of tether management. The tether managers communicate with the pilot and copilot regularly and watch and listen carefully to ensure the ROV has the right amount of tether during operation, and that the tether remaining above water does not pose a hazard on deck. Communication between the two sets of people reduces the risk of harming the ROV, personnel, and passersby.



LINN-BENTON ROV OPERATIONS PRE-CHECKS

OPERATIONS CHECKLIST – PRE-CHECKS	
Pre-Checks – Personnel	
All personnel are wearing proper PPE, closed-toed shoes, and no loose garments.	☐
Pre-Checks – Vehicle	
All electrical connections are made fully and securely.	☐
Any open connectors are properly plugged with blanks.	☐
All pneumatic hoses are securely attached per color coding.	☐
All components are without visible damage and properly secured to the frame.	☐
Pre-Checks – Control Station	
Switch box is in *OFF* position.	☐
Batteries are properly linked together; no visible damage to batteries or battery box.	☐
Connections between batteries, switch box, and tether are proper and secure.	☐
Connections between Dry Arduino, tether, and controller are proper and secure.	☐
Connections between monitor, camera control unit, and tether are proper and secure.	☐
Air compressor is in working order, without visible damage or rust. Pressure regulator is in use and in working order.	☐
Connections between air compressor, pneumatic control box and tether are proper and secure.	☐
Once all safety pre-checks are complete, switch box may be moved to *ON* position.	
Polytonic start-up sound plays fully.	☐
Vehicle may be placed into the water by two personnel; at least one tether manager must be available to ensure tether safety during this process.	
Call out "ROV in water." Personnel step away from vehicle.	☐

Figure 22: Operations Safety Pre-Checklist

Personal protective equipment (PPE) is also very important to Linn-Benton ROV. Safety goggles or glasses must always be worn during vehicle operation, and during any activity that involves open battery compartments. Closed-toed shoes should be worn during all vehicle operation activities, long hair must be tied back, and no loose garments that can create safety hazards may be worn during these activities. Additionally, Linn-Benton ROV is enforcing that all members in attendance use ample sunscreen throughout the competition, and the use of our signature hats, shown in Figure 23, for extra sun protection is strongly encouraged.

Figure 23: ROV in cowboy hat

VEHICLE SAFETY FEATURES

In order to meet standards for the MATE competition and safety in general, the ROV and control station have no exposed wiring that is not enclosed in either heat shrink and hot glue, epoxy, or another protective method (**ELEC-017E**). We also have no loose wiring on the ROV or in the control station (**ELEC-022E**). Leaving loose or exposed wiring is extremely dangerous and can cause fire and electrocution, so we have taken steps to ensure all wires are safe to handle and there are no loose wires inside the control boxes. Our power supply and all connection points are labeled, and there is a set procedure for setting up to diminish the occurrence of injuries.

The tether has proper a mesh sheath to contain all wires, as well as two strain reliefs: one at the ROV, and another entering the control station (**ELEC-024E**). The sheath and strain reliefs ensure that no wires are tugged or slip out during operation of the ROV.

All propellers are shrouded in 3D printed cases that we designed via SolidWorks (**MECH-006**). As an improvement on past designs, we made the openings in these shrouds very small to prevent the ghost net or any other materials from becoming wrapped around the propeller. These shrouds also ensure that ROV handlers cannot be injured by the propellors.

The frame was also redesigned and reduced in size for easier transport and to mitigate the risk of losing critical components during travel. The ROV frame has no sharp corners.

LOGISTICS

TEAM OVERVIEW

Linn-Benton ROV is based out of Linn-Benton Community College in Albany, Oregon. The project of designing and building an underwater remotely operated vehicle (ROV) provided over a dozen members with an opportunity to put their skills, both new and pre-existing, to the test in a collaborative and fun environment. With two returning members, Sara Leathers and Chloe Madden, the team came together from seven disciplines spanning science and engineering to partake in the engineering challenge set forth by MATE.

By not dividing the team into clear departments, or distinguishing superiors and subordinates, Linn-Benton ROV opened all activities to all members so that all may learn as much as possible during the process. Frequently, sub-team leaders would emerge naturally, taking on the role of organizer for the project to ensure that all goals and deadlines are met efficiently. Occasionally, the project was discovered to require input from various team members with varying areas of expertise, such that no individual organizer was necessary; instead, accomplishing goals and meeting deadlines was the responsibility of the entire team.

While Linn-Benton ROV believes that all members can and should be involved in all tasks to the best of their ability, the general breakdown of all sub-teams can be seen in Table 1.

Member	Sub-Team(s)
Nolan Andersen	Laser Team
Phoebe Andromeda	Sensors Team
Nic Barden	Float Team
Grant Baysinger	Camera Team
Kyle Davis	Float Team
Mikayla Heston	Documentation Team
Levi Kaup	Claw Team; Controls Team
Sara Leathers	Frame Team; Documentation Team
Chloe Madden	Controls Team
Remy Rouyer	Camera Team
Quade Stiansen	Camera Team
Morgan Sylvia	Laser Team
Alexander Van Brocklin	Laser Team
Kelly Watkins	Float Team
Emilia Watts	Float Team

Table 1: All team members and associated sub-teams

MEETING SCHEDULE

Linn-Benton ROV met bi-weekly during the school term on Tuesdays and Sundays. The Tuesday meeting, organized by head mentor Greg Mulder and hosted over Zoom, served to review what was completed the previous week as well as organize what will get done in the coming week. Round robin style, individuals or sub-teams would take turns explaining their plan, progress, and/or the hurdles they faced. If any assistance or collaboration with another sub-team was needed, it would be discussed at this time.

The Sunday meeting served as an in-person collaborative workday, and/or a day for testing, often at a local pool. These meetings would always end with a Tuesday-style group discussion of what had gone well, what hadn't gone well, and what direction to go next. Sub-teams often planned their own meetings and workdays during the week in addition to those shared by the whole team in order to accomplish goals more quickly.

TASK DISTRIBUTION

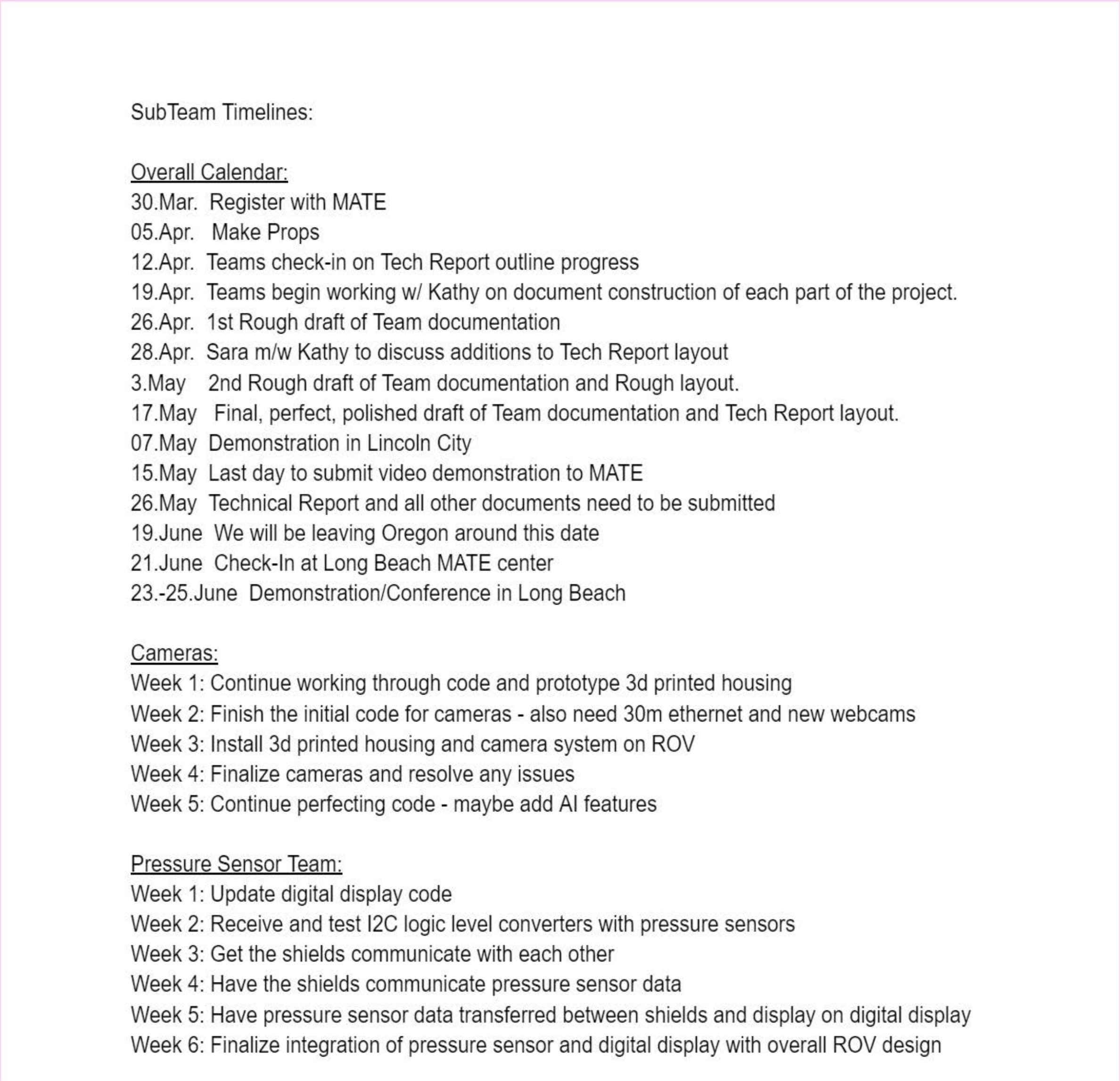
Throughout the build process, tasks were distributed largely on a volunteer basis, allowing members to start where they felt comfortable and branch out when they felt motivated. This philosophy ensured an easygoing environment for new members without the expectation of pre-existing ROV expertise.

Though divided into smaller sub-teams focused on each task, the build process at Linn-Benton ROV relied heavily on collaboration among the entire team. To help each build team overcome the challenges of their mission, an open planning style was used to encourage a free exchange of ideas. Once a few possible solutions had been put forth, the sub-teams would spend time researching and reconvene later to share what they had learned and decide on a plan moving forward. As a result, throughout the build process, countless ideas were exchanged about how to best go about design, construction, sourcing materials, integration onto the main ROV, and ensuring proper function for the intended task.

BUILD SCHEDULE

Building an ROV requires not only extensive collaboration but substantial planning as well. Due to pandemic restrictions, the team could not begin working together in-person until the start of 2022. As such, time was an even more precious resource than in past years. In response to this, Linn-Benton ROV developed a schedule plan for the overall build process, from familiarization with the existing vehicle in January, through the discussions, designs, and implementations of changes and improvements, and to the in-person competition at the end of June.

Furthermore, each sub-team developed their own schedule for the design, construction, and implementation of their specific component, including any points of collaboration with other sub-teams. A portion of this schedule, created on March 29th, 2022, is shown in Figure 24.



SubTeam Timelines:

Overall Calendar:
30.Mar. Register with MATE
05.Apr. Make Props
12.Apr. Teams check-in on Tech Report outline progress
19.Apr. Teams begin working w/ Kathy on document construction of each part of the project.
26.Apr. 1st Rough draft of Team documentation
28.Apr. Sara m/w Kathy to discuss additions to Tech Report layout
3.May 2nd Rough draft of Team documentation and Rough layout.
17.May Final, perfect, polished draft of Team documentation and Tech Report layout.
07.May Demonstration in Lincoln City
15.May Last day to submit video demonstration to MATE
26.May Technical Report and all other documents need to be submitted
19.June We will be leaving Oregon around this date
21.June Check-In at Long Beach MATE center
23.-25.June Demonstration/Conference in Long Beach

Cameras:
Week 1: Continue working through code and prototype 3d printed housing
Week 2: Finish the initial code for cameras - also need 30m ethernet and new webcams
Week 3: Install 3d printed housing and camera system on ROV
Week 4: Finalize cameras and resolve any issues
Week 5: Continue perfecting code - maybe add AI features

Pressure Sensor Team:
Week 1: Update digital display code
Week 2: Receive and test I2C logic level converters with pressure sensors
Week 3: Get the shields communicate with each other
Week 4: Have the shields communicate pressure sensor data
Week 5: Have pressure sensor data transferred between shields and display on digital display
Week 6: Finalize integration of pressure sensor and digital display with overall ROV design

Figure 24: Portion of a schedule planning document for individual sub-teams

CONCLUSION

FUTURE IMPROVEMENTS & PLANS

While we have done a lot of work in a short amount of time, Linn-Benton ROV still has plans for improvements. First, we plan to finish the camera and computer vision code, be it before or after the competition, for the sake of education and completion. Second, we plan to rebuild our tether to remove the unnecessary components, improve the neutral buoyancy, and lengthen it significantly, which would enable us to use the ROV in local lakes for research purposes. Eventually, we may consider building a time-of-flight-based laser rangefinder, as the tool could lead to a beneficial collision avoidance system.

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Linn-Benton ROV would like to thank our mentors, Greg Mulder, Kathy Austin, Heather Hill, and Mark Urista, for their tireless contributions to our success, both as a team and as individual students. Additionally, thank you to Teresa Woods for managing the team's purchases.

We would also like to thank Linn-Benton Community College for allowing our team to come together, and for providing the funds and space to meet, design, and build an underwater robot of our own.

We must also thank the Mid-Willamette Family YMCA for graciously allowing Linn-Benton ROV to use their pool each week for testing the ROV and practicing tasks.

APPENDIX I: BUDGET & PROJECT COSTING

Budget

Category	Type	Description	Project Cost	Budgeted Value
Hardware	Purchased	PVC pipe	$ 300.00	$ 300.00
Hardware	Re-Use Material*	Frame	$ 200.00	$ 200.00
Hardware	Purchased	Supplies i.e (valves, connectors)	$ 50.00	$ 100.00
Electronics	Purchased	Camera system	$ 578.00	$ 500.00
Electronics	Re-used	Controller	$ 20.00	$ -
Electronics	Re-used	Tether	$ 100.00	$ -
Electronics	Re-used	6 BlueRobotics T-100 thrusters	$ 480.00	$ -
Electronics	Re-used	2 Arduino control boards	$ 50.00	$ -
Electronics	Purchased	Lasers	$ 200.00	$ 200.00
Sensors	Purchased	Depth/pressure sensor	$ 100.00	$ 100.00
Travel	Purchased	Travel	$ 13,532.00	$ 15,000.00
General	Paid	MATE Registration & Fees	$ 425.00	$ 500.00
General	Purchased	Team T-shirts	$ 400.00	$ 400.00
			TOTAL (Budgeted):	**$ 17,300.00**

*Material purchased in previous year, all work done in 2022

ROV

Type	Description	Total Cost
Purchased	Plastic Sheet	$ 9.95
Purchased	Neodymium Bar Magnets	$ 3.99
Purchased	Low-Light HD USB Camera	$ 105.00
Purchased	Arduino Uno Ethernet Shields	$ 37.98
Purchased	5pc of LED numerical displays	$ 16.29
Purchased	650nm 5mW Red Laser Diode	$ 6.29
Purchased	microSDHC Memory Card	$ 13.50
Purchased	12V to 3V DC-DC Converter	$ 18.12
Purchased	12V to 5V DC-DC Converter	$ 6.79
Purchased	PS2 Controller	$ 9.99
Purchased	Red Laser Diode	$ 12.58
Purchased	1 ft of 2 in acrylic tube	$ 8.70
Purchased	2in Black Vinyl Caps; Qty: 6	$ 28.30
Purchased	Anti-Slip tape	$ 9.85
Purchased	5pc Stepper Motor Driver	$ 15.69
Purchased	5V Stepper Motor + Driver	$ 13.99
Purchased	Buoyancy Foam: R-3318	$ 304.00
Purchased	Arduino Uno Ethernet Shields	$ 17.69
Purchased	I2C Level Logic Converter	$ 40.00
Purchased	L-shaped interior brackets	$ 10.49
Purchased	4pc 90 degree Plate Bracket	$ 25.98
Purchased	2pc 135 degree brackets	$ 25.98
Purchased	Aluminum end caps	$ 7.99
Purchased	Drop In M5 T Nut Slot	$ 7.88
Purchased	Low-Light HD USB Camera	$ 105.00
Purchased	Acrylic Dome	$ 36.00
Purchased	Drop In M5 T Nut Slot	$ 7.88
Purchased	Socket Cap Screws	$ 7.99
Purchased	2 Low-Light HD USB Cameras	$ 198.00
Purchased	Tether Strain Relief	$ 24.14
Purchased	Ethernet Cable 50 ft CAT6	$ 14.99
Purchased	Acrylic Dome	$ 36.00
Purchased	Waterproof Stowaway	$ 5.32
Purchased	20pc 4 Pin Connector Plug	$ 7.69
	TOTAL	**$ 1200.03**
Reused	Control Team Hardware	$ 148.93
Reused	SubConn Connectors	$ 207.85
Reused	Cameras	$ 942.45
Reused	PCB	$ 50.85
Reused	Wires	$ 138.36
Reused	Cameras	$ 257.22
Reused	Thrusters	$ 20.94
Reused	Electronic Speed Controller	$ 1,440.00
Reused	Epoxy	$ 400.00
Reused	Claw for Pneumatic	$ 135.10
Reused	Epoxy	$ 99.79
Reused	Bolts	$ 87.54
Reused	Tether Strain Relief	$ 31.10
Reused	3D Printing	$ 35.52
Reused	Pneumatic	$ 13.85
Reused	Extruded Aluminum	$ 100.00
Reused	Pneumatic Cylinder	$ 125.00
Reused	Epoxy	$ 300.00
	TOTAL	**$ 4,534.50**

Vertical Profiler

Type	Description	Total Cost of an Item
Donated	Solenoid Valve	$ 35.98
Purchased	Collapsable Silicone Bowl	$ 17.17
Purchased	2pc PVC S&D Cap	$ 6.54
Purchased	Linear Actuators	$ 147.82
Purchased	#18 O Ring	$ 2.92
Purchased	#17 O Ring	$ 2.92
Purchased	7/16 Neoprene Washer	$ 1.31
Purchased	M barb brass adapter	$ 23.00
Purchased	brass tee fitting	$ 8.77
Purchased	brass nipple fitting	$ 5.35
Purchased	hose clamps	$ 10.85
Purchased	1-1/4 inch PVC pipe	$ 6.23
Purchased	1 x 24 inch PVC	$ 4.46
Purchased	PVC Socket Cap	$ 1.52
Purchased	Clear Vinyl Tubing	$ 5.94
Purchased	3/4 inch PVC plug	$ 1.97
Purchased	F barb brass adapter	$ 19.00
Purchased	1/2 inch brass nut	$ 16.24
Purchased	latex balloon for bladder	$ 4.00
Purchased	Tomato Cage	$ 4.98
Purchased	White Sewer Pipe	$ 26.63
Purchased	Arduino Pro Mini	$ 23.60
Purchased	8 x AA 12V Battery Holder	$ 8.00
Purchased	120pcs Dupont Wire	$ 6.98
Purchased	Stainless Steel Funnel	$ 11.80
Purchased	High Power Motor Driver	$ 15.99
Purchased	5pc Rubber O-Rings	$ 8.95
Purchased	Flexible Pipe	$ 17.55
Purchased	DC Motor Drive	$ 54.45
Purchased	FTDI Basic Breakout	$ 16.95
Purchased	25pc 3-color LEDs	$ 34.74
Purchased	8pc 236 Buna-N O-Ring	$ 8.19
Purchased	Pressure Release Valve	$ 42.47
Purchased	Pressure Relief Valve	$ 10.99
Purchased	Solderable Breadboard	$ 12.99
	TOTAL	**$ 627.25**

Competition

Description	Total Cost
Fluid Power Quiz	$ 25.00
MATE Registration	$ 400.00
Pink Cowboy Hats	$ 197.82
Bulk Tiaras 20 piece	$ 22.99
AirBnB	$ 4,380.00
Plane Tickets	$ 3,216.00
Rental Van	$ 950.00
Food	$ 4,956.00
TOTAL	**$ 14,147.81**