# LBCC ROV: 2019 Technical Documentation

Linn Benton Community College

Corvallis, OR

| Team Member | Role | |
|---|---|---|
| Nathan Alexander | Software Engineer | 1st year |
| Joey Bernards | Production Engineer | 2nd year |
| Everett Brandt | Electrical and Software engineer | 2nd year |
| Hunter Cato | CTO, Pilot and Software engineer | 1st year |
| Mike Furrer | Production engineer | 1st year |
| Caleb Hedin | CFO | 1st year |
| Trinity James | CEO | 2nd year |
| Jesse Kayne | Production engineer | 1st year |
| Keana Kief | Technical Writer | 1st year |
| Sara Leathers | Design Engineer | 1st year |
| August May | Marketing | 1st year |
| Emily Nussdorfer | Graphic Artist | 1st year |
| Jason Pfahler | Design Engineer | 2nd year |
| Jenny Smucker | Co-pilot | 1st year |
| Wyatt Weaver | Mechanical Engineer | 2nd year |
| Emma Wycoff | Production Engineer | 2nd year |

Mentors: Greg Mulder, Heather Hill, and Brian Reed

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# 1 Abstract

Figure 1: LBCC ROV Team

Linn Benton Community College's (LBCC) Team came together from a variety of disciplines to create an underwater remote operated vehicle (ROV). The LBCC ROV team has been competing in MATE competitions since 2008. There are six returning members this year: Trinity James, Wyatt Weaver, Jason Pfahler, Joey Bernards, Emma Wycoff, and Everett Brandt. The rest of the team participating this year are new first year members. There are Freshman to Senior level students on our team.

The ROV is an EXPLORER class vehicle, 55 cm X 52 cm X 19.4 cm in dimension, and weighs 13.8 kg, out of water. The LBCC ROV took approximately 9220 student-hours to design and build since September, 2018. Total cost to build the ROV comes to $4,267.50, excluding travel.

Special features include: Modular components including detachable tether, thrusters, receiver Arduino, cameras, and power conversion in order to build a platform with room for improvement.

Safety features include: Different sizes and shapes of connectors are used to ensure there are no wrong connections. Thrusters are within a shrouded casing to ensure propellers are not a finger hazard. Metal components have been powder coated to ensure that sharp edges are eliminated. Fuses are used in the power conversion boards to ensure that the boards to do not short in a failure.

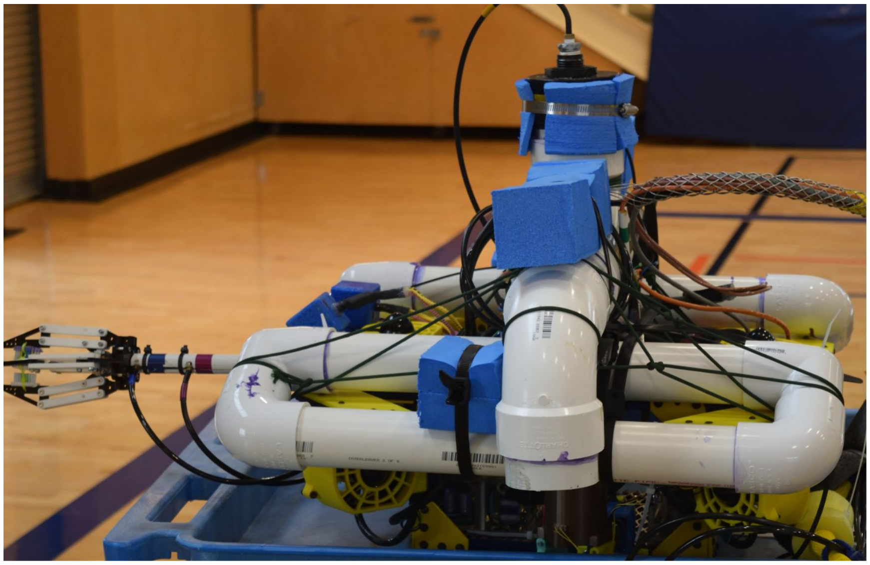

Figure 2: Finished ROV, as of April 20th, 2019

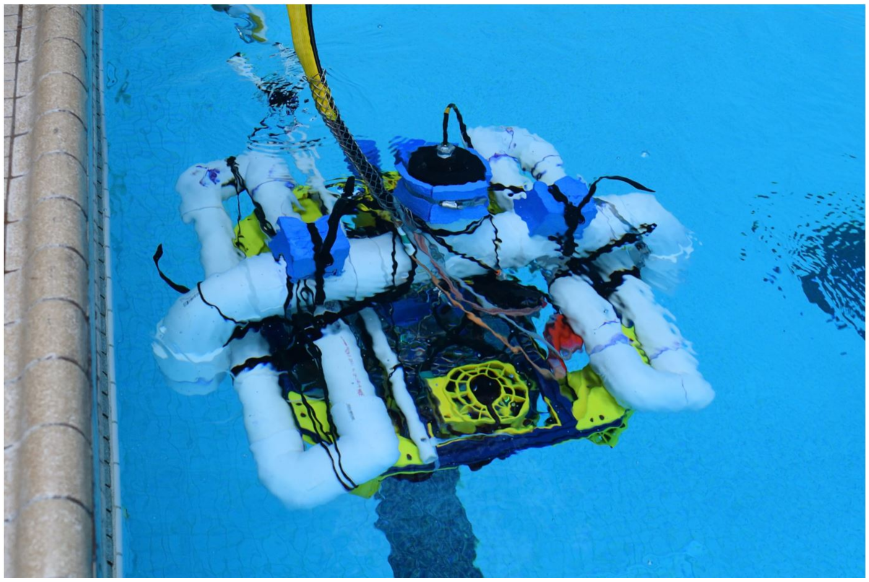

Figure 3: Finished ROV, as of April 20th, 2019

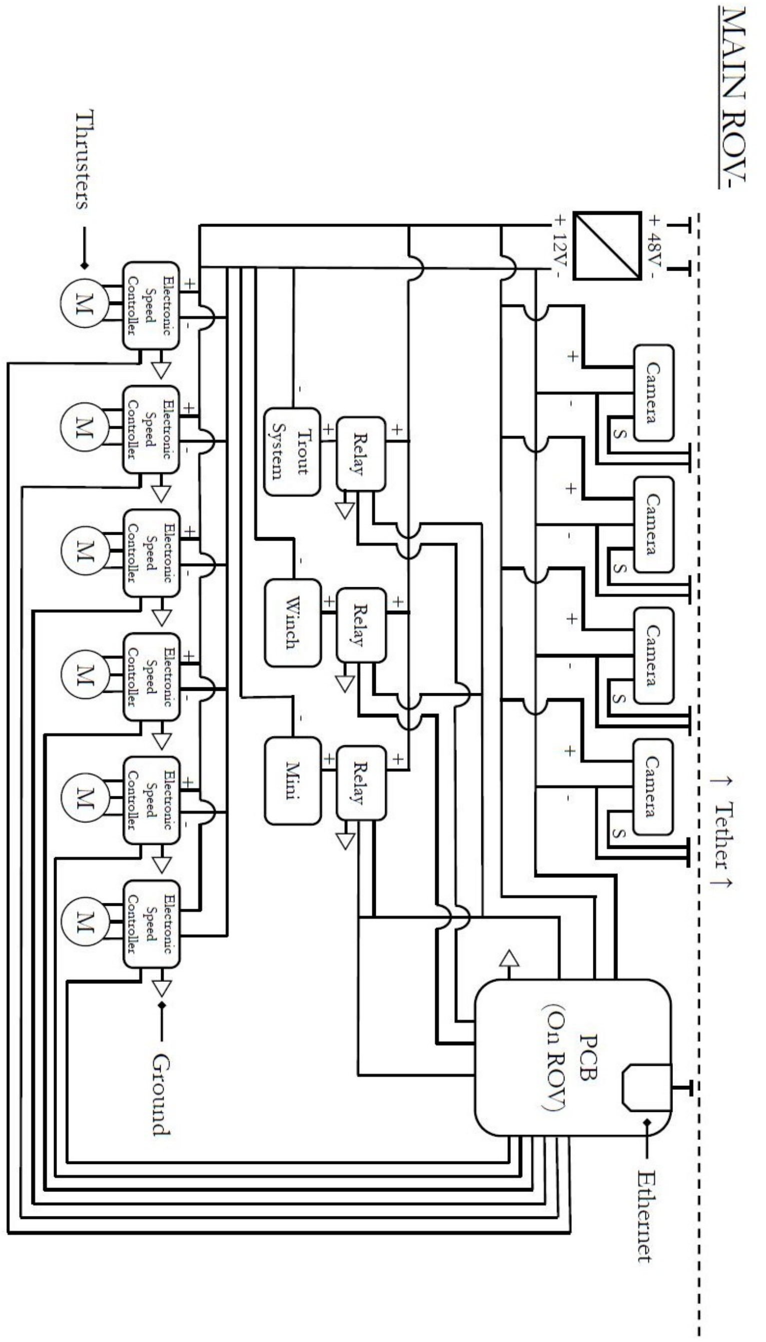

Figure 4: The System Integration Diagram (SID) of the LBCC ROV.

# 2 Project Management

The LBCC ROV team met tri-weekly during the school term on Mondays, Fridays, and Saturday. The Monday meeting served to review what was completed the previous week and organize what will get done that current week, round robin style. The CEO, Trinity James, or the head mentor, Greg Mulder, would organize and run the meetings on Mondays. The Friday meeting was a collaborative work day, while Saturdays always served as testing time, usually at a pool.

An example of the organization completed in the Monday meetings is presented in the Gantt chart in Figure 5. Each team was reported on the things that they had completed, things that were delayed, or the next thing that would be completed.

Throughout the build process countless ideas were exchanged about how to best go about construction and sourcing materials. To help each build team overcome the challenges of their mission a more open planning stile was used to encourage a free exchange of ideas. Once a few possible solutions had been put forth the teams would then do research, reconvening later to share what they had learned and decide on a plan moving forward. In order to reduce waist a priority was placed on solutions that used components already possessed by the team. Such priorities also lowered costs and reduced production times as shipping was not an issue. Reusing materials is not always possible however, so when necessary and after consulting team members, purchases were made with heavy consideration of product specification.

Tasks were distributed largely on a volunteer basis, allowing members to start where they felt comfortable and branch out when they felt motivated. This freer form style resulted in heavy collaboration between teams and thus helped to ensure smooth integration of vehicle sub-components.

KEY
🟩 = Done
🟥 = To Do

| SUB TEAM | DATE: | 4/6/19 | 4/7/19 | 4/8/19 | 4/9/19 | 4/10/19 | 4/11/19 | 4/12/19 | 4/13/19 |
|---|---|---|---|---|---|---|---|---|---|
| | DAY: | Saturday | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
| Pnuematic | | | Completed arm adjustments<br>(Joey) | submit arm prints<br>(Trinity) | | | | Rebuild arm<br>(Mike) | Test new arm grip<br>(pool team) |
| Camera | | | | obtain stl files from joe<br>(Caleb) | Print new housings<br>(Trinity)<br>Order more epoxy<br>(Trinity) | | | | |
| Thusters | | test different code<br>(Everett) | | | adjust code<br>(Everett) | | | | test different code<br>(Everett) |
| Bouyancy | | test pipe version of fixed<br>(pool team) | | vbs is still being printed... | | | | adjust pipe VBS<br>(Mike) | test pipe version of variable<br>(pool team) |
| Mini ROV | | | | begin printing winch<br>(Trinity) | | | | Solder lights<br>(Emily) | Test Pressure housing<br>(pool team) |
| Grout Fry | | | | begin the tech report<br>(Jenny) | | | | | test trout grout<br>(pool team) |
| Hook | | | | print extended peices<br>(Trinity) | | | | re asseble with new peices<br>(Hunter) | test<br>(pool team) |
| Tether | | | | | | | | put extra air hoses on tether<br>(Jesse) | Test teather swatches<br>(pool team) |
| Props | | | | | finish the trash racks<br>canoon stand<br>(Jason) | | | | Test with hooks and claw<br>(pool team) |

Figure 5: Example of the Gantt chart filled out during the Monday, April 1st, to be used from April 6th to April 14th. The purpose of the Gantt is to set goal date on everything to be completed, and to hold people accountable.

# 3 Design

## 3.1 Frame

The fame is composed of 80/20 20mm extruded aluminum, segments are secured via metal brackets or 3D printed brackets constructed from polylactic acid (PLA). 3D printing was chosen over a conventional manufacturing method, because it allowed for more flexibility in the design, as well as the added benefit of cost efficiency.

A chosen benefit of the extruded aluminum frame is the spring loaded drop-in fasteners. The drop-in fasteners allow for quick changes in attachment points to the frame, without the requirement to disassemble the frame. This system allows the ROV to be very modular, as well as dynamic. Each metal segment is powder coated as a safeguard against sharp edges (MECH-006), as well as increased aesthetics.

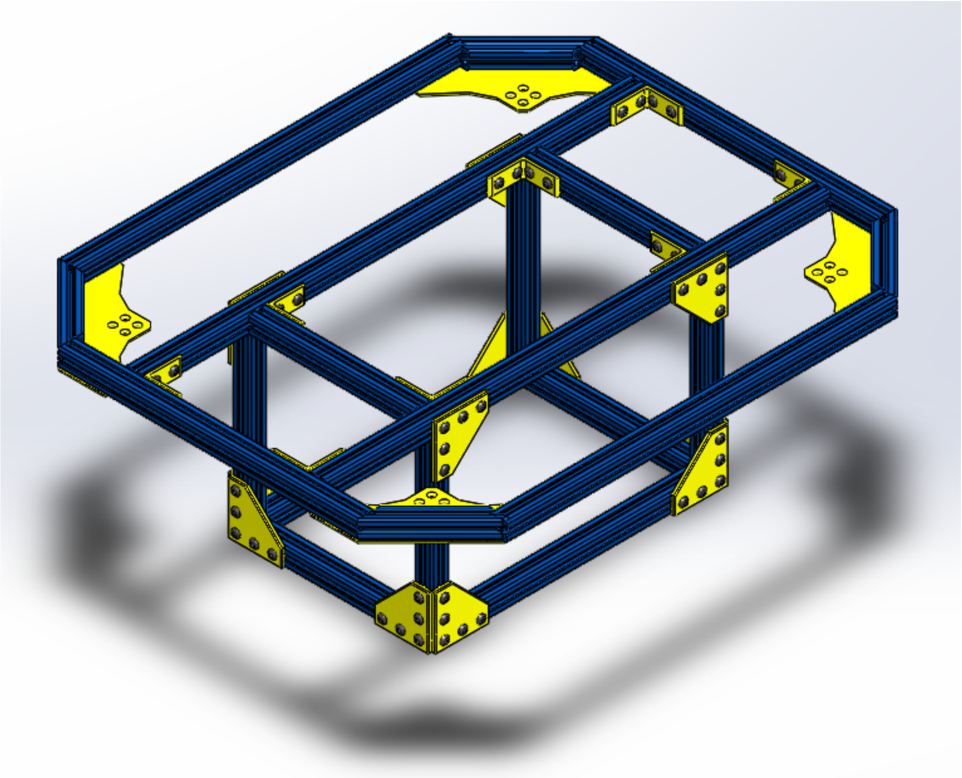

Figure 6: 3D CAD Model of the Frame

## 3.2 Tether

The tether was designed to be neutral buoyant and detachable. The 9m tether is composed of five wire cords, three air hoses, and a strip of polyethylene foam for buoyancy, all of which is contained in a wire sheathing.

Wires contained in the sheathing are:

- Ethernet for the camera signal.
- Ethernet for the Arduino signal.
- Two 18 gauge power wires for the 48V power-in and ground.
- Two pneumatic air hoses with a 148 psi rating for the claw.
- One pneumatic air hose with a 120 psi rating for the Variable Buoyancy System.
- Swan visual signal cord for the mini ROV.
- Polyethylene foam for buoyancy.

On the bottom of the tether, there is a closed mesh, double eye strain that connects to two metal U-bolts. The connections from the tether wires come from the strain and connect to their specified places. Three 48V power connections, connect to the top of the PCB through a SubConn Low Profile, two contact female connectors. The two Ethernet cables have circular SubConn eight contact, male connectors, the grey camera Ethernet connects to the camera system, and the orange control Ethernet connects to the Arduino. Two of the air hoses connect to the pneumatic claw, and the third connects to the variable buoyancy system. 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 ROV flight path.

Figure 7: Unsheathed cross section of the tether.

## 3.3 Cameras

Blue Robotics Low-Light Analog Cameras were chosen for the size, price range, and simplicity. A DVR is required to process the analog images on the top side to display the video and use the images in the artificial intelligence software. Due to the analog cameras lower image quality, compared to a digital camera, a balun was wired directly to the back of the camera as well as at the top side connection from the camera Ethernet on the tether to the DVR. Two baluns create a an overall better image.

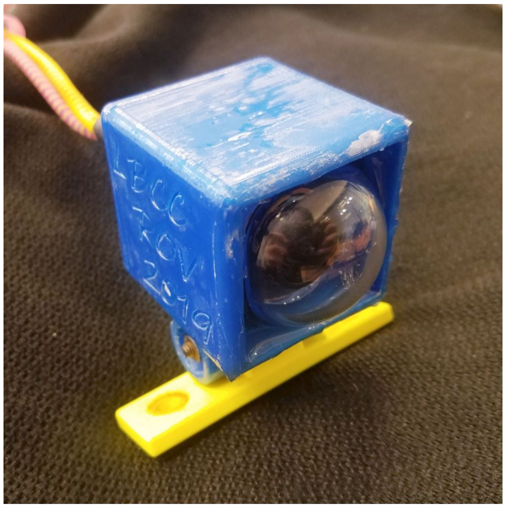

Figure 8: Initial camera design.

The cameras, baluns, and wire connections are encased in a 3D printed housing filled with epoxy to ensure they are waterproof. A dome with a diameter of 4.5cm encloses the lens, because epoxy over the top of the lens would not produce a clear image. The size of a single waterproof camera is 5cm X 5cm X 5cm. The power and signal wires come out of the back of the encasing. The power and ground connect to a circular SubConn two contact, male connector which connects to a 12V power outlet on a power converter board.

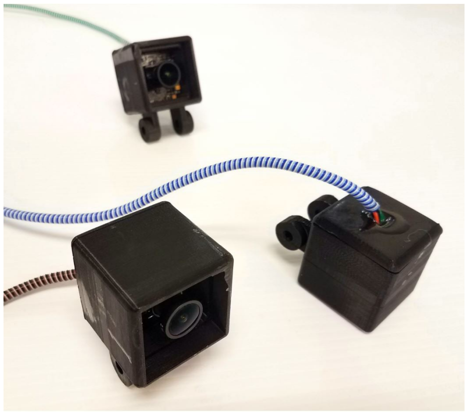

Figure 9: In progress, recreation of the camera system.

### 3.4 Movement Systems

The ROV utilizes a vector thrust approach to lateral movement. This involves mounting the thrusters on each corner of the ROV at a 45° offset. Figure 10 shows the individual thruster direction with respect to the entire ROV moving forwards. The benefits of this design include increased stability and the ability to have yaw control along with straight movements. One drawback of our vector thrust design was the efficiency of the movement. When moving in lateral directions, half of the thrust will be used to move in the wrong direction. This movement will be counteracted by the partner thruster on the opposite side (Figure 10), however this still causes half of the force from the thrusters to be unused. While this is a large flaw in the design, it was decided that the stability and control that vector thrust gave us outweighed the issue of loss of thrust.

The ROV also uses two separate thrusters pointed upwards to control the up, down, and pitch. The two thrusters were programmed to thrust in the same direction when going up and down, and to thrust in different directions when changing pitch. This allows the ROV to move vertically efficiently, but also allows the pilot to tilt, which gives them a wider range of motion when using tools fixed to the ROV.

Our team opted to use BlueRobotic's T-100 brushless motors to propel the ROV. One of the advantages of this design is its ability to use variable thrust. Within our controls, we utilized analog control sticks to control movement, which gives the pilot the option to move faster or slower depending on how far the analog stick is moved. The thrusters are ultimately controlled by the electronic speed controllers and Arduinos, and these can interpret the analog signal and send the appropriate signal to the thrusters.

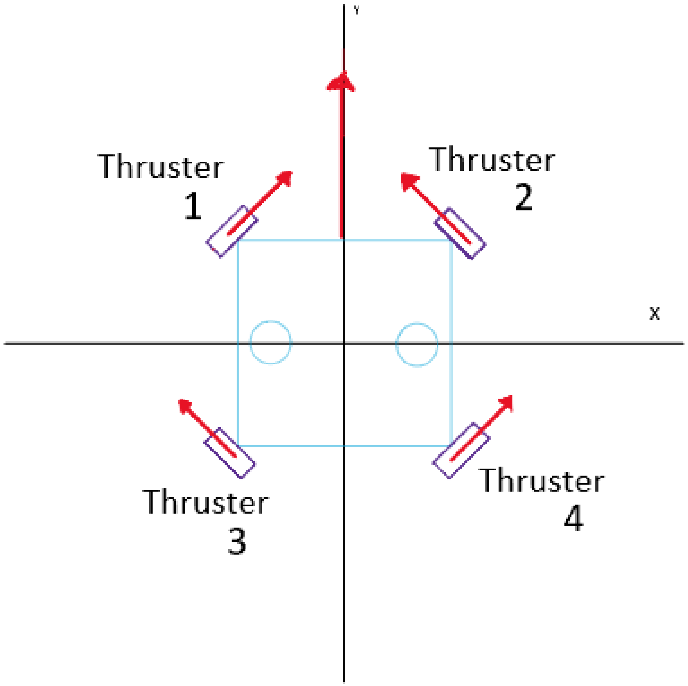

Figure 10: Directions of individual thrusters when R.O.V. is programmed to move forwards.

#### 3.4.1 Controls

Figure 11: Monitor viewing station.

The ROV is controlled by pneumatic levers and a PlayStation2 controller. This design was chosen because of the ease of use. The PlayStation2 controller also has plenty of buttons and analog sticks to choose from, so when new functions are added to the ROV, it's simple to program them into the system. Compared to last year's design, which involved adding a new button to the control panel, the new design is more adaptable to change.

To control the logic of the controller, thrusters, and tools, we used a sender receiver design with two Ethernet Arduinos. This was chosen because of how simple the Arduino's are to program the number of libraries already included within its interface. All the tools we used were also supported by Arduino, so it made it very simple to program.

Figure 12: PS2 Controller and sender Arduino.

We utilized the analog sticks on the PS2 controller to control the movement of the ROV. The left analog stick is used to control lateral movements and the right analog stick controls the vertical and yaw movement. The right y-axis of the analog stick is used to control the up, down, and pitch, while the x-axis is used for yaw control. The left bumper on the controller is devoted to switching the vertical thrusters from up and down to pitch control. In the code this button causes the up and down thrusters from thrusting in the same direction to thrusting in opposite direction. The pilot also has the option of turning down the maximum thrust using the D-pad up and down buttons. Pressing on these buttons on the D-pad will lower or raise the thrust by 10 percent increments. This is helpful when maneuvering into tight spaces, as using the variable thrust may still be too much thrust for the R.O.V.

The digital buttons on the PS2 controller are used to turn the micro-ROV, electromagnetic and reel on and off. The Buttons are also used to request data from the receiver and display them on the screen. This process involves the sender sending a signal to the receiver, the receiver receiving the signal, getting the data from the sensors, and sending it back to the sender.

The sender Arduino is placed in the control panel on the surface and gets the values inputted from the controller, converts them into a byte array, and sends them down the Ethernet cable using User Datagram Protocol (UDP). The sender Arduino also has the responsibility of checking the dead-band of the controller. This is done so any small movements don't cause accidental ROV movement.

The receiver Arduino's role involves receiving data from the sender, converting that data and sending it to the electronic speed controller, getting input from the sensors on the ROV and sending it back to the sender, and turning on and off the different tools on the ROV.

### 3.4.2 Thrusters

Six T100 thrusters provide the force to move the ROV. Control of the thrusters is accomplished by utilizing ESCs and an Arduino microcontroller. Each T100 can produce up to 22 N of thrust in forward or reverse directions. The thruster shrouds were designed using CAD software to fit around the T100 and provide a place to mount the ESC. The shrouds were 3D printed by the Oregon State University Library. The T100 were chosen because they had been used by a previous team and were still functional.

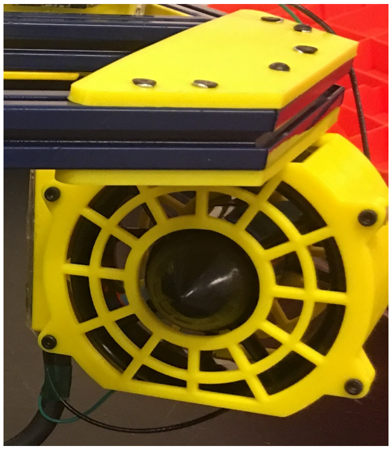

Figure 13: T100 thruster and thruster guard.

### 3.4.3 Fixed Buoyancy System

In order to achieve neutral buoyancy for the ROV, $4500\,\mathrm{cm}^3$ of air volume was required to overcome its weight. To achieve this, multiple designs were proposed including numerous styles of tubular PVC, aluminum cylinders, foam blocks and acrylic boxes. After consideration of the possible designs, it was determined that the most efficient use of available space would be to use two identical boxes, symmetrically placed on the wings of the ROV. They were constructed using clear polycarbonate to provide adequate durability and minimize obstructing the view of other components.

## 3.5 Lifting Systems

### 3.5.1 Variable Buoyancy System (VBS)

As a part of the mission specifications the ROV needed to be capable of returning a variety of objects to the surface, some of which could be outside its lift capacity. Possible solutions to this problem included the addition of more thrusters, a soft lift bag or a hard VBS. Adding additional thrusters would overtax the power budget and a soft lift bag presented pool side retrieval issues, so the VBS was the best choice. Initially constructed using 4in schedule 200 PVC, consisting of a single union tee placed in the middle of a horizontal pipe, terminating with open 90-degree elbows on each side. The VBS was placed horizontally on top of the ROV. The VBS is connected to the surface pneumatic control system through an airline in the tether, and upon launch must be allowed to fill with water. Should it become necessary, pressurized air will be let into the VBS causing water to be forced out of the open ends, creating a buoyant air pocket. The initial design, though functional, was heavy and generated to much drag prompting a redesign.

The new VBS was constructed using lighter 4in ABS pipe to reduce weigh and consists of two identical tubes measuring 0.5m providing a max volume of $8171\,\text{cm}^3$. The two tubes were also placed horizontally on top of the ROV, but with each tube offset equidistant from the mid-line. These modifications reduced the weight, drag and the overall dimensions of the ROV, allowing it to more efficiently complete its mission set.

### 3.5.2 Cannon Hooks

Figure 14: 3D printed cannon hooks.

A new gripping method was needed to lift the cannon, because the pneumatic claw is not large enough to effectively grip and lift the cannon. As a solution, hooks were added to the bottom of the ROV to provide a larger lifting surface. Main concerns considered when designing the hooks were ease of use, weight distribution when the cannon is in tow, effect on the form factor of the ROV, and cost of the material and assembly. Two hooks attached at the bottom of the ROV allowed an easy method of grabbing the cannon by lowering the ROV on top of the cannon and rotating the ROV to seat the cannon. The two hook system also allows the cannon to sit below the ROV's center of mass while it is being lifted. The hooks were bolted to a stamped metal bracket on the frame. Using a wing nut allows the loosening of the nut by hand so that the hooks to lay flat along the bottom of the frame when not in use. 3D printing the hooks was a cheap and fast method of manufacturing the design.

## 3.6 Power Conversion Board (PCB)

The power conversion board was designed to be small and replaceable. Each power conversion board has three or four 12V outputs. The first version of the PCB has three outputs, while the second version has four 12V power outputs. All 12V power outlets are circular SubConn two contact, female connector. All devices that use power on the ROV use a circular SubConn two contact, male connector to connect and disconnect from the power, as needed.

The 48V power from the tether connects to the top of the PCB through a SubConn Low Profile, two contact female connectors. Different power connections are used for the PCB inputs and outputs. To ensure that mistakes are not made, inputs to the PCB use square plugs and outputs use circular plugs.

The PCBs are epoxied in an acrylic box, to protect the electronics from water. The bottom side of the box is an aluminum plate. The converter from the power converter board is glued to the aluminum plate using a thermally conductive glue. The aluminum plate acts as a heat sink for the power conversion system.

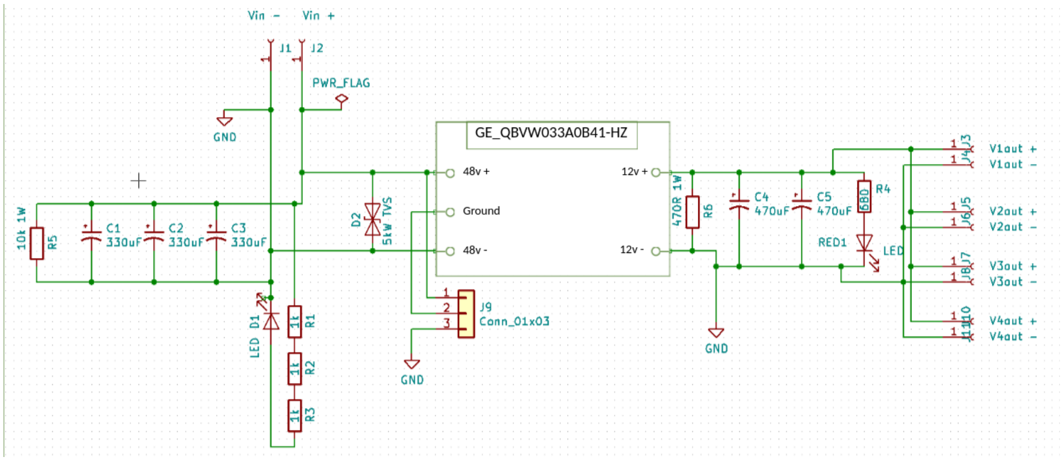

Figure 15: The System Integration Diagram (SID) of the PCB.

## 3.7 Pneumatic Control System

In order to operate both the pneumatic claw and the variable buoyancy system (VBS) an air distribution and control system was required. Using a commercially available compressor with built in tank pressure gauge, output pressure gauge and emergency pressure relief valve, air is provided to the control system. The VBS air supply is controlled using a manual 90-degree ball valve spliced from the main input airline using a union tee connector. The pneumatic claw is operated using four electrical valves from AOMAG that are normally closed and rated to 145 psi. These valves are arranged to operate in two tandem sets as shown in figure 16, requiring 12v direct current supplied by a class 2 Condor transformer and operated with the use of a single two-way switch. All hoses in the system are one quarter inch outside diameter polyether polyurethane, rated to 148 psi, well beyond the minimum 2.5 times the operating pressure for safety. (FLUID-010)

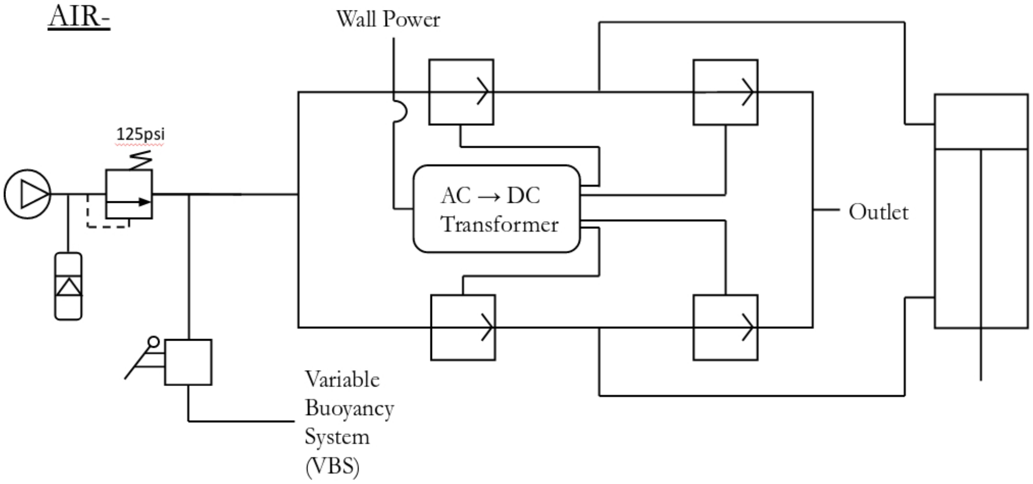

Figure 16: The System Integration Diagram (SID) of the Pneumatic Control System.

## 3.8 Claw

Figure 17: Initial gripping claw with scale.

It was clear from the onset of this project that the ROV would need to be able to interact with a variety of objects throughout its mission, potentially including grasping, pushing and pulling. A pneumatic claw was the best option to accommodate a wide array of tasks. The decision to use a pneumatic actuator rather than an electric one allowed to maximize the grip strength to weight ratio of the system. To save time, a commercially available pneumatic claw from Robotpark with a four-finger design, model X4M, was obtained and modified. This choice allowed the option of scaling down to a two-finger configuration should that be necessary. The claw was then highly modified so that it operated more effectively in the 2019 MATE contest.

Modifications included:

- Replacement of original linear pneumatic actuator with a larger diameter pneumatic actuator from CHLED cylinders in order to achieve greater grip force.
- Replacement of existing claw base to allow fitting the up-scaled pneumatic actuator.
- Extension of the claw fingers to allow for manipulation of larger objects.
- Extension of the claw fingers to allow for manipulation of larger objects.

Addition of high friction pads to the fingers to make a better connection with objects. The modifications were designed using CAD software to be retrofitted onto the original claw, then 3D printed using one hundred percent fill polylactic acid. The final design weighs point four kilograms and is a total of twenty-eight centimeters in length and nine centimeters in width, with fingers measuring thirteen centimeters which provide ten centimeters of finger span.

## 3.9 Trout and Grout

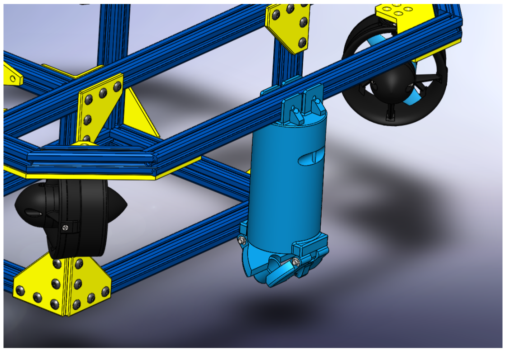

Figure 18: 3D CAD model of trout fry and grout release mechanism.

For the design of the Trout Fry and Grout release mechanism, a tubular cup shape that has a slightly larger radius at the opening on the bottom than at the top was chosen. This was to encourage the rocks and fry to fall out, rather than stick in the tube. On the cup itself, near the opening, was placed one electromagnet. Another electromagnet was placed on one of two doors, positioning it so that when the doors were closed, it would match up with the electromagnet on the cup. The door with the electromagnet has a ridge on it that goes over another door when it's closed. When the electromagnets are on, the door with the magnet attaches to the cup and holds the other door in place, thereby containing whatever is needed to be kept in the cup.

The mechanism is designed to hold objects such as the two small trout fry or many small grout rocks and then release them in a desired location. To release the objects, a button is pressed on the controller that sends a signal to a relay to cut the power supply running through that relay. The electromagnet power supply on the doors of the device are then cut off and the electromagnets release from each other. Once the magnets are released the the doors are free to swing open due to the tension caused by the rubber bands. The contents of the mechanism then fall out of the container due to the force of gravity.

The mechanism is designed for use in two scenarios: releasing trout fry in a specific area, and inserting grout into a void. For this competition, we need to be able to drop two fishing lures into a designated 40 cm by 40 cm area. In the real world, this could be used for depositing different aquatic species into a desired underwater location, thereby helping to resupply the body of water with that aquatic species.

The other use for this mechanism is inserting grout into a void in a dam. For this competition, the ROV needs to drop enough rocks into a plastic container to cover a certain line. In the real world, this could be used to fill underwater cracks or other holes with gravel to help maintain the dam's structural integrity.

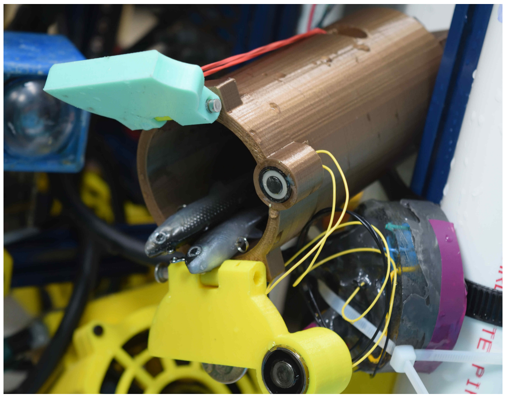

Figure 19: Actual trout fry and grout release mechanism loaded with trout fry.

## 3.10 Micro-ROV

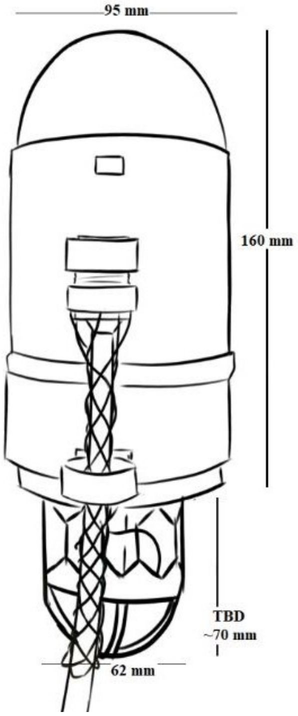

Figure 20: Micro-Rov dimensions.

The micro-ROV Figure 21 is composed of an entirely plastic frame, including a clear acrylic dome, 3D-printed Polylactic Acid (PLA) body, plastic thruster mount, and a PLA thruster guard. The dome and body of the micro-ROV measure 160 millimeters long, while the thruster guard is predicted to extend an additional 70 millimeters from the back of the body Figure 20. The micro-ROV measures 95 millimeters in diameter. As permitted, the non-ROV device contains a Johnson Pump motor cartridge for use as a thruster, as well as a low-light analog camera surrounded by sixteen 5V LEDs (ELEC-NRD-002). Internally, the micro-ROV also contains a power conversion board which converts 12VDC power to 5VDC power to supply the LEDs. With the exception of the thruster cartridge, all of the electronic components are encased in epoxy as a method of preventing exposure to water.

12V power is supplied to the micro-ROV by the primary ROV using copper wire, and 3.82A is drawn by the micro-ROV (ELEC-NRD-001). Copper wire was chosen for time conservation. There are no batteries on board the micro-ROV (ELEC-NRD-004). The 3.7-meter tether contains copper wires for power supply and ground, as well as a copper wire for signal transmission. A 7.5-amp fuse was used as a safety measure at the point of connection to the primary ROV (ELEC-NRD-003).

The purpose of the micro-ROV falls within the task of Ensuring Public Safety - Dam Inspection and Repair. The micro-ROV is to be deployed from the primary ROV to enter a 6-inch drain pipe to allow for the identification of areas of muddy water flow. The micro-ROV returns to the primary ROV via a winch controlled by a relay. The winch reels in a fishing line connected to the micro-ROV tether; as the fishing line is reeled in, the micro-ROV tether is gathered and contained on the primary ROV.

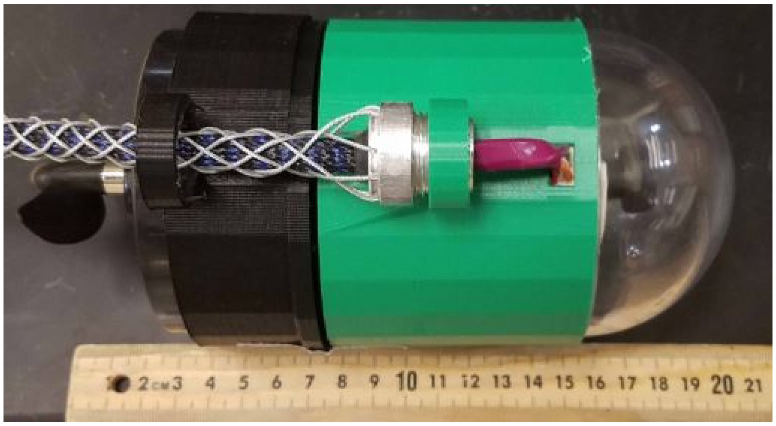

Figure 21: Micro-Rov without PLA thruster guard.

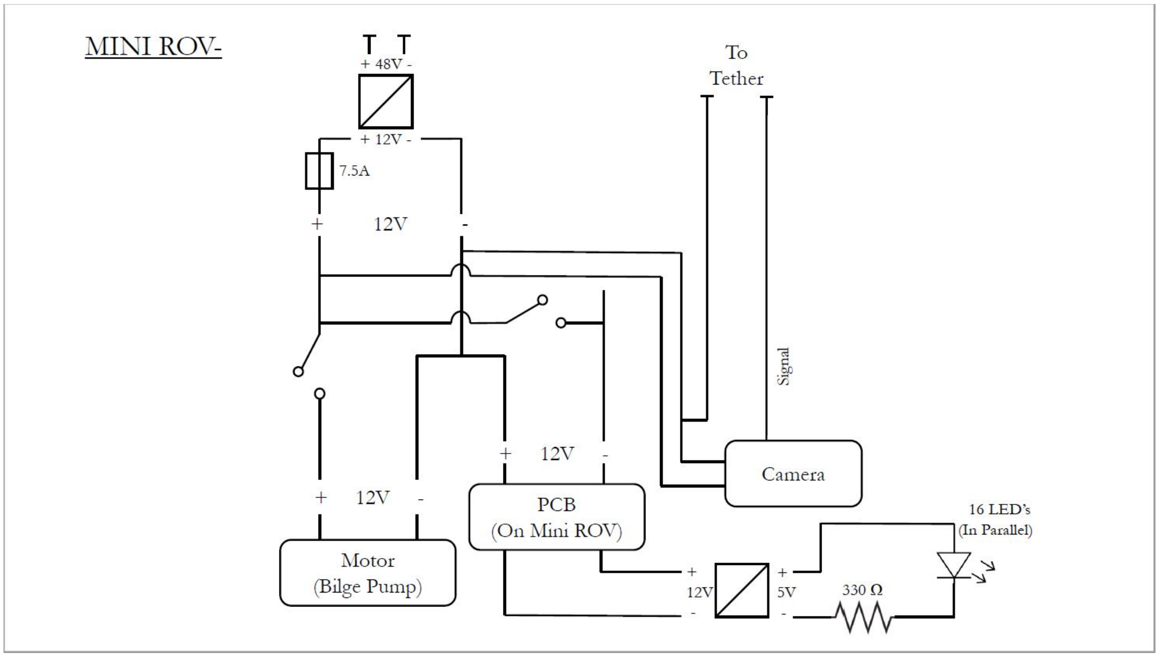

Figure 22: The System Integration Diagram (SID) of the Micro ROV.

# 4 Autonomous Control

## 4.1 Blue Line Measurement

Detection and measurement of the crack is done by utilizing python, and the open source computer vision library OpenCV. Video from the ROV cameras is routed into a DVR which converts the signal from analog to digital. The video stream from the front facing camera is captured from the DVR via a RTSP network connection. A frame from this video stream is extracted and analyzed. Analysis begins by performing a gaussian blur to smooth out any imperfections in the image that may throw off the algorithm. The blurred image is converted into the HSV colorspace and blue shapes are extracted with OpenCV's inRange function. The edges of these shapes are found using findContours. For each of these contours the perimeter is found via arcLength. This is done by reducing the contour to a set of vertices and calculating the side lengths of the contour. The short and long side lengths are averaged, and the length of the short side is compared to the known width of the tape to determine a pixel/centimeter ratio. The length of the tape is then calculated using this ratio. Through testing it was discovered that the algorithm consistently underestimates the real length of the tape. Because of this bias, there is a flat 1cm added to the calculated length before it is displayed.

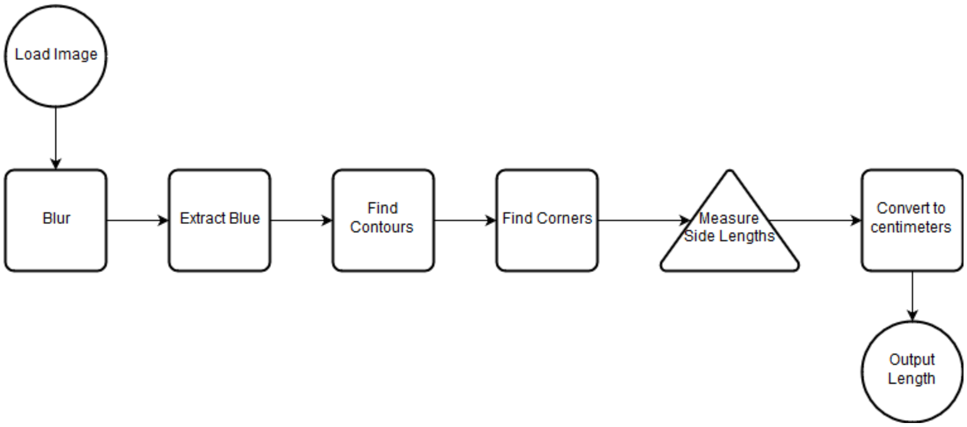

Figure 23: Blue line measurement data flow diagram.

## 4.2 Benthic Species

Benthic species detection and counting is done by utilizing python, and the open source computer vision library OpenCV. When the python script is called, a frame is extracted from the DVR's video feed and passed to the shape counting script. Analysis of the frame occurs as follows: the image is converted to grayscale using the cvtColor function. Then the image is smoothed using GaussianBlur to reduce image noise. Shapes in the image are separated from the background by thresholding each pixel value. The mean pixel value of the image is used as the threshold value. Contours, the outline of the shapes, are extracted with findContours. For each of these contours, the contour is reduced to a set of vertices, and the number of vertices are counted in order to determine the shape of the contour. Once the shapes of the contours are determined, the number of each shape is counted and the final tally is printed to screen.

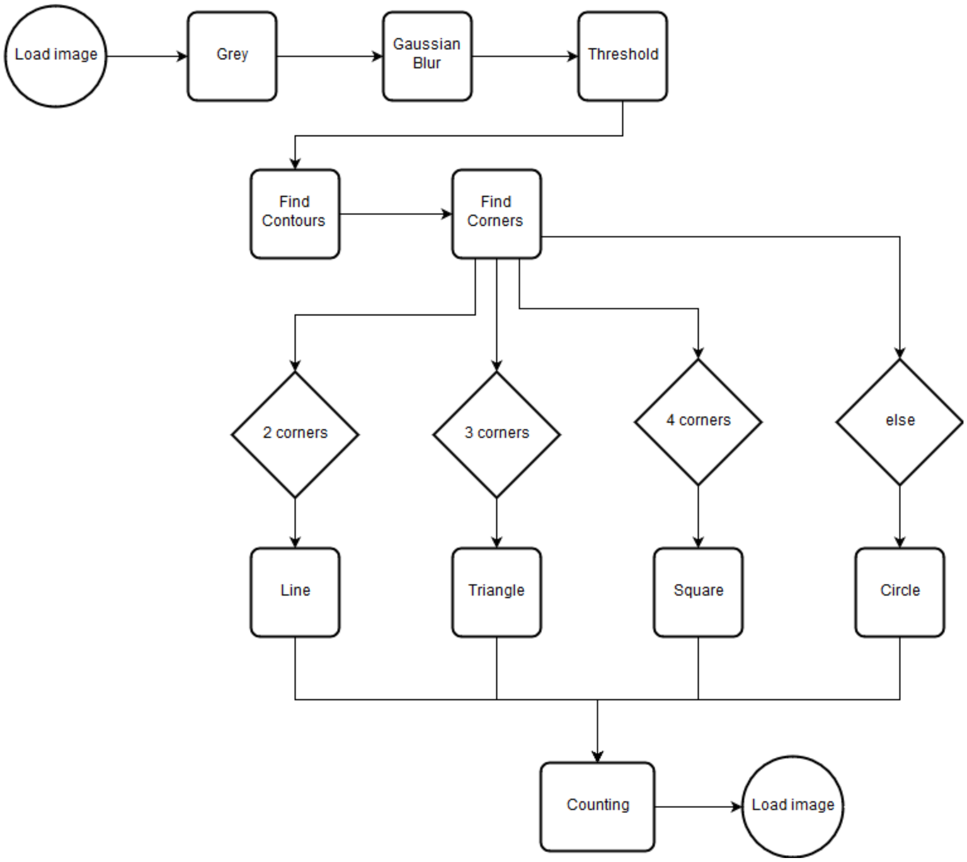

Figure 24: Benthic species data flow diagram.

# 5 Safety

The LBCC ROV team takes safety very seriously. Thus, there are a number of actions and precautions the team has made not in only in building the ROV, but also in operating it.

## 5.1 Safety Content

In order to meet both competition requirements and maintaining a safety protocol, the ROV has no exposed wires. Exposed wires can lead to possible fires, short outs, and electrocution. Therefore, the inside of the control box does not have exposed wiring (ELEC-017E), and the control box is laid out with attention to workmanship (ELEC-022E). A separation and identification of 120VAC wiring from DC and control voltages (ELEC-023E) is also displayed.

SBS50 Anderson Powerpole connectors are the main point of connection to the MATE power supply (ELEC-010R). The Anderson Powerpole connectors to the 48V power supply are labeled with green and yellow electrical tape. The green tape represents power in to the

ROV and the yellow labeled connectors are for the power out. This prevents any possible confusion there may be for attaching the main power to the ROV.

The tether leading to the ROV also has proper strain relief (ELEC-024E) using a closed mesh, double-eye strain. This metallic mesh will prevent any of the wires from being tugged or pulled during operation of the vehicle. In previous years, the team has used pressure housings on the ROV, for this ROV however, the team instead used epoxy to ensure zero water leaks and therefore eliminate any possible issues or accidents regarding pressure. Every Propeller on the ROV is shrouded (MECH-006). This ensures any cord or object the ROV runs up against will not be damaged by a running propeller. The ROV has no sharp edges, or any elements of the frame, that could cause damage (MECH-006, ELEC-017R).

## 5.2 Safety Procedures

As said previously, every member of the team practices safety, and therefore, there are many preventative measures taken in order to avoid accidents. Every person in the team has something they are responsible for and has a job they must do with preventative measures accounted for.

Jason Pfahler, the power manager, is responsible for Charging the batteries. In doing this, he has been trained to actively monitor the battery, to attach cables first to the power, then to the ground. He also is responsible for always wearing gloves when handling the battery, and only touching the alligator clips one at a time. In doing these things, Pfahler prevents overcharging of the battery, electrical fires, touching poles, electrocution, acid burns and body contusions.

Top Side Pre-Checks are left to the responsibility of the Pilot and Co-Pilot. The Pilot is Hunter Cato and the Co-Pilot is Jenny Smucker. Cato makes connections of everything that must be plugged into a power supply and he does this far from the water. He also thoroughly inspects the cords and outlets for damage and ensures nothing comes in contact with leads when plugging in the required cords. The cords he is responsible for includes: Monitor, Air Compressor, Pneumatic Control, and DVR chords. In doing so, he prevents electrical fires and shorting wires too close to the water. Smucker, however, has many more preventative measures. She thoroughly inspects wires and connectors for damage and ensures nothing comes in contact with leads. She is responsible for connecting the extension cord to the 120V AC outlet, connecting the tether to the switch box, and connecting the switch box to the 48V power supply. By doing these things, she prevents electrical fires and shortages. Smucker is also responsible for connecting airlines to the control box, and connecting the pneumatic control box to the compressor. She wears gloves while doing this, and confirms when the output regulator is off. This part of her job prevents pinch hazards and air leaks.

The next step in preventative safety is bottom side pre-checks. These prechecks are up to the responsibility of Tether Manager 1 (TM1), Tether Manager 2 (TM2), and the CEO. The TM1 is Jesse Kayne, the TM2 is Jason Pfahler, and the CEO is Trinity James. It is Kayne's job to tether Square SubConns to 3 PCB's. While doing so she thoroughly inspects plugs for damage and ensures nothing comes in contact with leads. Kayne is also responsible for connecting gray 8-pin plugs from the tether to the cameras, connecting orange 8-pin plugs from the tether to the Arduino, and hooking up the tether strain to the main body. While doing so, she wears gloves and has strict adherence to set up protocols in order to prevent electrical mishaps and pinch hazards. TM2, Pfahler, connects the yellow air hose to the VBS, and the blue/purple air hose to the claw. He also plugs in 2 Thrusters ONLY per PCB [Yellow], and unravels the tether. As he does all of these things, he wears gloves, confirms the output generator is off, he labels which thrusters have been plugged in and he has a tether monitor to communicate to team members. This prevents pinch hazards, air leaks, shorting PCB, fire, and trip hazards. Lastly, the CEO, James, checks to make sure all PCB holes are plugged, and visually inspects the plugs or uses dummy plugs to prevent shorts and electrocution.

During the launch, the Demonstration Assistant, Mike Furrer, has two jobs. He turns on the Trout Grout and is in charge of placing the ROV in the water. He does so using both hands, and organizes the team lift of the ROV into the water. He instructs to use legs, not back, while lifting and not to wear any loose fitting clothing. This prevents a pinch hazard with the Trout Grout and stopping anyone from falling into the pool. During the Operation, TM1, TM2 and the Demonstration Assistant have safety preventative jobs. TM1 and TM2 manage the tether to prevent anyone from tripping on the tether, or from the tether getting snagged on an object which may result in an accident. Meanwhile, it is the Demonstration Assistant's job to take any objects out of the pool, including the ROV. In doing so he will not wear loose clothing, he will communicate with the Pilot and the rest of the team as well as organizing a team lift of the ROV out of the water. In having Furrer in charge of these things, it prevents people from falling in the pool, snag hazards, and damage to the ROV.

# 6 Testing and Troubleshooting

On a small scale we tested portions of the ROV to confirm their functional use and waterproofing prior to adding a component to the ROV. Once we confirmed in the lab that a piece was functional we added it to the ROV body.

The ROV was tested in a campus water feature and pool. In the water tests we used the MATE props to trial and confirm that the ROV could move through the water and perform the required tasks.

# 7 Challenges and Lessons Learned

The current domed camera system stuck out further than many other pieces of the ROV and would hit obstacles and scuff the waterproof lens, leading to blurry and obscured vision. The legs of the camera housing have a countersunk hole that the bolt went into that made it impossible to completely tighten. The countersunk hole placing also made it difficult to put on or remove the cameras.

Due to the bends at the end of the current variable buoyancy system (VBS), there is a tendency for the air bubble to shift to one side of the pipe which causes the ROV to tilt where it becomes stuck. The tilt of the VBS stops the ballast from being able to clear, so the ROV is unable to be righted without returning to the surface.

The use of relays to toggle power for the micro-rov's motors and the electromagnets on the trout-fry proved to be more difficult than expected. Due to the inductive properties of the motors and electromagnets there was a voltage spike across the relay when the switch flipped. This voltage spike caused problems for not only the relays, but for the Arduino controlling them as well. The team spent hours troubleshooting before discovering that the problem did not lie in the controls, the relays, or the Arduino but that special precautions had to be taken when using a switch on an inductive load. After researching, the team found that a capacitor in series with a resistor across the relay would solve the problem by allowing current to the inductor to drop over a period of time rather than instantaneously.

# 8 Future Improvements

In the future the team is working to remake the camera system. The scuffed lenses are being replaced with new waterproof dome lenses. The mounting of the camera is being moved to allow for full tightening of the camera housing to the ROV frame, and easy removal of the cameras. Cameras are being places on the ROV in such a manner that they are not the most exposed portion of the vehicle, which will prevent the domes from being scuffed.

The variable buoyancy system is being redesigned to have a more even weight distribution and a smaller frame. A more even weight distribution will allow for better piloting of the ROV and prevent air bubbles from unbalancing the ROV. It also provides a more even lift. The smaller frame allows the ROV to fit within the smallest MATE competition size category.

New power conversion boards (PCB) are being created so that we have access to more ports to power devices on the ROV. Extra ports also provide back up power sources if a port fails. Additionally the lights of current PCBs do not turn off after 5 seconds, as per the competition guidelines.

The gripping claw is being remade to have a stronger grip and a wider aperture. This will allow for easier completion of tasks that require gripping objects.

The team is in the process of completing an autonomous line following program.

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# 10 Acknowledgements

The Linn Benton Community College ROV team would like to thank our mentors: Greg Mulder, Heather Hill, and Brian Reed for the support they have given us this year.

Thank you to Sea-Bird Scientific (WET Labs) for donating waterproof connectors and epoxy.

Thank you to Lindenwood Apartments for letting us use their pool for wets runs of the ROV.

Thank you to Kambria Wallace for managing the team's purchases.

Thank you to Josh for permitting access to various lab equipment.

# 11 Appendix

## 11.1 Budget and Cost Accounting

|  |  |  | Reporting period |
|---|---|---|---|
| **School Name:** | Linn-Benton Community College | From: | 9/13/2018 |
| **Instructor/Sponsor:** | Greg Mulder | To: | 5/6/2019 |

# BUDGET

| **Category** | **Budgeted Value** | **Cost** |
|---|---|---|
| **Hardware** | $1,500.00 | $2,023.34 |
| **Electronics** | $4,000.00 | $3,813.48 |
| **General Funds** | $500.00 | $315.00 |
| **Travel** | $10,000.00 | $6,745.19 |
| **Total** | $16,000.00 | $11,585.94 |

*Purchased
***Re-Use

# Project Cost

|  | **Date** | **Company** | **Category** | **Description** | **Amount** |
|---|---|---|---|---|---|
| Electronics | 9/15/2018 | DKC Digi Key Corpo | Electronics | Arduino For Thrusters* | $148.93 |
|  | 9/20/2018 | Sparkfun Electronics | Electronics | Control Team Hardware* | $137.85 |
|  | 10/12/2018 | Int In Ocean Innovations | Electronics | Subcomm Connectors* | $533.20 |
|  | 10/15/2018 | Batteries and Bulbs | Electronics | Batteries* | $215.96 |
|  | 11/16/2018 | Blue Robotics | Electronics | Cameras* | $156.00 |
|  | 12/12/2018 | Blue Robotics | Electronics | Cameras* | $70.00 |
|  | 1/14/2019 | MacCartney Inc | Electronics | Subcom Connectors* | $253.25 |
|  | 1/16/2019 | APW Company | Electronics | Electromsgnet* | $33.19 |
|  | 1/22/2019 | CCTV Camera Pros | Electronics | Cameras* | $50.85 |
|  | 1/28/2018 | Amazon | Electronics | Relay Trout/Grout* | $5.50 |
|  | 2/13/2019 | Amazon | Electronics | PCB* | $3.97 |
|  | 2/26/2019 | APW Company | Electronics | Electromagnet* | $37.14 |
|  | 3/9/2019 | Blue Robotics | Electronics | Camera Team* | $138.36 |
|  | 4/5/2019 | Digi Key Corp | Electronics | Wires* | $20.94 |
|  | 4/5/2019 | Dfrobot | Electronics | PH Sensor* | $45.50 |
|  | Re-Use | LBCC ROV | Electronics | Thrusters*** | $1,440.00 |

| | | | | | |
|---|---|---|---|---|---|
| | Re-Use | LBCC ROV | Electronics | Electronic Speed Controller*** | $300.00 |
| | **Subtotal** | | $3,590.64 | | |
| **Mechanical** | 9/11/2018 | Allied Electronics | Hardware | Epoxy* | $117.66 |
| | 9/13/2018 | Master Electronics | Hardware | Epoxy* | $135.10 |
| | 10/3/2018 | Robotpark | Hardware | Claw For Pneumatic* | $99.79 |
| | 10/23/2018 | Amazon | Hardware | Epoxy* | $87.54 |
| | 10/24/2018 | Amazon | Hardware | Trout/Grout 3-D Printing* | $6.40 |
| | 1/14/2019 | McMaster-Carr | Hardware | Bolts* | $31.10 |
| | 1/16/2019 | Amazon | Hardware | Tether* | $35.52 |
| | 1/25/2019 | McMaster-Carr | Hardware | 3-D Printing* | $13.85 |
| | 3/15/2019 | Taishankeji | Hardware | Pneumatic* | $24.90 |
| | Re-Use | LBCC ROV | Hardware | Frame*** | $125.00 |
| | **Subtotal** | | $676.86 | | |
| **Travel** | 4/30/2019 | American Air | Travel | Tennessee* | $2,970.54 |
| | 4/30/2019 | American Air | Travel | Tennessee* | $1,485.27 |
| | 4/30/2019 | American Air | Travel | Tennessee* | $495.09 |
| | 5/1/2019 | American Air | Travel | Tennessee* | $495.09 |
| | 5/1/2019 | Amierican Air | Travel | Tennessee* | $246.80 |
| | 5/6/2019 | American Air via Expedia | Travel | Tennessee* | $557.30 |
| | 5/6/2019 | American Air via Expedia | Travel | Tennessee* | $495.10 |
| | **Subtotal** | | $6,745.19 | | |
| **General Funds** | 1/25/2019 | ACT Marine Advanced Tech | General Funds | Registraion for MATE* | $315.00 |
| | 2/12/2019 | No Dinx | General Funds | T-Shirts* | $258.25 |
| | **Subtotal** | | | | $573.25 |

| | | |
|---|---|---|
| | Subtotals | $11,585.94 |
| | Items Re-used | $1,865.00 |
| | **Total Expenses** | $8,934.49 |
| **Income** | Income | |
| | Remaining Fund from Previous Year | $7,473.07 |
| | Self Fund | $1,920.00 |
| | Co-Curricular Budget Committee  Donation | $2,500.00 |
| | **Subtotal** | $11,893.07 |
| | **Total Income** | $11,893.07 |
| | **Net Balance** | $2,958.58 |
| | Total ROV Cost | $4,267.50 |