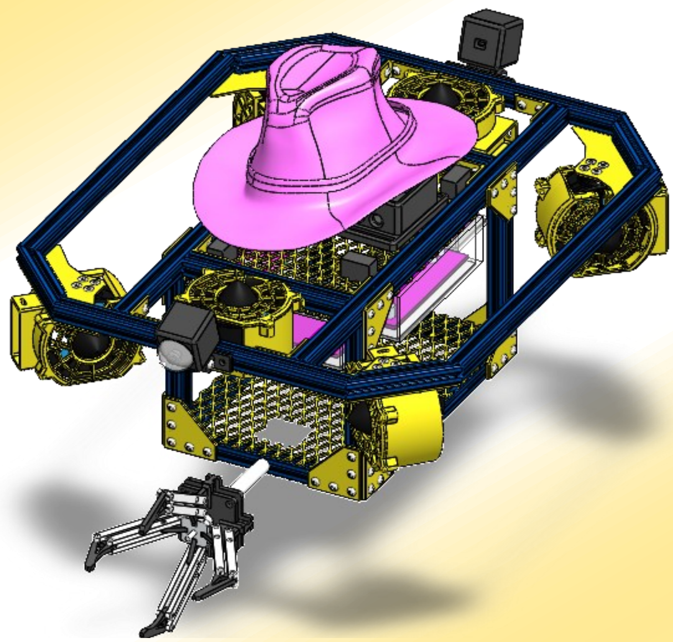
LINN-BENTON ROV



TECHNICAL DOCUMENTATION

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Yee haw.

Abstract

Linn-Benton ROV, based out of Linn-Benton Community College (LBCC) in Albany, Oregon, is made up of participants from a variety of disciplines spanning science and engineering. Linn-Benton ROV has been participating in MATE competitions since 2008.

Like undoubtedly all teams this year, the LBCC posse has faced many hardships this year in the construction of this underwater remotely operated vehicle (ROV). As such, the team is small, consisting of only four members. Two members are returning to MATE competitions: Sara Leathers and Emily Nussdorfer; while two members are new: Josh Palmer and Dale Sydnam.

The LBCC Team's EXPLORER-class ROV, Beta, was assembled for this year's MATE competition in only 3 weeks, or around 250 student-hours. The team saved time on construction by recycling the aluminum frame and thrusters from prior years. Measuring 55 cm X 52 cm X 19.4 cm, the vehicle weighs 13.8 kg out of water. The total cost of the vehicle, including that of recycled components, comes out to $4000.

Special features of the ROV include modular, detachable components such as the tether, thrusters, cameras, power converters, and onboard Arduino. This modular build style allows room for continuous improvement and expansion. Safety features include different sizes and shapes of connectors, ensuring there are no wrong connections; shrouded thrusters, ensuring propellers are not a finger hazard; powder-coated metal components, ensuring the elimination of sharp edges; and fuses built in to power conversion boards, ensuring there are no electrical shorts in case of a failure.

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Project Management

October 2019 — March 2020: Linn-Benton ROV met bi-weekly during the school term on Tuesday and Friday, as well as on Saturday on many occasions. The Tuesday meeting served to review what was completed the previous week and organize what will get done that current week, round-robin style. Each sub-team would report on the things they had completed, things that were delayed, and the next step in their process, as well as ask for assistance or suggestions for continuing forward. The CEO, Sara Leathers, or the head mentor, Greg Mulder, would organize and run the Tuesday meetings.

The Friday meeting served as a collaborative work day, while Saturdays served as testing time, usually at a pool.

March 2020 — June 2021: Linn-Benton ROV met weekly during Spring and Fall terms on Tuesdays via Zoom. These meetings ran similarly to the Tuesday meetings in-person, but the focus was shifted to various at-home projects. These projects included building a Solar Corona Imaging Polarizer, and individually using ROV components (thrusters, cameras, etc.) so that everyone involved could have the ROV Experience™ without meeting in-person.

July 2021: In light of restrictions being lifted, and with utmost precaution, Linn-Benton ROV assembled in-person, on Wednesdays, Thursdays, and Saturdays, with the goal of preparing the ROV, Epoxy Parton, for an international competition. The amount of time available one each day would vary significantly, but each meeting would begin with a review of what had been accomplished since the last meeting, and a discussion of what tasks lie ahead. A goal for the day would be set, and work would begin.

Throughout the build process, countless ideas were exchanged about how to best go about construction and sourcing materials. To help each sub-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-team would do research and reconvene later to share what they had learned and decide on a plan moving forward. In order to reduce waste, 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 open planning style resulted in heavy collaboration between sub-teams and thus helped to ensure smooth integration of vehicle sub-components.

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 as well as a nearby 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.

Design Rationale

Frame

The frame (Figure 2.1.1) is composed of 80/20 20-millimeter 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.

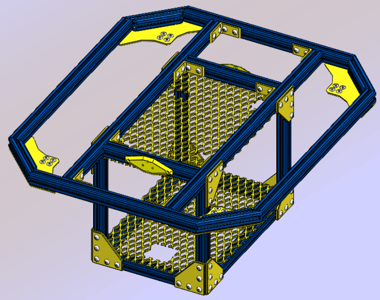

Figure 2.1.1: The extruded aluminum frame of the ROV.

Tether

The tether was designed to be neutrally buoyant and detachable. The 9-meter 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 (Figure 2.2.1). Components contained in the sheathing are:

- Ethernet for the camera signal
- Ethernet for the Arduino signal
- Two 18-gauge power wires for the 48 V 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*
- Swan visual signal cord*
- Polyethylene foam for buoyancy

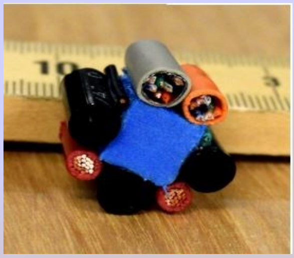

Figure 2.2.1: Cross-section of tether.

* Item was put in place for past component(s) and currently serve no function to the ROV, but have been properly maintained to aid in future add-ons.

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, indicated by both the shape of the connector and color-coding. Four 48 V power connections connect to the top of the power conversion blocks through SubConn Low Profile, two-contact female connectors. The two Ethernet cables have circular SubConn eight-contact, male connectors; the gray/purple camera Ethernet connects to the camera system, and the orange control Ethernet connects to the Arduino. Two of the air hoses, color-coded blue and purple, 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 ROV flight path.

Design Rationale

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 2.3.1: The cameras in 3D-printed housings.

The cameras, baluns, and wire connections are encased in a 3D printed housing filled with epoxy to ensure they are waterproof (Figure 2.3.1). A dome with a diameter of 4.5 centimeters 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 5 cm X 5 cm X 5 cm. 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 12 V power outlet on a power converter board.

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 2.4.1). The benefits of this design include increased stability and the ability to have yaw control along with straight movements.

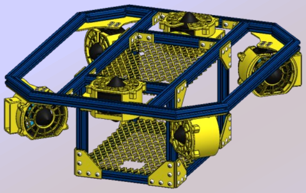

Figure 2.4.1: Thruster mounting design.

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, 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 (ESCs) and Arduinos, and these can interpret the analog signal and send the appropriate signal to the thrusters.

Design Rationale

Thrusters

Six T-100 thrusters (Figure 2.5.1) provide the force to move the ROV. Control of the thrusters is accomplished by utilizing ESCs and an Arduino microcontroller. Each T-100 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 T-100 and provide a place to mount the ESC. The shrouds were 3D-printed by the Oregon State University Library. The T-100 were chosen because they had been used by a previous team and were still functional.

Figure 2.5.1: The thruster inside 3D –printed shroud.

Controls

The ROV is controlled by pneumatic levers and a PlayStation2 controller (Figure 2.6.1). 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.

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 Arduinos are to program the number of libraries already included within its interface.

Figure 2.6.1: ROV 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 programming, this button causes the up and down thrusters to switch from thrusting in the same direction to thrusting in opposite direction. The pilot also has the option of adjusting 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 for the ROV.

The digital buttons on the PS2 controller can be used to turn on and off a variety of tools. 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 (Figure 2.6.1) 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 sensors on the ROV and sending it back to the sender, and turning on and off the different tools on the ROV.

Design Rationale

Buoyancy

In order to achieve neutral buoyancy for the ROV, 4500 cubic centimeters 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 (Figure 2.8.1). They were constructed using clear polycarbonate to provide adequate durability and minimize obstructing the view of other components.

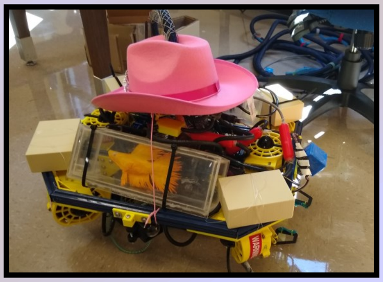

Figure 2.8.1: One of two buoyancy boxes.

Power

The power conversion board (PCB; Figure 2.9.1, Figure 2.9.2) was designed to be small and replaceable. Each power conversion board has three or four 12 V outputs. The first version of the PCB has three outputs, while the second version has four 12 V power outputs. All 12 V power outlets are circular SubConn two-contact, female connectors. 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 48 V 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 acrylic boxes to protect the electronics from water. The bottom side of the box is an aluminum plate. The converter on 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 2.9.1: Power conversion board.

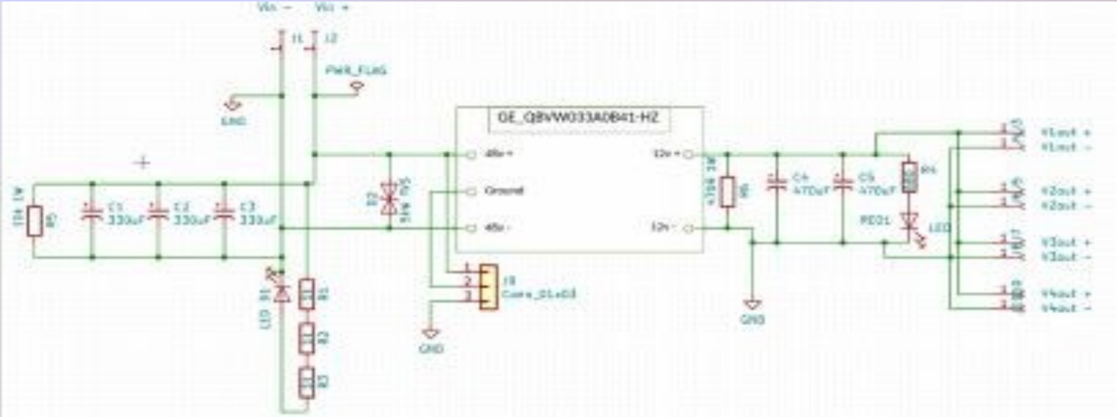

Figure 2.9.2: Power conversion board system integration diagram (SID).

Design Rationale

Pneumatics

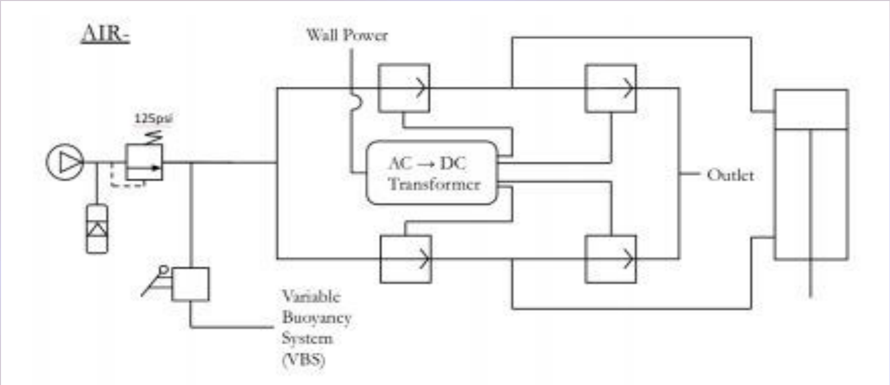

Figure 2.10.1: Pneumatics system integration diagram (SID).

The pneumatics system was designed to operate both a pneumatic claw and a variable buoyancy system, at which time 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 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 (Figure 2.10.1) requiring 12 V direct current supplied by a class 2 Condor transformer and operated with the use of a single two-way switch. The variable buoyancy system is no longer in use, but all associated hoses remain integrated into the air distribution system to aid in future additions.

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).

Claw

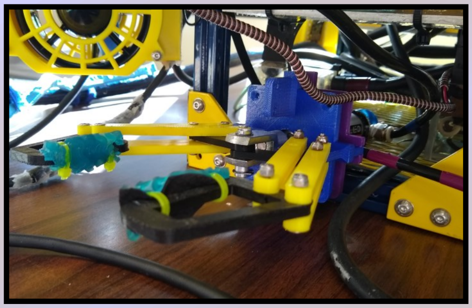

Figure 2.11.1: ROV Claw.

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, obtained in a previous year, was modified to fit the tasks. This choice allowed the option of scaling down to a two-finger configuration (Figure 2.11.1). The claw was then highly modified so that it operated more effectively for 2021 competition tasks. Modifications included:

- Replacement of original linear pneumatic actuator with a larger diameter pneumatic actuator from Sydien in order to achieve greater grip force.
- 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 clsaw, 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.

Accounting

Reused Purchases				
Date	Company	Category	Description	Amount
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
11/16/2018	Blue Robotics	Electronics	Cameras	$ 156.00
12/12/2018	Blue Robotics	Electronics	Cameras	$ 70.00
1/14/2019	MacCartney Inc Electronics	Electronics	Subcom Connectors	$ 253.25
1/22/2019	CCTV Camera Pros	Electronics	Cameras	$ 50.85
2/13/2019	Amazon	Electronics	PCB	$ 3.97
3/9/2019	Blue Robotics	Electronics	Cameras	$ 138.36
4/5/2019	Digi Key Corp	Hardware	Wires	$ 20.94
2018	LBCC ROV Team build	Hardware	Thrusters	$ 1,440.00
2018	LBCC ROV Team build	Hardware	Electronic Speed Controller	$ 300.00
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
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
2018	LBCC ROV Team build	Hardware	Frame	$ 125.00

New Purchases 2020/2021				
2/18/2020	Amazon	Hardware	Pneumatic Cylinder	$14.99
12/15/2020	Blue Robotics	Hardware	Buoyancy Foam	$50
7/12/2021	Amazon	Hardware	Cowboy Hat	$12
			Total ROV Cost	**$4,000.80**

Non-ROV Purchases 2020/2021				
1/22/2020	Acer Racing	Props	Anderson powerpole connectors	$4.99
1/22/2020	TinySine	Props	inductive coupling power connector	$29
1/22/2020	Amazon	Props	checkers or plastic chips	$6.39
1/22/2020	Amazon	Props	plastic test tube	$9.49
1/22/2020	Amazon	Props	mesh	$4.77
1/22/2020	Amazon	Props	Ping-pong balls	$4.95
1/22/2020	Amazon	Props	netting	$7.49
1/22/2020	Home Depot	Props	3-inch knockout cap	$0.46
1/22/2020	Home Depot	Props	plastic mesh	$17.38
1/22/2020	Home Depot	Props	1/2-inch 45 elbows	$0.77
1/22/2020	Home Depot	Props	1/2-inch cross	$1.45
1/22/2020	Home Depot	Props	Corrugated plastic sheeting	$21
1/22/2020	Home Depot	Props	2-inch pipe	$3.68
3/9/2020	Amazon	Power Source	Batteries	$145
3/9/2020	Amazon	Hardware	3D Printing Filament	$75
N/A	MATE	Competition	MATE Registration	$400
N/A	N/A	Travel	Estimated Travel Expenses	$2,000
			Total Expenses 2020/2021	**$2,808.46**

Due to extenuating circumstances on time, and not being able to meet in-person, a high percentage of Epoxy Parton is constructed of reused materials. Rest assured, the LBCC posse has grand plans for Epoxy Parton, however, none of those plans could be carried out over the course of 16 months of quarantine.