Southwest Virginia Community College Robotics Team

Technical Documentation – *SeaEagle*

MATE Pioneer Class 2022 World Competition

Members:

Luke Jennelle, President, Safety Officer

Joshua Thiel, CEO, Vice President

Anthony King, Secretary

James Hart, Treasurer (Not pictured)

Kevin Brooks (Not pictured)

Elisabeth Presley

Left to right: Elisabeth Presley, Luke Jennelle, Joshua Thiel, and Anthony King

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Abstract

Southwest Robotics Team, based out of Southwest Virginia Community College (SWCC) in Cedar Bluff, Virginia, consists of members from several different majors, including engineering, electrical electronics, and mechatronics. This year marks the first time that the Southwest Robotics Team has participated in any MATE ROV events, including the World Championship. In order to become somewhat familiar with the basics of underwater ROVs, the team purchased and reviewed *Underwater Robotics: Science, Design & Fabrication* [1].

SWCC's PIONEER-class ROV, *SeaEagle*, was assembled for 2022s MATE competition over a period of about five months, or around 674 hours in total. *SeaEagle* has a lightweight and durable frame made of PVC, measures approximately 61cm x 52 cm x 23cm, and weighs approximately 4 kg out of water. The overall cost of the ROV amounted to $1,600.62 dollars.

One noteworthy feature of *SeaEagle* is that the frame is made of PVC rather than extruded aluminum, which is common among ROVs. Some of *SeaEagle's* safety features include 3-D printed shrouds for its four motors and properly rated fuses within the specified distances.

Project Progression by Month

January 2022 - SWCC Robotics spent the vast majority of January attempting to become familiar with MATE ROV and competition rules, regulations, and tasks, as the entire team was new to underwater robotics, and robotics competitions in general. The team also began designing and building the first model of *SeaEagle*.

February 2022 – In February, SWCC Robotics elected team members to fill the offices of President, Vice President, Secretary, and Treasurer. This was also when the team began researching ROV lighting methods, different types of cameras and their respective capabilities, and CAD models for the ROV’s arms.

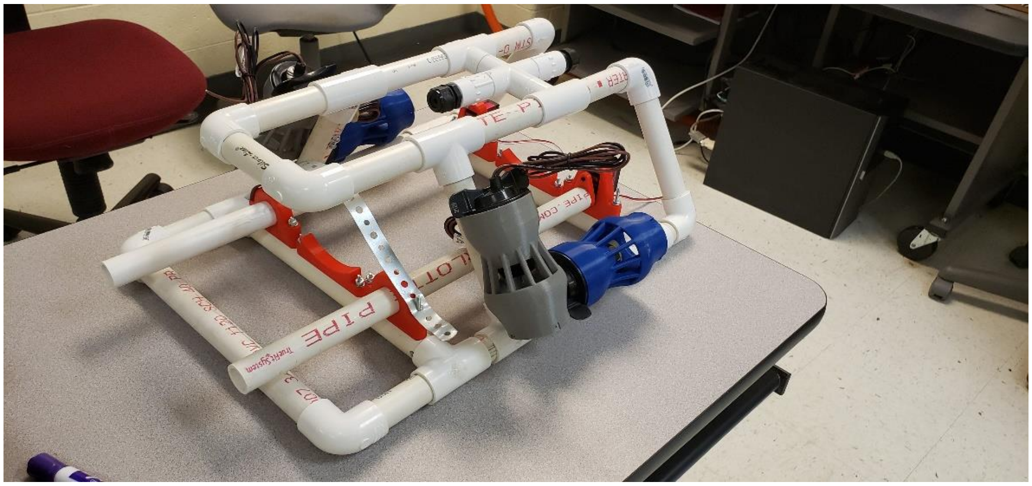
March 2022 – In March, SWCC Robotics began working on waterproofing some of the necessary electronics, such as the cameras, lights, and ESP32s, and testing out different arms for the ROV. This was also when the team made the decision to downsize the original *SeaEagle* and create a lighter, more compact frame for improved maneuverability.

April 2022 – Much of April was spent working on the new version of *SeaEagle*, and fitting everything to the smaller frame that was created. This was also when the team began to practice with the ROV and construct props to recreate the competition tasks. The team made calls to various establishments nearby Southwest Virginia Community College to inquire about pool availability.

May 2022 – The majority of May was spent filming the qualification videos for the competition and creating technical documentation for the ROV. A lot of troubleshooting had to be done on *SeaEagle* during this month, as the team discovered that the servos used for arm movement, as well as the cameras, were not sufficiently waterproofed.

Design Rationale

Frame



SeaEagle's frame consists of ¾ PVC pipe, with several 3D-printed PLA mounts. 3D printing was an efficient method of procuring mounts, as it allowed the team to directly customize and design whatever best suited the specific needs of the ROV. Additionally, there were multiple 3D printers available at the college, so funds were not needed to purchase a printer. The team chose to use PVC pipe for *SeaEagle's* frame as it is lightweight, inexpensive, durable, smooth-edged, and easily replaceable. The team also opted to paint the frame the school colors: blue, maroon, and gray.

Design Rationale

Tether

The tether was designed to be neutrally buoyant. It measures approximately 50 feet and is comprised of

- An Ethernet cable to allow access to the ESP32 cameras
- Two 8-conductor cables
- Two RCA cables for the two analog cameras
- An air hose for inflating the innertube used to adjust *SeaEagle's* buoyancy
- A rope for strain relief

The tether turned out to be somewhat negatively buoyant, so the team added segments of a pool noodle at spaced intervals on the tether to cancel out some of the excess weight.

Design Rationale

Cameras

Analog - SWCC Robotics used the two analog cameras provided with the Barracuda Video System Kit. The cameras are powered from the Barracuda control box and run on 12 volts. They both connect to the monitor provided with the video system kit, and the views can be easily switched between with the push of a button.

ESP32 Cameras – The team also used two ESP32 cameras, as they are inexpensive and possess integrated Wi-Fi and Bluetooth capabilities. A Raspberry Pi is used to bridge the network from the ROV to the surface, and the Ethernet cable included in the tether is needed to access the cameras' feed from the surface.

Waterproofing – In order to waterproof the two analog cameras, the team inserted each camera into a length of PVC pipe and epoxied a clear acrylic lens to one end of each tube to ensure a clear visual, and then effectively potted each camera in epoxy. For the ESP32 cameras, the team designed and printed 3D boxes in which to insert the cameras, making sure not to obstruct the lenses in any way, before sealing the boxes with epoxy.

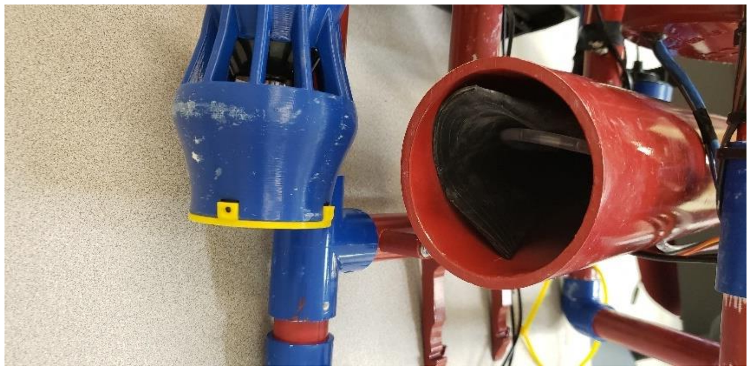
Design Rationale

Thrusters

SWCC Robotics equipped *SeaEagle* with the four thrusters included with the TriggerFish/Barracuda Four Motor and Propeller Kit. Two thrusters are mounted on the ROV at a 45-degree offset to allow for maximized maneuverability, while the other two are mounted parallel to the frame. The thrusters are controlled using the Barracuda Control Box Kit, which accomplishes control of the motors through usage of two Sabertooth motor drivers and are capable of moving the ROV through the water both horizontally and vertically. The PLA thruster shrouds (pictured) are designs obtained from Thingiverse [2] and were 3D-printed on campus, using one of the 3D printers available to students. The team decided to make the thruster shrouds dark blue, in keeping with the elected color scheme of the ROV.

Design Rationale

Buoyancy



The team had intended for *SeaEagle* to be neutrally buoyant, but attaining neutral buoyancy proved very difficult to do. Rather than perform calculations to determine the air volume needed to achieve neutral buoyancy, the team experimented with various flotation devices. The PVC pipe that was used to house the electronics and placed in the approximate center of the ROV held a considerable volume of air and kept the ROV from sinking to any significant depth. The pipe was subsequently downsized in order to reduce the buoyancy and allow *SeaEagle* to sink. Eventually, the team added an innertube encased in a PVC pipe (pictured above) to the approximate center back of the ROV to assist with variable buoyancy and quick ascents, with an air hose running from a bicycle pump on the surface to the innertube beneath the water.

Design Rationale

Arms

SeaEagle's arms were particularly hard to design due to the multiple parts and linkages that must work in unison. The gears were designed so that they would open and close with the least resistance possible, as well as have large enough teeth that a 3D-printer could print them out with sufficiently high resolution. The base was made to bolt onto a section of 1" PVC pipe and was printed with a higher infill density to ensure rigidity. The linkages of the arm and the gears are constantly parallel with one another, resulting in the fingers also remaining parallel. At the very end of each of the fingers is a single tooth which prevents ropes or pins from slipping out of the gripper.

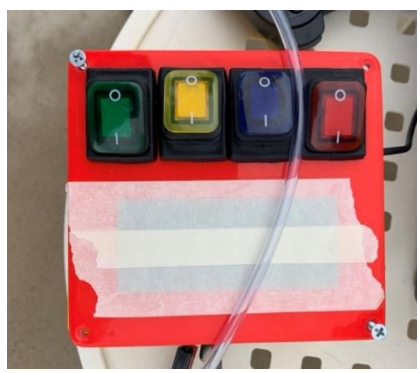
Design Rationale

Arm Controls

In order to move the robotic arms, the team used a library to assist with communication between a PlayStation 3 controller and an ESP32 board. Then the controller was programmed such that if designated buttons on the PS3 controller are pressed, the arms will open or close a specified number of degrees.

Power

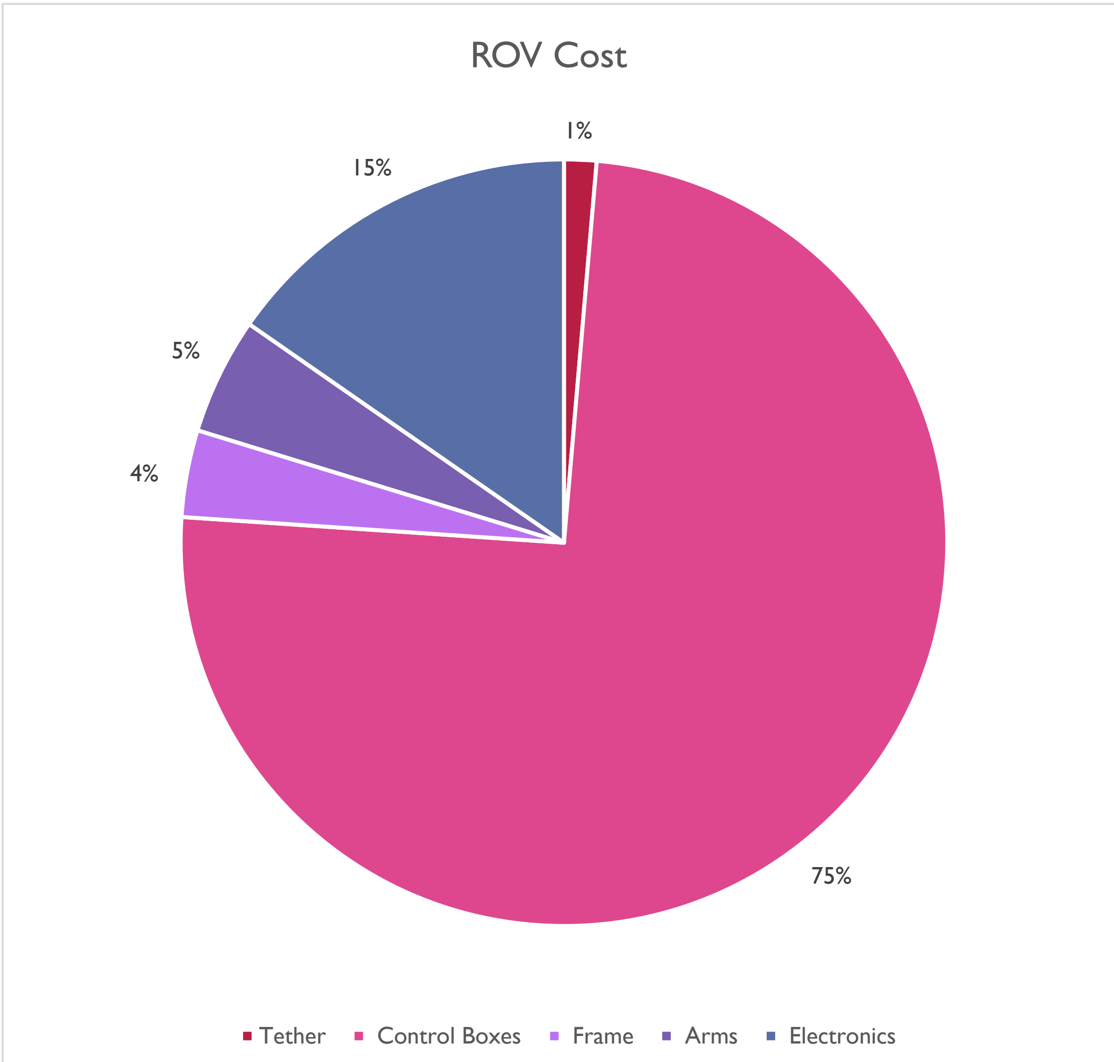
Power runs from the 12V power supply to the primary control box, secondary control box, and router. The primary control box, as well as the router, uses the 12-volt power without the need to convert it. The secondary control box, however, takes the twelve volts and converts it to five volts to power the ESP32, the ESP32 cameras, the two servos used for arm movement, and the Raspberry Pi.



Programming

The team uploaded the Raspbian Lite OS onto the Raspberry Pi and used RaspAP to handle server communication between the ESP32 cameras and the surface router. The Raspberry Pi acts as an access point between the router and the ESP32 cameras. For the control box and thrusters, the code was based on code provided on the MATE ROV website [3], and subsequently modified by the team to provide further efficiency and functionality.

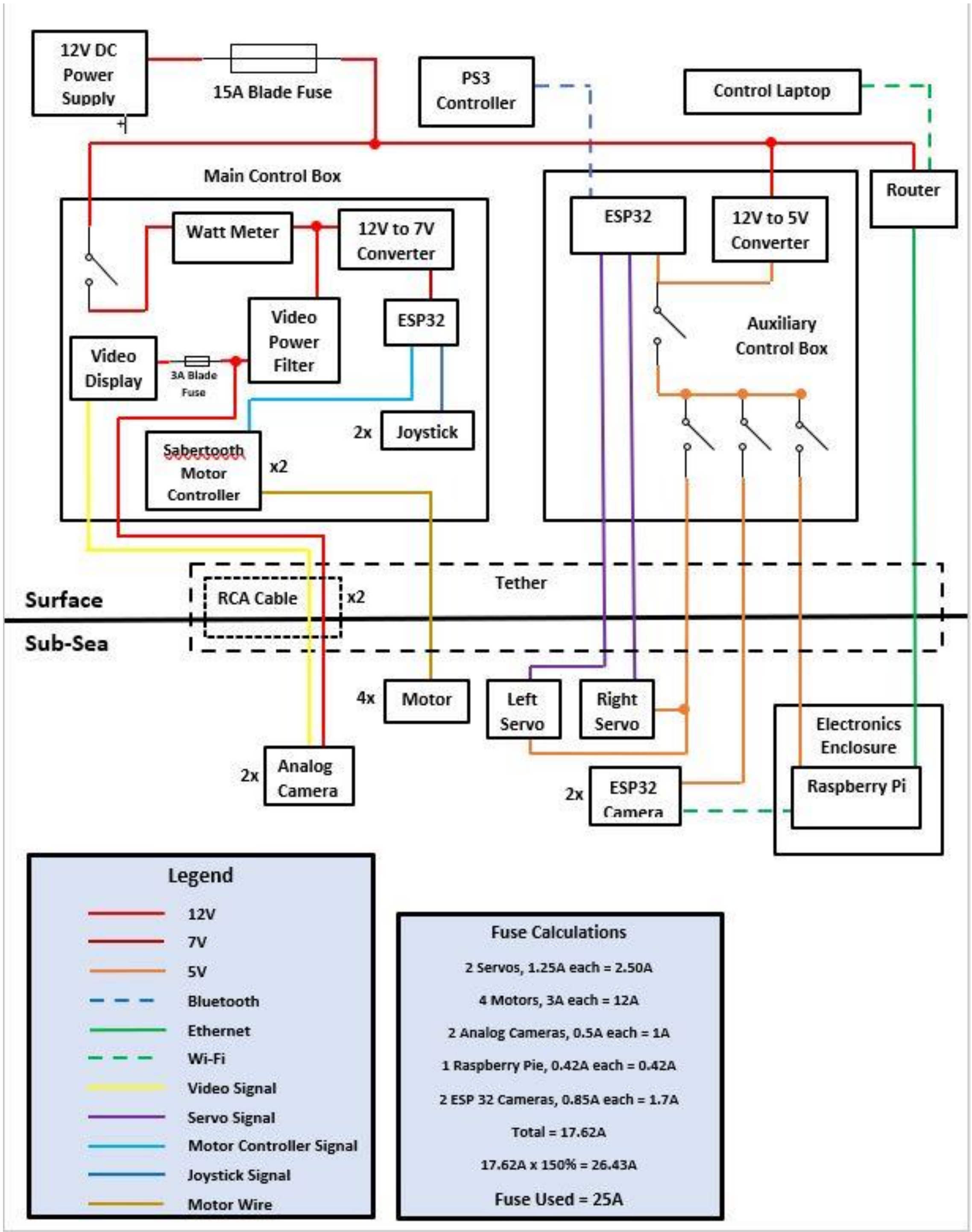
Cost of ROV


ROV Cost
1%
15%
5%
4%
75%
Tether
Control Boxes
Frame
Arms
Electronics

List of Purchases for *SeaEagle*

Description	Qty	Part Number	Cost	Total
Tether				
Airhose - 50 ft. aquarium line hose	1		7	7
Pipe Insulation - 6 ft	1		2.48	2.48
Ethernet Cable - 10 meters	1		12.99	12.99
Tether Total Cost				22.47
Control Boxes				
Barracuda Rov with thrusters and tether kit	1		1,200	1,200
12 volt to 5 volt converter	1		14.49	14.49
Terminal strip	1		2	2
Switches	4		2	8
Display	1		5	5
Control Boxes Total				1,229.49
Frame				
Cap	1		9.71	9.71
3\4 PVC pipe				
3\4 PVC T's	8		1.78	13.03
3\4 PVC Elbows	6		0.71	4.26
4" PVC pipe	1		13.25	13.25
Clean out adapter	1		9.18	9.18
Clean out cap	1		3.98	3.98
Coupling	1		6.98	6.98
Number 6-2" bolts	18			
Number 6 nuts	18			
Number 6 washers	36			
Frame Total				60.39
Arms				
Waterproof servos	2		27.51	55.02
Robotic arm	2			
3D PLA	1		25.99	25.99
Arms Total				81.01
Electronics				
Puffer fish video system kit two cameras	1		180.99	180.99
ESP32	1		10.49	10.49
ESP32 camera	2		12.99	25.98
Raspberry Pi 3 B+	1		34.99	34.99
Electronics Total				252.45
Total cost				1645.81

Electrical SID



References

[1] Moore, Steven W., et al. Underwater Robotics: Science, Design & Fabrication. Marine Advanced Technology Education (MATE) Center, 2010.

[2] Sthone. "MATE Compatible ROV Kort Nozzle for Bilge Pump Thruster." Thingiverse, https://www.thingiverse.com/thing:2854024 (accessed March 24, 2022).

[3] Scott Fraser, Leroy van der Vegt. July 2020. Sabertooth Motor Test. files.materovcompetition.org/docs/resources/Barracuda/code/CUDA-Arduino-Joystick-Control.ino.

Appendix

This checklist is a poolside mission launch safety inspection sheet put together by the team, intended to be reviewed before the ROV enters the pool at the competition.

Primary:

- [ ] Safety Equipment On
- [ ] All Equipment is Accounted For

Inspection of ROV:

- [ ] Motors
- [ ] Arms
- [ ] Raspberry Pi and Raspberry Pi Housing
- [ ] Camera
- [ ] No leaks

Check All Connections:

- [ ] Primary Control Box Set Up
- [ ] Tether is Connected
- [ ] Secondary Control Box Set Up
- [ ] Router is Connected
- [ ] Computer is Connected
- [ ] Power Supply is Connected

Test Functionality:

- [ ] Motors
- [ ] Arms
- [ ] Raspberry Pi
- [ ] Cameras

Allotted Time:

- [ ] 5 Minutes for Setup
- [ ] 15 Minutes of ROV Operation
- [ ] 5 Minutes Cleanup