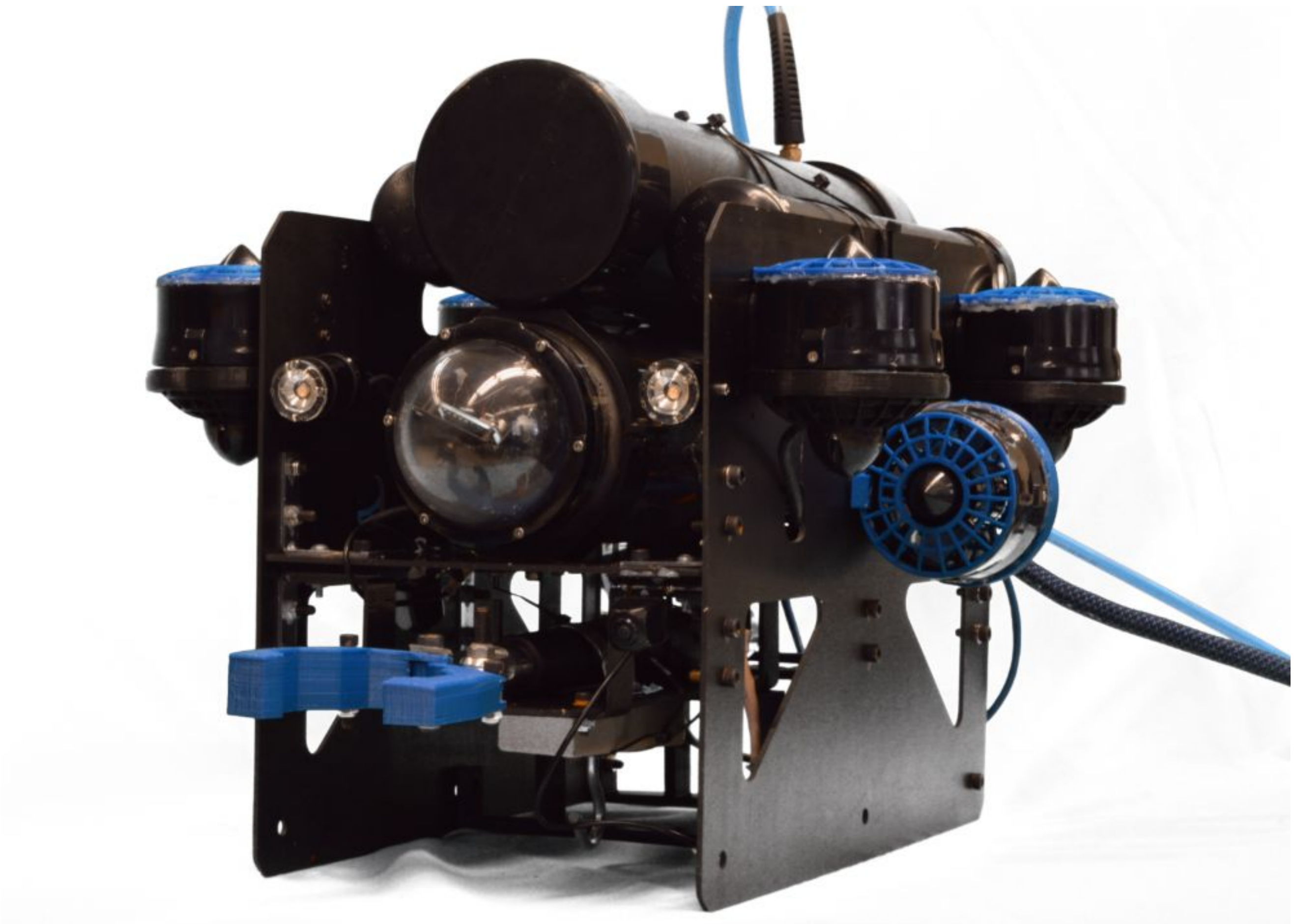
SOUTH SHORE ROBOTICS

Bridgewater, Nova Scotia, Canada



SS Enterprise

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2019
Bridgewater, Nova Scotia, Canada

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Front L-R: Eli Langille, Aditya Kondapuram
Back L-R: Teo Milos, Evan Kinsmen, Adam Culbert, Ciaran O'Brien

Abstract

South Shore Robotics, located in Bridgewater, Nova Scotia, Canada has constructed the SS ENTERPRISE, an ROV designed to meet the needs of the Eastman Company of Kingsport, Tennessee. This Fortune 500 company has issued a request for proposals (RFP) for a remotely operated vehicle (ROV) and crew that can operate in the freshwater environments of Boone Lake, Boone Dam, and the South Fork of the Holston River. Specifically to complete tasks related to (i) ensuring public safety, (ii) maintaining healthy waterways, and (iii) preserving local history of the Civil War era.

Our ROV has been specifically designed to inspect and make repairs to the Boone hydroelectric dam, monitor its water quality, determine habitat diversity, and restore the fish habitat of the South Fork Holston River, as well as recover Civil War era cannons while marking the location of unexploded cannon shells in the freshwater environments of Boone Lake, Boone Dam, and the South Fork of the Holston River.

In our third year of designing and constructing ROVs, we have been able to apply much of what was learned in our first two years to improve on our products design and functionality.

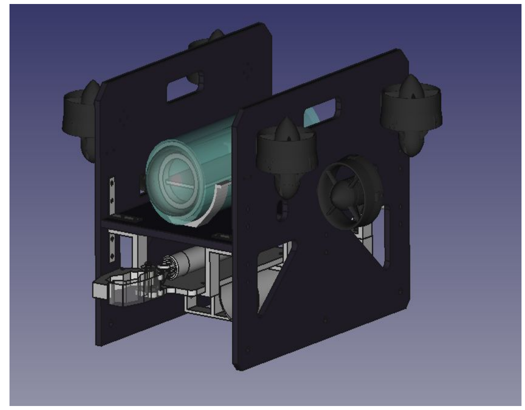
Our focus this year has been on constructing an ROV that improves upon our first two attempts in as many areas as possible.

Our first improvement over last year's ROV was to redesign our frame to be strong and lightweight while improving buoyancy. Our carbon fibre and 3D printed frame is extremely strong, lightweight and allows for the installation of accessories.

Another area where our ROV struggled was in thruster power. This year, we have equipped our redesigned ROV with four T200 thrusters for vertical movement, and two T100 thrusters for forward/backward movement. The SS ENTERPRISE provides the operator with four camera feeds, illuminated with bright lights, to ensure the operator is aware of their surroundings. Our current ROV is also controlled digitally with an XBOX controller, a Raspberry Pi 3b+ on-board computer with Adafruit PWM Servo Motor Hat. This affords a greater degree of control for the operator on the surface. Our programmers have developed a robust delivery system that allows for pitch, roll, yaw, and other unique movements of the ROV.

Frame Design

We collaborated with STELIA North America Ltd of Lunenburg, Nova Scotia to construct a strong, lightweight, carbon fibre frame. The frame is made from ten layers of carbon fibre sheets which were stacked in a pattern with the fibres at 45 degree angles to one another. The raw carbon fibre was baked overnight in a kiln and then milled with STELIA's equipment. Further drilling and sanding were done by South Shore Robotics.



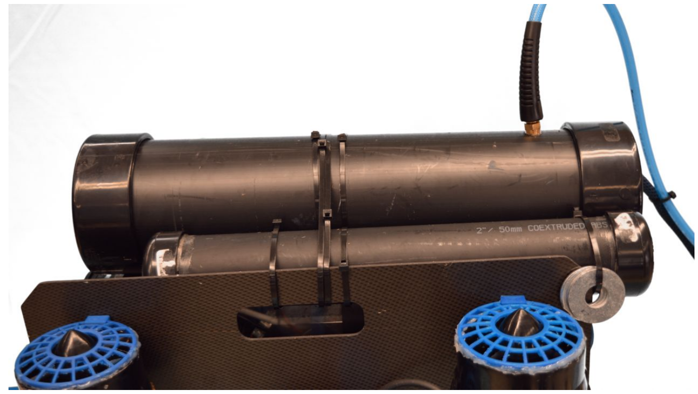
The frame provides room for electronic components and six motors. A parking garage at the base allows for the addition of micro-ROV components. We designed the ROV to protect the electronic tube on the inside to reduce the risk of damage resulting to leaks. The ROV is also designed to be easily transported without problems. The addition of handles allows the ROV to be easily taken in and out of the water.

Tether

The tether consists of a ¼" air compressor hose (used to provide air to our variable buoyancy system), two CAT6 ethernet cables (for power delivery to cameras and lights as well as transmission of data to the Raspberry Pi 3b+), and the power cable from the MATE Pufferfish Kit (re-used from last year's ROV). Enclosing the tether is a 1" expandable plastic sleeve for additional tether buoyancy. Some pool noodle support provides additional flotation. The tether sleeve keeps all of the crucial communication and power lines to be neatly assembled in one seamless cable.

Buoyancy

Neutral buoyancy is a vital aspect of the ROV's stability as it allows the ROV to remain stationary and level once underwater. To maintain neutral buoyancy throughout, flotation material is evenly distributed within the frame. This was achieved with a small amount of architectural buoyant foam centered below the electronics tube as well as two 2" PVC tubes with end-caps, and ¼" PVC tube connected to a ½" air hose, where air can be pumped to create a variable buoyancy tank.



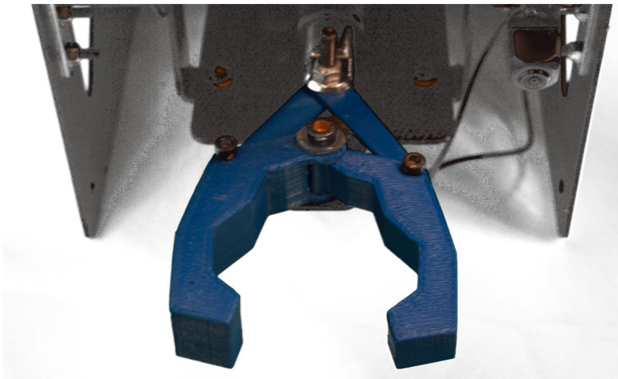
The housing for the electronics is naturally buoyant, being mostly filled with air. Because of this, the tube is centred in the frame to maintain a centre of buoyancy in the middle of the ROV. Weight distribution is also important when creating an ROV that is neutrally buoyant underwater. The motors, manipulator, cameras and lights are placed in identical positions on either side of the ROV to create a centre of mass that is near the centre of buoyancy of the ROV. To carry heavier payloads, a hook is mounted on the underside of the centre of mass to avoid tipping when moving objects.

Propulsion

The SS Enterprise uses four Blue Robotics T200 thrusters to move vertically in the water column. Another two T100 thrusters from Blue Robotics move the ROV horizontally. The combination of all motors allow the pilot to pitch, roll and yaw the ROV when completing complex tasks. These motors offer a great amount of thrust, yet were limited to avoid drawing too much power and ensure that our ROV meets the power and amperage guidelines set by MATE.

Claw

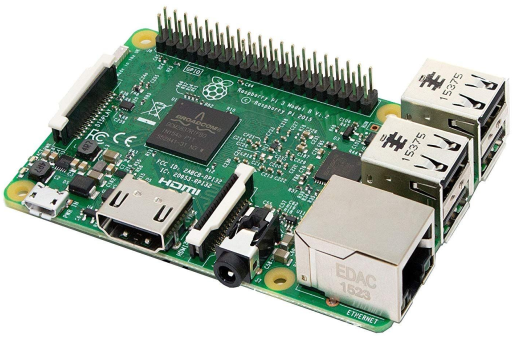
The manipulator is an essential part of an ROV's design. We needed to design a claw that would allow us to have a good grip on differently shaped and differently sized objects underwater. The manipulator also needed to be strong enough to lift certain objects underwater, and it had to close and open quickly enough to accomplish tasks in a set amount of time. Our newly-designed claw uses a waterproof linear actuator motor (seen to the left), controlled via Adafruit Motor Hat on our Raspberry Pi3b+. This motor provides up to 180 lbs of force. The 3D printed claw is located at the end of the actuator.



Cameras

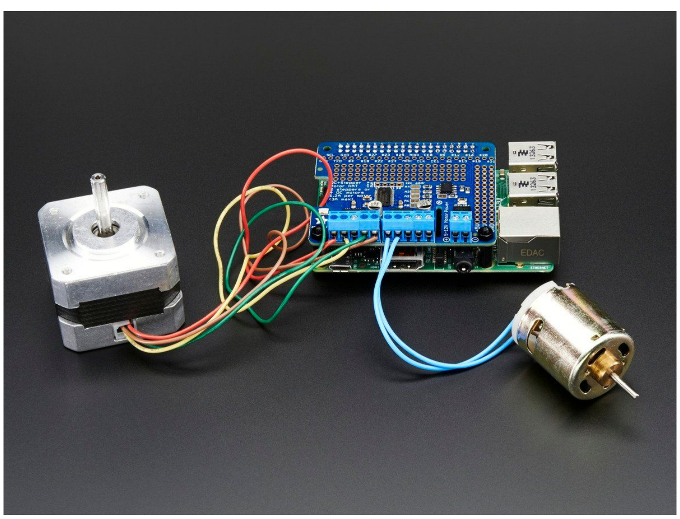
To accomplish tasks underwater, an operator on the surface must have good visibility of the ROV's surroundings. To achieve this, SS Enterprise has four wide-angle and low-light cameras positioned around its frame. Together, they provide a view of the main manipulator, underside hook and general surroundings of the ROV. Camera feeds are transmitted back to the surface via a CAT6 cable and then into a video split screen box(multiplexor). This allows the operator to view all camera feeds simultaneously. The advantage of using analog cameras and signal is there is little latency providing the operator real time video.

Digital System

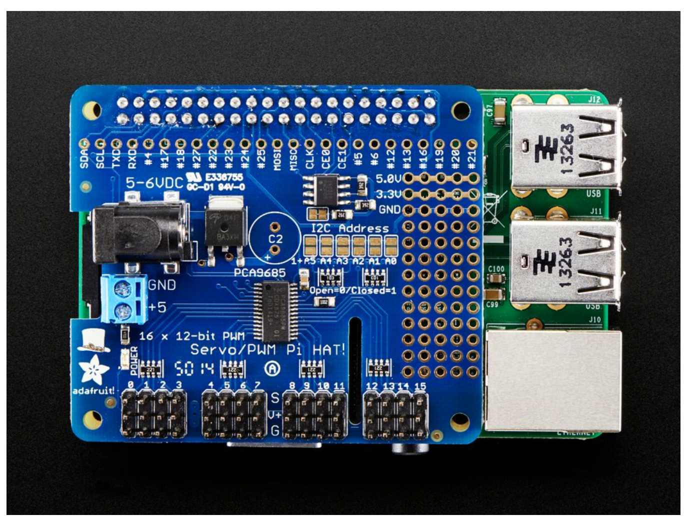


The digital system uses a laptop computer and a Raspberry Pi3b+ microcomputer to control the ROV. A linux- based OS on the laptop at the surface communicates with the Raspberry Pi 3 through the ethernet adapter. The Raspberry Pi has on it a PWM hat for controlling 6 Blue Robotics Thruster and lights while the additional Motor hat is used to control the motor for the Micro-ROV, a claw and a stepper motor which releases and retracts the winch.

A Microsoft XBOX 360 Controller is used to by the operator to control all systems on the ROV. The laptop computer decodes and concatenates the XBOX controller input to a single data packet to send via a CAT6 ethernet cable to the ROV. All scripting is done in Python for ease of use and readability. This digital control system allows for fast and seamless control of the ROV. If needed, the code on the Raspberry Pi can be easily edited through the ethernet connection if the ROV configuration changes through SSH. This allows the ability to change the code on the fly in case of a change of controls. This is mainly used for testing purposes, but can also be done once the ROV is deployed.

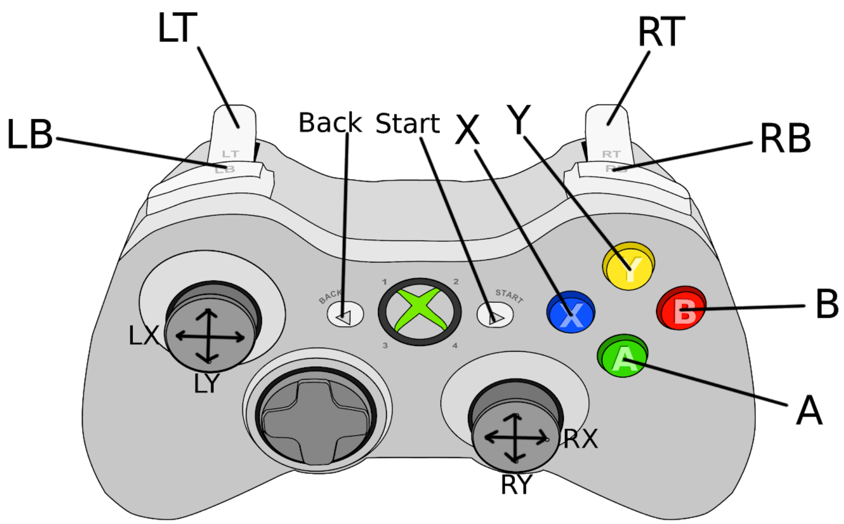


Adafruit Motor Control Hat



Adafruit PWM/Servo Hat

Control Scheme



LB - Open Claw & RB - Close Claw

LT - Backward Thrust & RT - Forward Thrust

LX left - Yaw Left & LX right - Yaw Right

LY up - Thrust Upwards & LY down - Thrust Downwards

RX left - Roll Left & RX right - Roll Right

RY up - Pitch Downwards & RY down - Pitch Upwards

A - Micro ROV Motor Backward & B - Micro ROV Motor Forward

X - Winch Roll Up & Y - Winch Roll Out

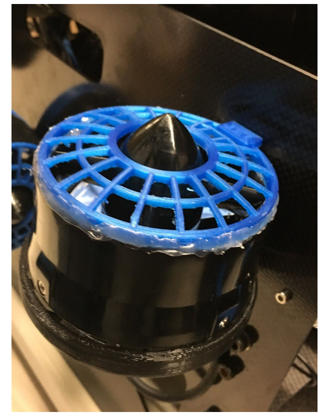
Press Back and Start - Shutdown ROV

Hold Back and Start - Shutdown ROV and Server

Safety

Shrouds

All thrusters must be shrouded to avoid any accidents while the ROV is in operation, or while it is being recovered after use. The T200s' and T100s' propellers are covered using 3D printed shrouds that are a modified design from Thingiverse.com, and are made to fit those motors specifically. These shrouds ensure foreign objects, such as fingers, are unable to reach the ROVs propellers during use.



Waterproofing

All electronics on the ROV are housed within a 4" acrylic tube purchased from Blue Robotics. This tube uses O-rings and silicon grease to create a waterproof seal between the acrylic and the aluminium end-caps at the front and rear of the ROV. Wires are fed through penetrators designed to work with the Blue Robotics end-caps. The connections going through these end-caps are waterproofed using marine epoxy to seal the tube.

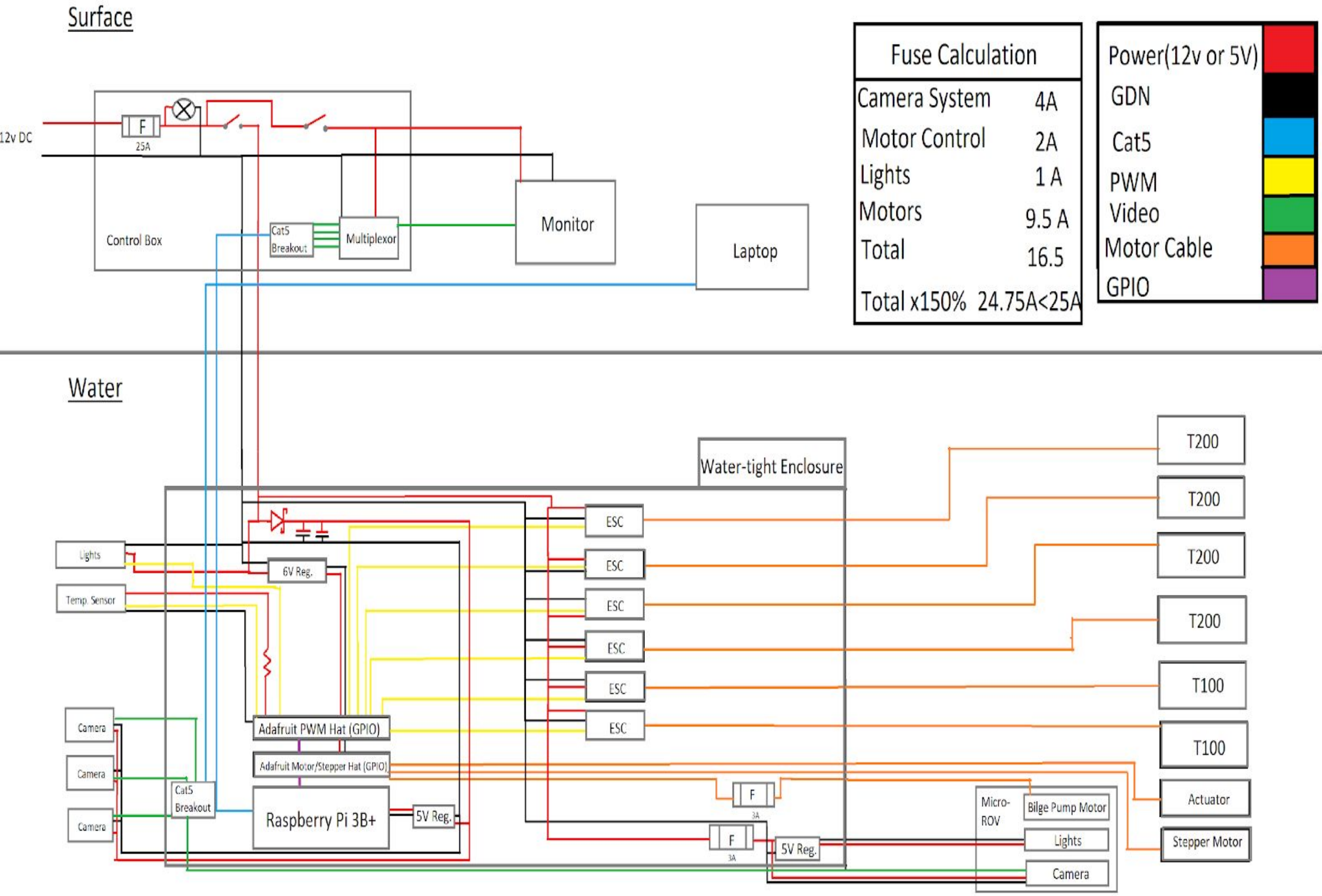
Fuses

Overcurrent protection is important in protecting against accidents caused by currents that exceed the acceptable range of our ROV. MATE guidelines require that our overcurrent protection is 150% of the current used by our ROV at full load. This is achieved by limiting thruster power.

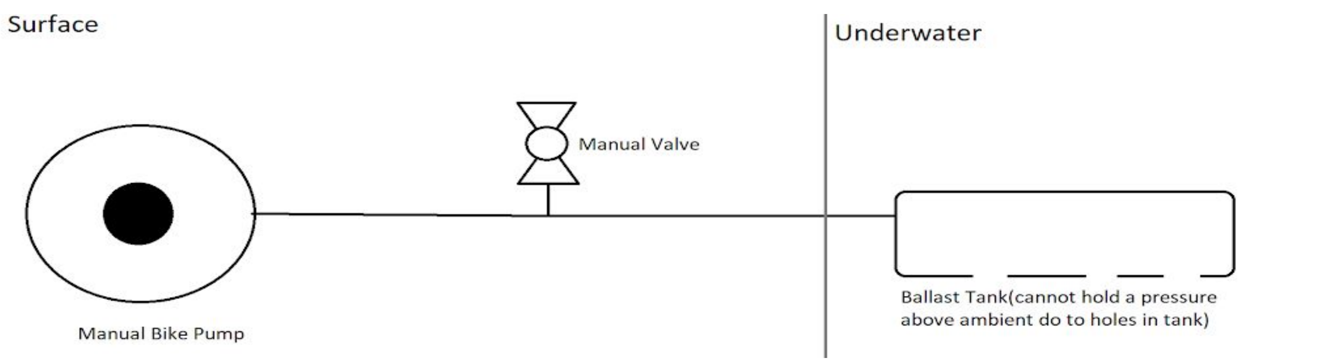
A 25 Amp fuse is placed in line between the power supply and the ROV. This is to prevent power surges from the surface reaching the underwater ROV.

The Micro-ROV has 2 fuses, each rated at 3 amps for a total of 6 amps. One inline with the motor and the other inline with the camera and lights.

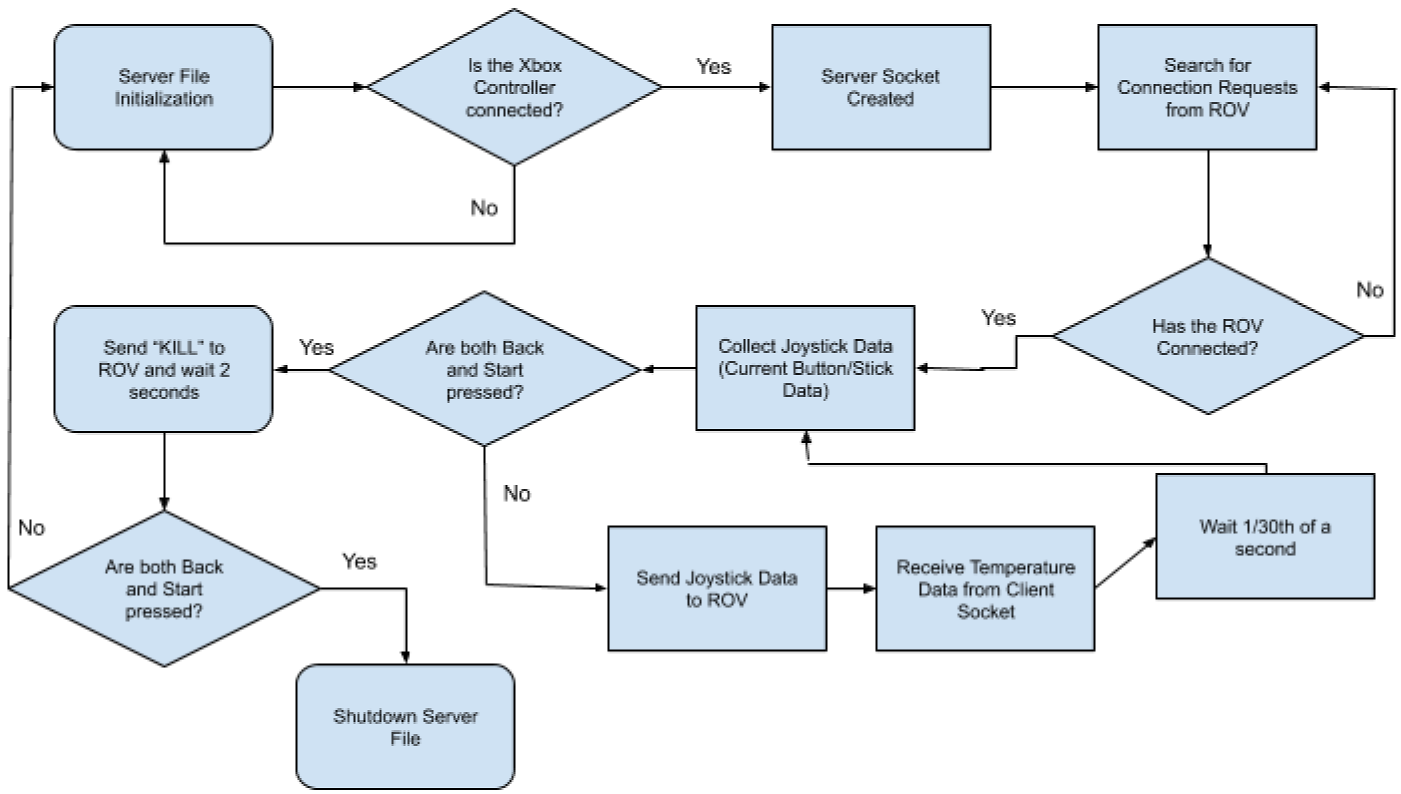
System Integration Diagram

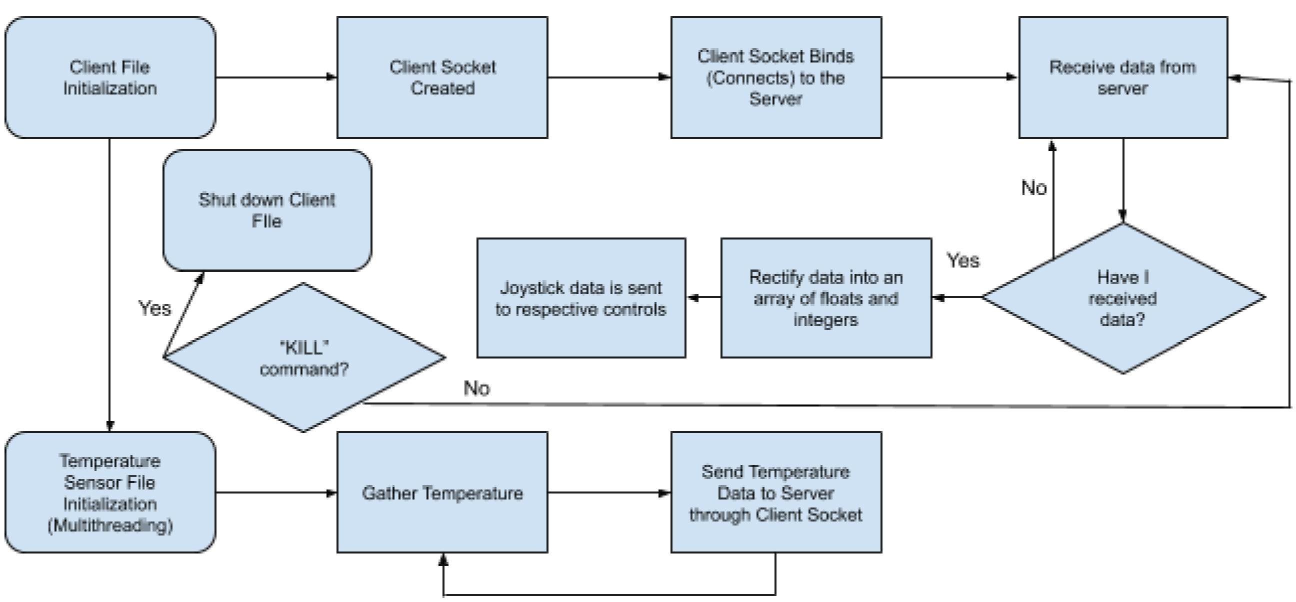


Fluid Power Diagram



Software Flowchart





Reflection and Conclusion

Challenges

This is, for most of the team, our third year building ROVs. This year, the team lost four veteran members to graduation while bringing on three new members. Consequently, when working on our ROV we were challenged in learning how to work together to tackle problems. It took us a little time at the beginning of the year to give the new members an appropriate orientation and to share some of the wisdom our senior members gained from their previous years of competing.

We knew we wanted to improve on our frame from last year. We thought it would be a great opportunity to continue our relationship with a company like STELIA North America Ltd, so that our members could get a better understanding of the manufacturing process in a large company. STELIA's engineers were enthusiastic about supporting our project but we ran into some scheduling complications. STELIA was very busy and it took longer than expected to schedule times that worked for both parties.

Waterproofing was an issue again this year. After adding epoxy, hot gluing and applying grease to all areas where leaks were possible, we still had trouble creating a water-tight seal. It took us many different approaches including the use of a hand-powered vacuum pump before we finally managed to find a small leak in our end-plate. Finally, we were able to keep water out of our acrylic electronics tube.

This year, the micro-ROV posed the greatest engineering obstacle. Many ideas were tossed around until a consensus was reached. Several prototypes were designed and tested before a model consisting of three wheels (minus the rubber), a bilge pump motor, and a stepper motor winch with pulley system were employed.

Lessons Learned

What we've learned this year is to budget our time more efficiently. This would include getting an earlier start to the planning process and being more thorough during the design phase so that there isn't a need for re-design further on.

Shipping times for parts can be a major setback when building an ROV in a place where local shops aren't a viable option. So, improved planning to create a list of necessary components earlier would be beneficial. Parts could be ordered sooner and simultaneously to ensure shipping times aren't a setback.

Future Improvements

This was our first time using a digital control system with a laptop at the surface. A lot of time was used setting up communication between the laptop at the surface and the Raspberry Pi 3 Model B+ and on how to better control the motors to have the ROV pitch, roll, and yaw with an XBox controller. We feel that, equipped with a better understanding of the coding side of ROV production, that we can improve on this system in controlling both motors, claw, and video feed in years to come.

Although it is a big technical and technological challenge, another possible future improvement is adding a degree of automation to the ROV. Rudimentary functions such as maintaining a pitch lock or roll lock or even having the ROV hold its position would ease a lot of the pressure off of the operator and also give more time to think and react to a situation. Such an improvement would require new sensors on board such as a gyroscope and an accelerometer.

Budget Overview

Description	Cost Per Unit - USD (if applicable)	Cost Per Unit - CAD	Quantity	Subtotal - CAD	HST	Total - CAD (with HST)
Paxcoo 62pcs PCB Board Kit	-	$19.99	1	$19.99	N	**$19.99**
28552 Marine Pump Cartridge for 500 GPH Motor	-	$29.77	1	$29.77	Y	**$34.24**
4" Enclosure Clamps	$39.00	$52.04	2	$104.08	N	**$104.08**
T100 Thrusters	$144.00	$192.14	2	$384.28	N	**$384.28**
4" Aluminum End-Cap w/ 18 Holes	$48.00	$64.05	1	$64.05	N	**$64.05**
10m Thruster Cable (3 conductors, 18 AWG)	$66.50	$88.73	1	$88.73	N	**$88.73**
M10 Cable Penetrators for 6mm Cable	$4.00	$5.34	16	$85.44	N	**$85.44**
M10 Cable Penetrators for 8mm Cable	$5.00	$6.67	4	$26.68	N	**$26.68**
Potting Kit (x10)	$10.00	$13.34	1	$13.34	N	**$13.34**
Basic Electronic Speed Controllers	$25.00	$33.36	4	$133.44	N	**$133.44**
Shipping	$31.12	$41.52	1	$41.52	N	**$41.52**
Duties/Taxes/Fees	-	$83.45	1	$83.45	N	**$83.45**
Waterproof Linear Actuator IP67M	-	$337.49	1	$337.49	Y	**$388.11**
Shipping/Handling/Duties/Taxes	-	$19.04	1	$19.04	Y	**$21.90**
Adafruit DC Stepper Motor HAT for Raspberry Pi - Mini Kit	$22.50	$30.02	1	$30.02	N	**$30.02**
GPIO Stacking Header for Pi A/B/Pi 2/Pi 3	$2.50	$3.34	1	$3.34	N	**$3.34**
Adafruit 16-Channel PWM / Servo HAT for Raspberry Pi - Mini Kit	$17.50	$23.35	1	$23.35	N	**$23.35**
Shipping/Handling/Duties/Taxes	$28.24	$37.68	1	$37.68	N	**$37.68**

Gikfun DS18820 Temp. Sensor	-	$14.46	1	$14.46	N	**$14.46**
Usongshine Stepper Motor	-	$14.99	1	$14.99	N	**$14.99**
Car Rover 1080p NighVis Cams	-	$40.99	2	$81.98	N	**$81.98**
Promotion for Amazon Order	-	-$1.30	1	-$1.30	N	**-$1.30**
4-pin Euro Style Terminal Blocks	$2.25	$3.13	10	$31.30	N	**$31.30**
Shipping and Handling	$32.47	$45.18	1	$45.18	N	**$45.18**
Brampton Marine Epoxy	-	$38.23	1	$38.23	N	**$38.23**
Shipping/Handling/Duties/Taxes	-	$39.00	1	$39.00	N	**$39.00**
ROV Carbon Fibre Frame (Estimation)	-	$683.90	1	$683.90	N	**$683.90**
Carbon Fibre Frame Processing (Estimation)	-	$325.00	1	$325.00	N	**$325.00**
Security Camera	-	$20.00	1	$20.00	Y	**$23.00**
Locking Nuts	-	$0.35	26	$9.10	Y	**$10.47**
Bolts	-	$0.25	26	$6.50	Y	**$7.48**
Raspberry Pi Touchscreen LCD	-	$126.90	1	$126.90	Y	**$145.94**
Raspberry Pi 3 Starter Kit	-	$119.95	1	$119.95	Y	**$137.94**
T200 Thrusters	$194.00	$250.26	4	$1,001.04	Y	**$1151.20**
Basic Electronic Speed Controllers	$25.00	$32.25	2	$64.50	Y	**$74.18**
Lumen Subsea Lights	$99.50	$128.36	2	$256.72	Y	**$295.23**
4" Acrylic Tube	$54.00	$69.66	1	$69.66	Y	**$80.11**
O-Ring Flange	$29.00	$37.41	2	$74.82	Y	**$86.04**
Adafruit 16 Channel PWM/Servo Shield	$39.39	$50.81	1	$50.81	Y	**$58.43**
Dome End-Cap	$59.00	$76.11	1	$76.11	Y	**$87.53**
BNC Male Connectors	-	$0.87	8	$6.96	Y	**$8.00**
ESKY Water Resistant Car Camera	-	$24.99	1	$24.99	Y	**$28.74**
4-Channel DVR	-	$186.99	1	$186.99	Y	**$215.04**
50' CAT6 Cable	-	$16.38	2	$32.76	Y	**$37.67**

Fathom-E Tether Interface	$19.00	$24.51	1	$24.51	Y	**$28.19**
4" Aluminum Tube Clamps	$19.50	$25.16	2	$50.32	Y	**$57.87**
Blank (No Hole) Cable Penetrators	$3.40	$4.39	6	$26.34	Y	**$30.29**
Marine Grease	-	$3.99	1	$3.99	Y	**$4.59**
1" Braided Sleeving for Tether	-	$18.00	2	$36.00	Y	**$41.40**
1/2" Braided Sleeving for Tether	-	$15.00	2	$30.00	Y	**$34.50**
Rough Amount of Nuts & Bolts	-	$0.05	115	$5.75	Y	**$6.61**
25A Smartglow Fuses	-	$9.52	2	$19.04	Y	**$21.90**
In-line Fuse Holder	-	$5.51	1	$5.51	Y	**$6.34**
U-Bolt for Strain Relief	-	$1.69	1	$1.69	Y	**$1.94**
Voltage Regulators	-	$17.88	2	$35.76	Y	**$41.12**
Heat Shrink Tubing	-	$0.03	10	$0.30	Y	**$0.35**
Anderson Powerpole Connectors	-	$2.30	4	$9.20	Y	**$10.58**
Solder	-	$13.95	1	$13.95	Y	**$16.04**
						$5605.07

Sponsors

We, at South Shore Robotics, would like to thank the following sponsors for helping us with materials, financing, and moral support. Without the help of our community, building an ROV as well as competing in this year's MATE competition, would not have been possible! Thank you!

Michelin Bridgewater Plant Employees

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