64° WEST ROBOTICS

Halifax Robotics

Halifax, Nova Scotia

Canada

2018 Technical Report

Liam Acres – Software Engineer; CEO – 1st year Computer Science

Matt Glencross – Mechanical Engineer; Pilot – 1st year Engineering

Daphne Finlay – Mechanical Engineer; CFO - 1st year Engineering

Francisca Annan – Safety Officer – 1st year Medical Science

Gabriel Iturriaga – Software Engineer - 1st year Computer Science

Logan Crooks – Electrical Engineer - 1st year Engineering

Colin Melia - Mentor

Abstract

Figure 1: Team photo; Top left to bottom right: Logan Crooks, Daphne Finlay, Francisca Annan, Matt Glencross, Liam Acres, Gabriel Iturriaga
Credit: JinHyuk Mo

64° West Robotics consists of 6 Nova Scotian students who are enthusiasts in the STEM fields. We have designed an ROV which can fulfill the Applied Physics Laboratory and the University of Washington's request for an ROV capable of aircraft detection and recovery, installation of earthquake detection equipment, and construction of tidal turbines.

We built Blue using the knowledge gained from our 3 years competing in the Ranger class. This being our first entry into the Explorer class we decided to upgrade from a 4" electronics tube to a 6" tube and shift our focus from modularity to reusability. At 64° West Robotics, we employ company-owned 3D printers to build custom-designed parts for Blue. Special focus from the mechanical and design divisions at 64° West resulted in our best looking ROV to date. The software team developed an acoustic communication method and image recognition software to efficiently complete the mission. We retained the key 6 degrees of freedom featured in previous years, allowing for exceptional maneuverability.

We at 64° West Robotics believe that Blue is the ROV which can complete the tasks provided by Seattle. It has proven itself repeatedly throughout months of development, testing, and refining.

Contents

1. Design Rational

1.1. Design Process

When designing Blue, we at 64° West Robotics, put special focus on reusability, size, and general utility of the ROV. To achieve these goals, we wanted to build an ROV which could compete for several years running without major redesigns. Our frame is designed with channels for the thrusters to sit while still having large flat surfaces on the top and bottom for mounting actuators, buoyancy, and any other necessary peripherals. Our frame has a handle complete with strain relief fit into the top of the ROV for easy handling. Our frame was originally modelled in CAD using SolidWorks shown in Fig.3. Our final design can be seen in Fig.2.

Our frame is fully printed in polylactic acid (PLA) using company-owned 3D printers. Our choice to use PLA was based on its low price, non-toxicity, and availability. By using PLA we could model, print, and test a new component in a few hours for a very low cost. Effectively, we could reprint the entire frame in a matter of days for about $100 (CAD). This allowed us to develop multiple prototypes of our frame, including one major redesign which changed the diameter of our propeller channels from 70mm to 80mm to accommodate the original size of the propellers. This resolved many of the movement issues that were plaguing Blue.
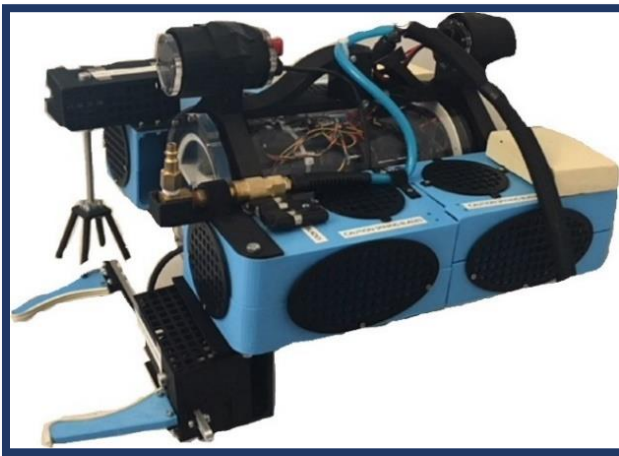
Figure 2: Blue completed   Credit: Liam Acres

Figure 3: A 3D render of Blue's frame 1   Credit: Matt Glencross

1.2. Systems Interconnected Diagrams

This section will show the system interconnected diagrams for the electrical, pneumatic, and network systems on the ROV; and the external lift bag and OBS systems interconnected diagrams.

Part	# of parts	Amps Used	total amps
Motor	10	12.5	125
Rasp Pi 3	1	0.25	0.25
Camera	4	0.6	2.4
Encoder	4	0.42	1.68
Laser	1	0	0
Ethernet Switch	2	0.25	0.5
Tenda	1	0	0
		Total Uncontrolled	129.83
		Uncontrolled x1.5	194.745

With software limited motor (actual) speeds

Part	# of parts	Amps Used	total amps
Motor	10	1.52	15.2
Rasp Pi 3	1	0.25	0.25
Camera	4	0.6	2.4
Encoder	4	0.42	1.68
Laser	1	0	0
Ethernet Switch	2	0.25	0.5
Tenda	1	0	0
		Total Controlled	20.03
		Controlled x1.5	30.045

We use a 30A fuse due to our maximum overall current draw of 30.0 A

Figure 4: The ROV electronics systems interconnected Diagram   *Credit: Logan Crooks*
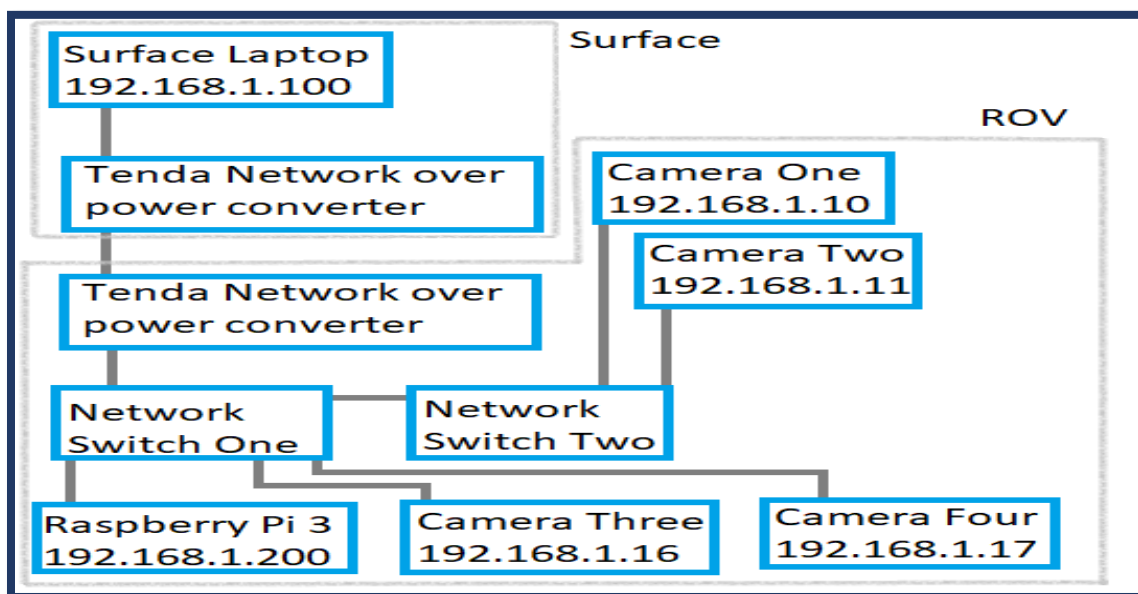
Figure 5: The Network System Interconnected Diagram   *Credit: Logan Crooks*

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Pneumatic Diagram
All components are rated to
300 PSI or greater

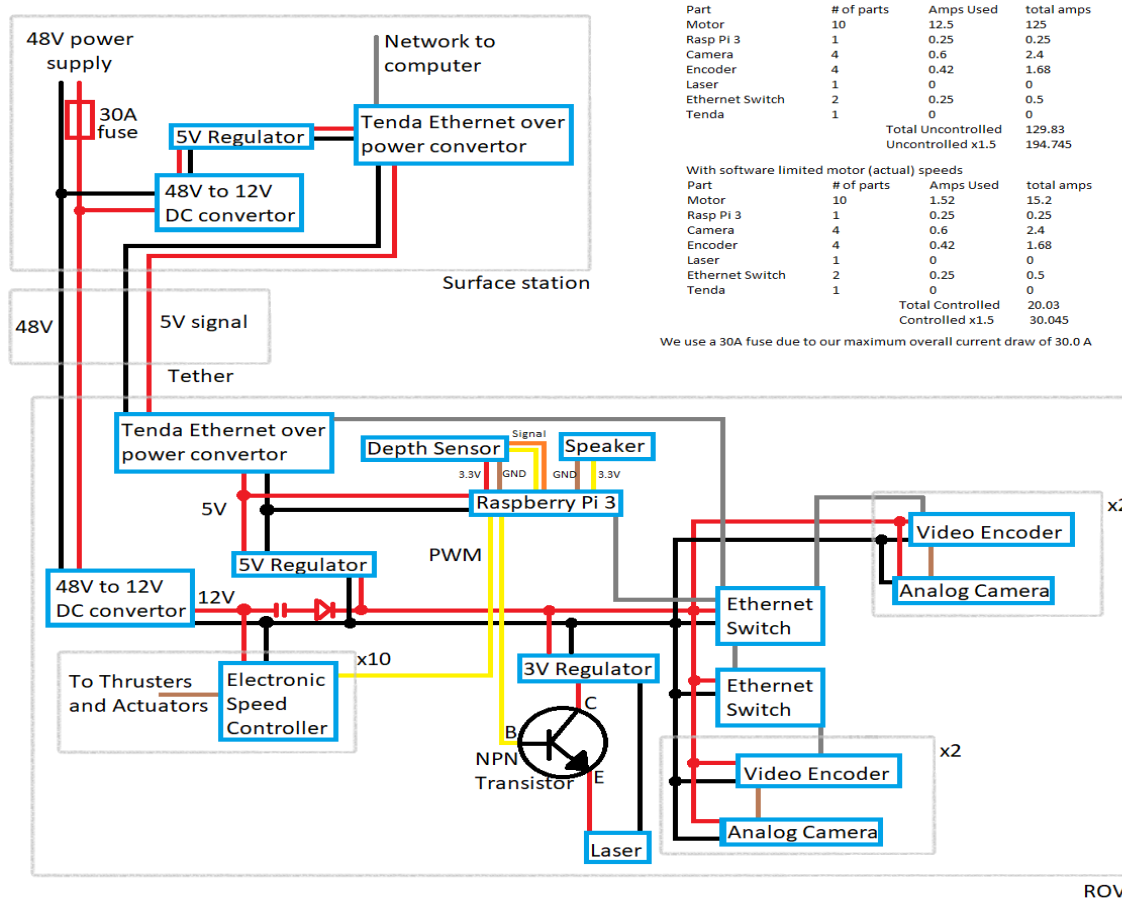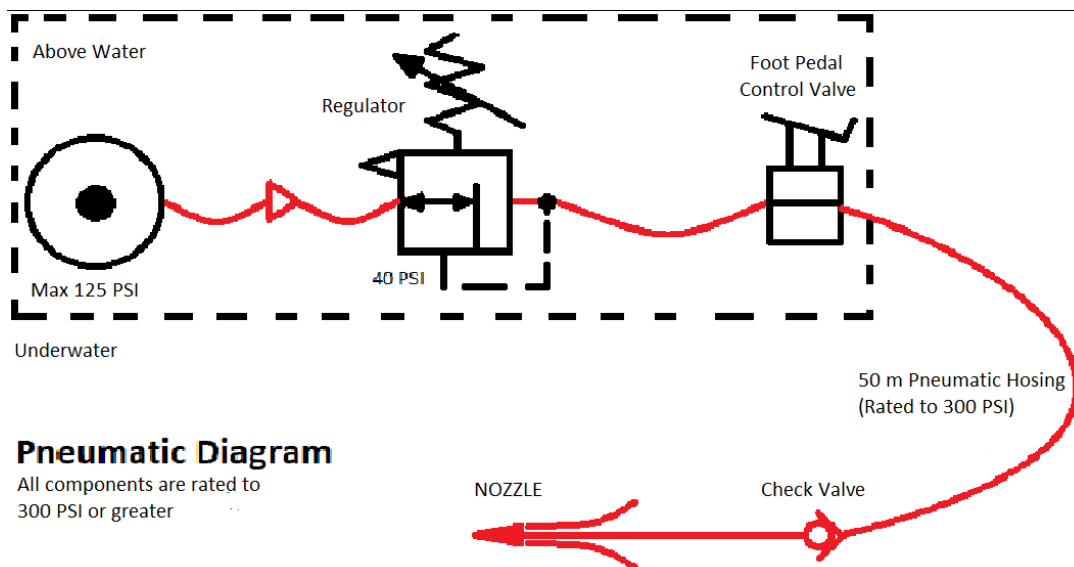*Figure 6: The Pneumatic Systems Interconnected Diagram*   *Credit: Matt Glencross*
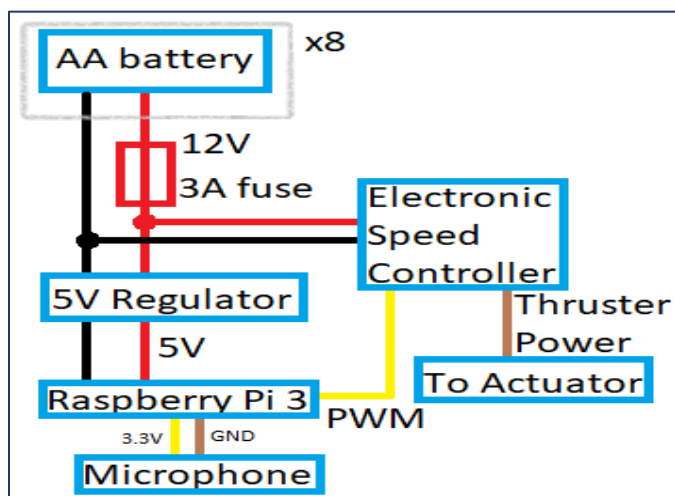
Figure 7: Lift Bag Systems Interconnected Diagram   Credit: Logan
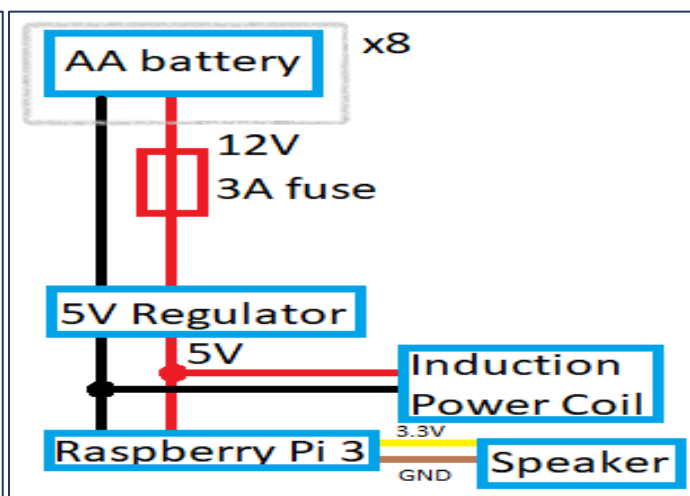
Figure 8: The OBS Systems Interconnected Diagram   Credit: Logan

1.3. Mechanical Design

1.3.1. Frame

Blue's frame was constructed around a 6-inch Blue Robotics tube with the intent to manage wires, house the thrusters within the frame, and have large, flat surfaces for mounting. As shown in Fig.9, our frame meets all our design specifications. There are tracks within the frame for thruster, actuator, and camera wires to run. We have channels 80mm in diameter to fit our modified thrusters, and the top and bottom have space for mounting. There is also a handle with strain relief built into the ROV to allow for easy handling.

Our frame was modelled in-house using SolidWorks and printed using company owned 3D printers with PLA filament. PLA was chosen due to its low cost, biodegradability, and non-toxicity. This provided major benefits when prototyping as we could design and test a part within a couple of hours. This also allowed for fast and cheap repairs in case of damage.

There are two external tubes featured in Blue's frame—one in the top front and one in the top back. The top front tube is used to hold the main driving camera as it provides the best possible frontal view in terms of positioning and maximum field of view. In the rear, there is a buffer tube between the tether and the main ROV core. This buffer tube allows for the tether to be disconnected and either replaced with a shorter tether for testing or total tether separation for easy transportation.
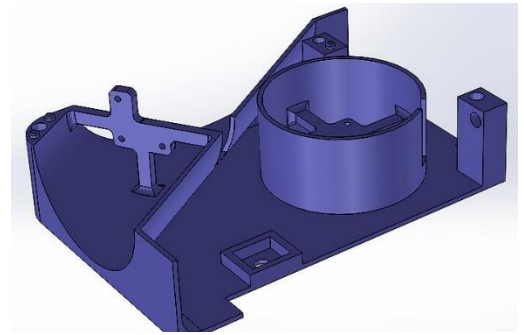

Figure 9: A model of a Bottom corner part of the ROV
Credit: Matt Glencross

1.3.2. Propulsion

We opted for an 8-thruster design on Blue, four vertical and four horizontal. The four horizontal thrusters are offset 33° from the centre axis and allow Blue to surge, sway, and yaw, while the four vertical thrusters allow for pitch, roll, and heave. Through this 8-thruster design Blue achieves all six degrees of freedom.

We use Blue Robotics T-100 thrusters on our ROV. These thrusters are capable of outputting about 5lb of force when drawing 11.5A of current. We bought and subsequently modified these thrusters by removing the stock thruster guards and motor housing. These stripped-down versions were inserted into their designated places within the frame. The decision to use the T-100 thrusters but include these modifications for a more compact design was based on previous years' experience and the excessively large design of the stock thrusters.

Our original design used custom edited, scaled-down propellers with a diameter of 64 mm allowing our frame to be smaller and our entire ROV to be lighter. However, during testing we found that the propellers were so small that they provided very low thrust and caused power surges resulting in a total shutdown of Blue. The thrusters were then retrofit with their original Blue Robotics propellers which fixed all the problems previously stated.

The thrusters powering Blue were all reused from previous years to lower the cost. The old thrusters still worked at optimal or near optimal capacity meaning that a total or even partial replacement was not necessary.

1.3.3. Actuator Design

Blue has two actuators that can be used to interact with the environment in a variety of ways. Our main articulator (Fig.10), which sits horizontally at the front of Blue, has interchangeable fingers which can be adapted to accurately suit the task at hand. The main articulator can grasp objects up to 200mm in diameter and grip with about 120 Newtons of force. In addition, our set of signature Flex Claws are able to conform around most objects in its grasp.

Figure 10: Blue's main actuator intended for grabbing and lifting
Credit: Liam Acres

The main articulator is constructed from a PLA gearbox and claws. Housed within the gearbox is a modified Blue Robotics T-100 thruster with a M-100 magnet array

attached. The modified thruster opens and closes the claw using worm gears with a 50:1 ratio which reduces the thruster RPM from 4200rpm to 84rpm. The worm gear then moves a sliding rail inward or outward, opening and closing the claw. The claw can close from its maximum open position in just over one second.

Blue also has a spinning actuator located at its front right corner which allows us to spin objects. This actuator is discussed at length in section *2.2.1*.

The motors used for the actuators were bought new because previous years we only had 8 total motors (thrusters and actuators) meaning that when all previous motors were used as thrusters we needed new thrusters. Another benefit of new thrusters for the actuators was a longer possible wire allowing for variance in where the actuators were placed.

1.4. Software Design

1.4.1 Overall

Much of our code base is reused from last year. The core functionality of the code has been kept due solid performance. However, it was necessary to adapt the code from a six-thruster configuration to an eight-thruster configuration. One significant challenge was altering the software to account for the placement of the front and rear thrusters at a 33-degree angle, as well as the incorporation of four vertical thrusters. This change greatly affected the stabilization code but was worthwhile due to the ability to make precise pitch stability adjustments using the four vertical thrusters. Reusing a previous code base meant that most of our time could be spent working on solutions specific to this year's competition. Such focus points included the creation our image recognition software, OBS device, and acoustic release mechanism for the lift bag.

1.4.1. Surface-Side

We have a laptop surface-side running our C# application. Every 10 milliseconds (ms), the software checks the XBOX controller and uses the state, along with the latest sensor data from the robot, to send output values to the robot at 1 byte per channel. The robot converts these to pulse width modulation values for electronic speed controllers (ESCs), motors (used to open/close and turn articulators) and thrusters, and to on or off values for the laser. The robot reads the sensors values and continuously sends those back to the application. There are two threads: one to read the motion sensor and another for the depth sensor. They both put values into memory and signal another thread, which picks up the values and sends them back to the laptop. See Appendix D for the PC App flow diagram and the Robot app flow diagrams.

1.4.2. ROV-Side

Like last year, we used a Raspberry Pi 3 microcomputer to host software from within our ROV. Our C# app is downloaded onto a Raspberry Pi 3 running Windows 10 IoT core. This makes it easy to remotely deploy, run and debug the application from Visual Studio over the network cable. A 16-channel PVM 'hat' is used on the PI, allowing us to control all our motors and thrusters.

1.5. Electrical Design

Blue's electronics were designed to allow easy replacement and troubleshooting for problem parts identified in previous years, as well as improved heat dissipation.

The biggest problem part we found in previous years was the electronic speed controllers overheating and heating the connectors between the ESCs and the thruster wires. To prevent that this year, the ESCs were screwed into terminal blocks at both ends, then the thrusters and power were also connected through these terminal blocks. This simple change fixed the common issue of ESCs breaking during our previous experiences in the Ranger class and made servicing the ESCs, and thruster connections, easier due to lessened clutter. We also moved the Raspberry Pi 3 to a more open location to allow quick trouble shooting should any problems arise and allowing a quick replacement should the Pi fail like in previous years.

The core's new open design (shown in Fig.11 and Fig.12) allows for improved heat dissipation which caused major problems in previous years, such as condensation forming in the electronics core and the ESCs disconnecting due to the plastic bullet connectors deforming. In previous years we stacked the ESCs vertically with minimal room. However, this year the ESCs are spread out beside each other over a larger area. Also, we are no longer using the ESCs to power the Raspberry Pi 3 using the built in back power feature which greatly lowered the heat generation.
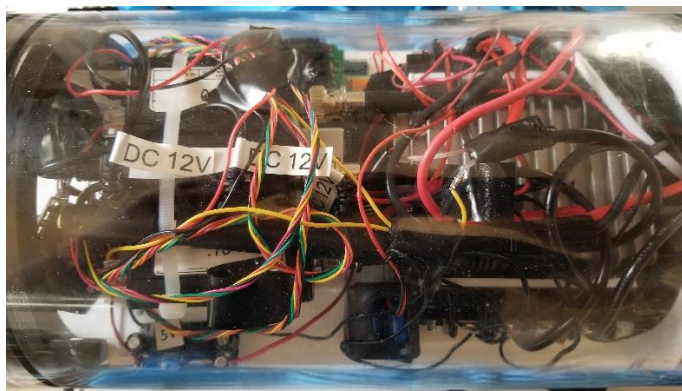
Figure 11: A view of the top of the electronics core   Credit: Liam Acres   *Figure 12: The bottom of the core   Credit: Liam Acres*
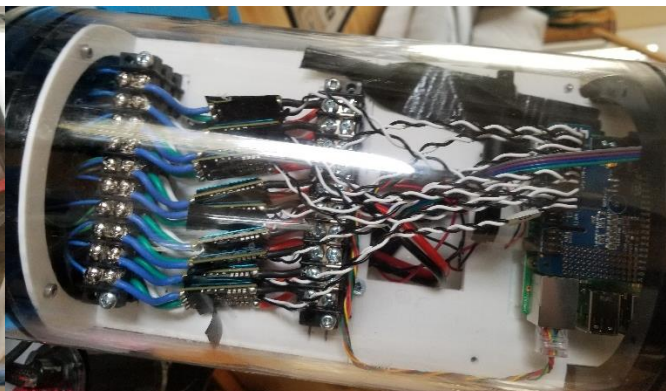
1.5.1. Cameras

Blue has 4 onboard analog cameras connected to low latency digital encoders. Three of the cameras are looking forward with two cameras placed specifically to view the actuators and one placed in the top centre of the robot which serves as the main piloting camera. The fourth camera is placed looking through the bottom of the ROV.

The analog to digital encoder setup allows for a latency of about 240ms which is lower than the 280ms latency our purely digital cameras provided in previous years. This is done by streaming in MJPEG quality and both increasing the band while decreasing the video quality. While pure analog video feed would be faster, it would also require an extra ethernet cable to be added to the tether which compromises our goal of a lower weight. We are also able to imbed the digital video feed into our control software and remove the need for extra monitors or equipment which would be required should we use pure analog video.

The decision to buy new digital encoders and analog cameras this year rather than using the combined digital cameras from previous years was caused by the large stream delay caused by the old cameras. After some research, we found that our current setup would allow a lowered delay while maintaining the same video quality.

1.5.2. Network

Blue's Raspberry Pi 3 and surface operating station communicate via a network established by modifying two Tenda home plug AV connectors and placing one on the surface and one in the ROV. These are connected via two 24 AWG zip-cord carrying a 5V signal. The benefit of using two converted home plug AV connectors rather than an Ethernet cable is the weight and size reduction within the tether and a lowered cost of production.

Onboard our ROV there are 2 Ethoslite network switches which serve to connect the video encoders and Raspberry Pi 3 to the network and thus to the surface. The Ethoslite is an incredibly small (45mm x 45mm) network switch which allows the connection of up to five different ethernet to Pico Blade connections.

We reused both the Ethoslite network switches and Tenda home plug AV convertors from last year because both worked reliably. Re-purchasing an Ethoslite would cost the company about $250 which is an unnecessary expenditure when the original part works fine. Both Tendas worked well, and we had spares from last year which we could be used for replacement should one fail.

1.5.3. Power Distribution

The 48V 30A DC surface power supply first splits with some power being stepped down to 12V DC and then 5V DC to power the home plug AV network over power surface transmitter. The 48V sent to the ROV is immediately stepped down to 12V 30A DC by a transformer rated to operate under 30A. The electricity is then distributed to two terminal blocks which supply power to the onboard systems. This power is further regulated by two voltage regulators from 12V DC to 5V DC and 3V DC respectively.

The 5V DC supplies power to the Raspberry Pi 3 and our home plug AV network over power convertor. The 3V DC supplies power to our transistor and laser, allowing for range finding underwater. There are separate terminal blocks supplied with 12V DC power specifically for powering the ESCs controlling Blue's eight thrusters and two actuators.

Blue was fitted with all-new ESCs and voltage regulators this year. The Blue Robotics ESCs were upgraded this year allowing for more efficient heat dissipation, which as a major problem in previous years. The voltage regulators were re-purchased, due to previous years' regulators suffering some water damage. The 48V-12V DC convertor was purchased new due to this being the first year it was required.

1.5.4. Tether

Blue's tether was designed to be as light-weight and compact as possible. To do this we used two 12AWG cables which carry the 48V DC between the surface and the ROV. There are also two 24AWG 5V signal cables which establish the network connection between the surface and ROV. Finally, there is the newly added pneumatic tube which is used to inflate the lift bag. The whole tether is contained within a half-inch mesh tube. The mesh tube provides protection from penetration or tearing damage and helps with transportation and storage of the ROV.

Blue had an all-new tether built this year as the tether used in the previous year belonged to the Halifax Robotics Ranger class team, and they intended to use the tether this year.

2. Task Specific Additions

Blue's payload was upgraded this year with actuators and a pneumatic airline. Every addition was first modelled in CAD, then a prototype was 3D printed and tested with mission-specific scenarios before being finalized and added to Blue.

2.1. Aircraft Recovery

The aircraft recovery task involves lifting and moving debris and an engine from the ocean floor. To do this we custom designed a lift bag and pneumatic airline attachment. As well, our software had to be upgraded to have image recognition.

2.1.1. Lift Bag

We custom designed a lift bag from scratch, using both sketches (Fig. 13) and CAD software. We then 3D printed and lined the inside of the lift bag with epoxy, ensuring it holds air properly when in use. Our lift bag has a volume of 7000cm^3 and can lift the 45N engine block; it can produce 68N of lift when full of air. To ensure reusability we allow some air to slowly leak from the lift bag. This serves to assist in lowering the debris to the floor and allows the bag to be detached and reattached rather than needing multiple lift bags.

The onboard control tube contains 8 AA batteries supplying 12V regulated through a 3A fuse. This powers an ESC which controls the release mechanism. The 12V power is regulated to 5V which powers a Raspberry Pi 3. The Raspberry Pi controls the release motor and uses the microphone to listen for tones which tell the lift bag to release. See Appendix F for the lift bag flow diagram.
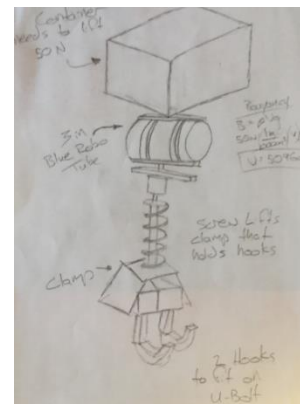
Figure 13: A hand drawing of the lift bag capable of supporting 45N Credit: Matt Glencross

2.1.2. Image Recognition Software

In the competition manual it is stated that our software must be able to identify the aircraft's ID without user input. Upon identification, the software must output an identifying coloured symbol or coloured letter to the screen, indicating to both the pilot(s) and judge(s) which aircraft has been found at the crash site.

The algorithm receives an input of pixel data in the form of a byte array. It will also receive the height, width, and format of the data, either RGB or ARGB. The algorithm goes through the pixel data looking for a colour, filtering out colours with low and high R, G, and B values. Upon the finding a colour that passes through the filters, the algorithm stores the RGB values and its x coordinate within the data set. While searching for colours, the algorithm also searches for the colour white, high R, G and B value, and stores the x coordinate. After going through all the data, the RGB and x-position values are all averaged. The average RGB values will determine the colour on the tail section, either red, blue or yellow. To determine the shape, the average x-position of the colour is compared to the average x-position of the white pixels. The average position of the white pixels will very close to the middle of the tail section. Therefore, if the average x-position of the colour is within a certain range of the average white position, then the shape is a rectangle, as the colour is centred relative the white pixels. Otherwise, the shape is

a triangle. The output of the algorithm will be the colour found, either red, blue or yellow, and the shape determined by the comparison. If no conclusion can be reached, then the algorithm will output question marks to indicate this result.

2.2. Earthquake Detection

We were tasked with setting up, powering, and levelling an ocean bottom seismometer to monitor for earthquakes and other similar events. Once that is accomplished, we must collect the seismograph data over wi-fi and auto-generate a graph of these points.

2.2.1. Spinning Actuator

We custom designed a spinning actuator specifically to spin the legs on the OBS allowing us to level the platform. The spinner is designed with a four-pronged inverted pyramid (Fig.14). This design allows the pilot to easily line up with the OBS leg and lock the robot into place while the spinner is operational. Our original design for the spinner was smaller in length, width, and height relative to the final spinner design which has a height of 65mm.

Our spinning actuator is built from a combination of a Blue Robotics T-100 thruster core and an M-100 magnet array. There is a worm gear used on the modified thruster which steps down the thruster's maximum RPM from 4200 to 84 using a gear ratio of 50:1.

Figure 14: the spinner claw
Credit: Matt Glencross

2.2.2. Power Connector

We designed an inductive power coupling module to power the OBS and establish a connection between the OBS and the ROV. The module is built from 8 AA batteries supplying 12V DC regulated through a 3A fuse. This power is then distributed to the inductive coil and the Raspberry Pi 3. The Raspberry Pi supplies signal and power to the onboard speaker. The induction coil can supply the required 5V 1A energy to allow the OBS to send the wi-fi signal.

2.2.3. Wi-fi Connection

There is a Raspberry Pi 3 and speaker combination onboard the OBS power transmitter module. The Raspberry Pi connects to the OBS via wi-fi, at which point the OBS data is converted into Bytes, then Bits, then Tones, and these tones are sent via the speaker to the ROV. The ROV then does the reverse process and send the OBS data to the surface where the graph is plotted. See Appendix E for the OBS Power Coupler flow diagram.

2.3. Energy

The energy supply task requires the placement of a turbine in a specific location extrapolated from a tidal map. We are then required to install an acoustic doppler velocimeter (ADV) a specified distance from the base of the turbine and complete the installation of an intelligent adaptable monitoring package (I-AMP). To accomplish this task, we use our main claw and an in-house designed laser range finder.

The turbine base, turbines, and I-AMP will all be installed using the main claw both to transport the objects and to lock the turbine and I-AMP into place.

2.3.1. Laser Measurement

We designed a laser measurement device in-house which can be used to find the distance between the ROV and any given location. To accomplish this task, we placed a camera and the laser as far apart (vertically) as possible. We then configured our software to find the location of the green dot produced by the laser and the number of pixels from the centre of the screen. Next, we found the number of pixels at several known distances and plotted this as a linear regression. This linear approximation is now included in our software and works at the touch of a button by the pilot.

2.3.2. Mooring and ADV Installation

Installing the ADV mooring will be done using Blue's main claw and the laser rangefinder. Once the pilot transports the mooring to the bottom of the pool, the correct distance can be found, and the mooring can be properly positioned. At this point the ADV will be installed on the U-bolt using the main actuator.

3. Safety

As has always been our practice, 64° West Robotics made safety a number one priority when designing, testing, and deploying Blue. We made sure to thoroughly consider the safety of the persons operating the ROV, as well as to implement features protecting the vehicle itself from malfunction or other damage.

3.1. Safety Protocol

When operating hand tools or power tools, all team members were required to wear to safety glasses, always. Similarly, members were required people to wear both safety glasses, protective gloves and masks while working with irritants and substances that may produce potentially hazardous fumes. Such materials include epoxy, solder, and superglue. With these policies in place, 64° West Robotics operated for the entire year without any injuries.

When using the air compressor, we followed the MATE specified guidelines and enforced eye protection to ensure the safest possible workplace. Our compressor was always set at or below 40PSI and was always checked, and re-regulated if needed, before ROV operation. Our power supply was always checked to ensure the proper setting before use and if the maximum setting deviated from the MATE specified 48V 30A DC, this was corrected before vehicle operation. A 30A fuse was installed to verify Blue never drew too much current, causing damage to itself, the environment, or putting its operators at risk of injury. In addition, the main power was disconnected before work was done on the electronics core of the ROV to prevent electric shock.

In addition to the measures taken while constructing and testing the ROV, team members developed and followed a series of safety protocols, which are enforced by the safety officer, for when Blue is being operated. A checklist of protocols can be found in Appendix C.

3.2. Safety Features

Blue has many integrated safety features to protect the operator(s) while in use. There is a handle as seen in Fig.2 to allow for easy transportation of the ROV and to ensure a strong and stable handhold. All sharp edges of the vehicle have been rounded off. Custom designed grates are placed over every thruster channel (Fig.15) and gearbox.
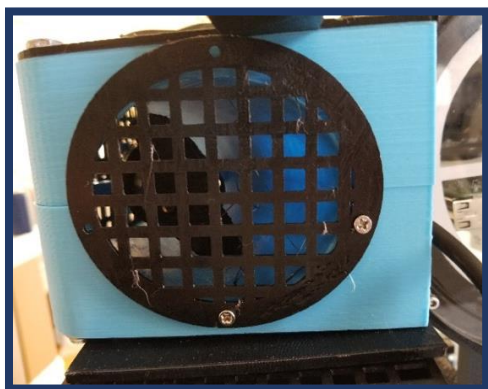
Figure 15: A Thruster Guarding Grate   Credit: Liam Acres   Figure 16: Warning Label   Credit: Liam Acres

These grates prevent any appendages from being caught in or damaged by the thrusters during operation of Blue. Coupled with the guards, there are visible warning labels placed around every blade shown in (Fig.16). As well, there is a 30A fuse placed in line to prevent any current overloads protecting the operator in case of electrical failure.

Blue also has several safety features designed specifically to keep it from incurring damage during operation. One such feature is the strain relief shown in Fig.17 located in the handle to prevent strain being placed on the power wires entering the tube. There is an inline 30A fuse within 30cm of the power supply preventing the ROV using too many amps at once and damaging any electronic components. The thrusters are protected by the thruster guards stated in the previous section. Finally, all wires are routed within the frame preventing them from being caught on anything during operation and allowing Blue to move without fears of getting tied up in any props. These features effectively minimize the risk of damage to Blue.
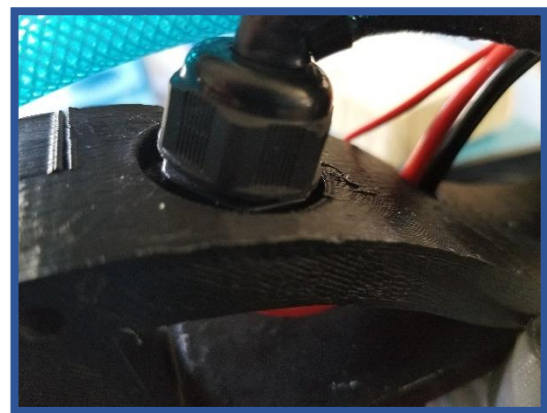
Figure 17: The strain relief preventing tether damage
Credit: Liam Acres

4. Accounting

At the beginning of this year, our team wanted to make sure we had a well-revised budget to base our expenses around. We first went to last year's ROV to see what we could re-use to make sure we did not have to re- buy certain parts. This year we wanted to focus a large portion of our budget on electronics to update the main core and create functional Non-ROV devices. We also wanted to make sure that we invested funds into high-quality PLA so that we would could fabricate a robust, PLA intensive frame.

We made the budget and found that we did not have to fundraise as much money as we originally thought, as seen in Appendix A. Throughout the year we made sure that all purchases were communicated with the team and group decisions were made on each purchase. Measures and discussions were made to make sure that proper funds were given to the areas that required the most attention. For the international trip, it will be necessary to request additional member fees to pay for the flights. We will be approaching sponsors to see whether we can decrease the additional member fees.

Last year, we had a very long, detailed budget which took up 4 pages of the Tech Report. Our new simplified, refined, and effective Project Costing report can be seen in Appendix B.

5. Project Management

5.1. Roles of the Company

Last year we had a team of 16 members which made it easy to assign specific roles. This year we had 5 returning members from the previous Ranger team and one new member. Having a smaller team challenged all members to take on a larger amount of work in a variety of areas. The areas that needed to be covered to create a functional ROV broke down into 5 main departments.

The 3D CAD designer had to specialize in 3D printing the frame and organizing how everything was going to fit together. Our mechanical engineer was responsible for creating our tools and gear boxes, while our electrical engineer would handle cameras, servos, and the internal components. The software engineers programmed and updated the control system for our ROV. And finally, our administrative team organized and planned tasks, managed the budget, and created technical documentation.

Being a small team meant there was often one person responsible for a major component of the ROV. This could have been problematic, but we communicated big ideas and problems with the whole team or select individuals so that members didn't feel alone when making decisions.

5.2. Phases of Design

We developed our ROV in two distinct phases. The first stage was a research phase starting in November and lasting about 2 months during which we proposed and tested our ideas. The second phase was completing a design that would be more refined to make as safe as possible.

Our research phase involved making 3D printed prototypes of various components and testing them on objects as well as props made to simulate the competition. For example, our multipurpose claw designs were printed and hand-operated to find the best design. The chambers for the thrusters were not working with our newly designed propellers, so we ended up changing them back to the Blue Robotics propellers with bigger thruster chambers.

The task phase used team meetings and recordings to make lists of tasks left to do and improve upon. This began once we decided on final overall design. Final designs were then fine-tuned to be safe and finalized.

5.3. Group Meetings

Last year, we used an Agile Scrum system to help us with managing tasks. However, for our particular team and style of work, we found that it was difficult follow and adopted a different meeting structure this year. We wanted to have detailed meetings at the beginning of every session to establish a work plan and at the end to debrief what had been accomplished. This system also created a safe space for the sharing of ideas and concerns. These team meetings were documented, in order to keep track of the magnitude of ideas and stay organized. It was important to all members, especially the CEO, that such meetings took place consistently throughout the year and didn't taper off as deadlines approached. In this way, the team was able to work collaboratively to solve problems and each member had a good idea of what they needed to get done for every work session. As always, constant effective communication between all members was one of our biggest priorities.

6. Challenges Faced and Lessons Learned

6.1. Technical Challenges

This year we faced several challenges. One major issue was with the buoyancy for our 3D printed frame. Blue's frame is almost entirely 3D printed in PLA which is a major factor on the buoyancy. When the ROV was first prototyped, only 20% fill density was used in the prints to reduce time, cost, and environmental impact. However, this allowed for a lot of empty space between the layers of the 3D print. When the ROV was placed in the water, some of these gaps would fill with water while others remained full of air. Over time the empty gaps would fill with water and dramatically change the buoyancy. To fix this problem we experimented with different fill densities to find a frame that does not experience buoyancy changes but is still cost effective. After several different iterations we decided that a frame printed with an 80% fill density suited our needs, solved the buoyancy problem, and was still cost efficient.

6.2. Team Challenges

Last year our team consisted of 16 students, all from the same high school. Each member was given a specific task and was able to focus solely on that one component of the project. This year our team consists of only 6 members, all in their first year of university. With a much smaller team, we initially had a difficult time adjusting to the new workload. This challenge pushed the team to develop more efficient time management skills in order to keep up with the scheduled production time. To do this we would meet as an entire team at the beginning of each meeting, set a series of goals that needed to be accomplished, and allocate the responsibilities amongst the team. We quickly learned the importance of team efficiency and organization as we became accustomed to the new team size. We now see it to be beneficial in some ways to have a smaller team. Our communication has become much stronger and each member has a better understanding of the project as a whole.

7. Testing and Troubleshooting

7.1. Testing methods

We put each of our components through multiple tests to ensure they perform safely and efficiently when placed under various stresses. Once the team is confident with the performance of each part, it is integrated into the overall design and tested once again. After Blue was entirely put together we were able to conduct minor tests in a large water tank, 2m long by 1m wide by 1.5m deep, at our facility. This tank also accommodated all buoyancy testing for both the ROV and tether. On top of this, we were also fortunate enough to receive permission from the Nova Scotia Community College to use their testing pool on two occasions. There, we were able to test the full operating capabilities of Blue and practice with our own competition props.

7.2. Troubleshooting techniques

If we ever came across an issue or problem during the testing process, we would address it immediately. First, as a team, we would identify the issue then discuss possible solutions. After a solution was found, a member of the team who worked in that specific area would create prototypes to solve the problem.
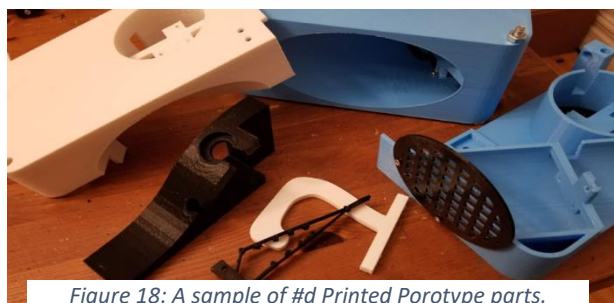

Figure 18: A sample of #d Printed Porotype parts. Credit: Matt Glencross

Then, as a team once again, a decision was made as to which prototype was the most compatible with the current design, was cost effective, and most accurately solved the problem at hand. During the troubleshooting process we would incorporate as much 3D printing as possible as well as re-use older parts to keep the cost down. This also allowed for fast prototype production and less waste in materials.

8. Team Reflections

8.1. Daphne Finlay

During my time with Halifax Robotics Explorer team 64°W Robotics I learned many things, including techniques for 3D modelling in SolidWorks. I also learned how to operate a Dremel tool and the proper safety precautions that came with it, such as wearing gloves to protect your hand and glasses for your eyes as well as a mask if needed. I also learned how to use an air compressor to inflate our lift bag. The skills in team work and communication that I have learned through robotics will be extremely beneficial for me in my future career as an engineer. In conclusion I am extremely grateful for having the opportunity to participate in Halifax Robotics and the skills that I have learnt from my mentor and team mates.

8.2. Matt Glencross

I first participated in the MATE ROV competition during my freshman year of high school to become involved with the extra-curricular community and explore possible career options. Four years have now passed, I successfully graduated high school and completed my first year of studies as a Mechanical Engineer, and I am still committed to the competition. Throughout the past four years the MATE ROV competition has encouraged me to develop a range of skills that have gotten me to where I am today. Beyond the technical skills such as 3D design, power tool operation, and mechanics my personal skillset has also grown. I have become a better problem solver which helps me stay focused and confident while writing exams or completing large projects. I have also learned how to manage my time more efficiently which allows me to strive in school, participate on the robotics team, maintain a part time job, and still find time for family, friends, and sleep. I am proud of the accomplishments of both my team and myself, and I look forward to continuing my participation in the MATE ROV competition with Halifax Robotics.

8.3. Logan Crooks

After four years of competing in the MATE ROV competition I find that the skills developed through the research, development, and presentation phases of the competition are building incredibly valuable skills. The time in the competition has influenced my life so much it shifted the career path I intended to peruse from physics to electrical engineering. I've learned invaluable skills throughout my time in this competition such as teamwork and time management. As well I've learned problem-solving due to having to work through many of the problems faced each year. I am the member of the team who works with the electronics meaning that my usefulness peaks right around exam period in school, this leads to many late nights but also exemplifies the importance of time-management and organization skills to ensure both school, work, sleep, and the ROV can be balanced on one schedule. I am incredibly thankful for the opportunity given to me my MATE and hope to continue working with ROVs and competing in the ROV competition for many years to come.

9. Acknowledgements

We at 64° West Robotics would like to thanks to Marine Advanced Technology Education for hosting the ROV competition annually, and Nova Scotia Community College for providing the time and resources to ensure the regional competition is completed flawlessly every year. We also thank the judges and volunteers who take time out of their busy schedules to allow this competition to happen each year and allow thousands of people worldwide the chance to learn. We would like to acknowledge the collaboration of the Ranger team at Halifax Robotics on the research of the lift bag, claw, and acoustic software.

We thank our sponsors: Ace of Clouds, Lockheed Martin, Saint Mary's University, Brilliant Labs.

Finally, we thank Colin Melia for mentoring both us and the Halifax Robotics Ranger team for the fourth year running. The effort and time that Colin puts into this team is difficult to put into words.

10. Future Improvements

For each of the past four competitions we have designed, constructed, and tested a new ROV from scratch to develop our skills and resolve problems discovered in previous years. However, we are now confident that this year's ROV, Blue, can provide strong results for years to come. By re-using the current design, the team will have more time to focus on refining individual components, reducing the cost of the ROV, and streamlining the construction process. The largest improvement we would like to make surrounds the manipulator design. Currently it consumes a large part of the frame and increases the overall weight. Although it currently functions adequately, we would like to decrease the size so that it occupies a smaller volume of space and can be attached in different arrangements. Finally, we would like to apply the experience of our team and ROV to further develop the ROV community in the Halifax area by providing demonstrations and social events.

11. References

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12.   Appendix A: Budget

Income					
Source					**Amount**
Members Fee					$ 1630.17
Expanses					
Category	**Type**	**Description/Examples**	**Projected Cost**	**Purchase Cost**	**Re-Used Cost**
Hardware	Purchased	Main Tube Assembly	$ 300	$ 300	-
	Re-used	Laptop	$ 500	-	$ 500
	Purchased	PLA	$ 200	$ 200	-
	Purchased	Blue Robotics tubes and extra or needed tools/hardware	$ 300	$ 300	-
Electronics	Re-used	Blue Robotics T100 Thrusters	$ 952	-	$ 952
	Re-used	T100 Thruster Cores	$ 240	-	$ 240
	Re-used	M100 Motor magnet arrays	$ 210	-	$ 210
	Re-used	Electronic Speed Controllers	$ 250	-	$ 250
	Re-used	Tether interface tube assembly	$ 93	-	$ 93
	Re-used	Tenda adapters with tether signal line interface boards	$ 117	-	$ 117
	Re-used	Voltage Regulators (5V/3V)	$ 6	-	$ 6
	Re-used	SanDisk Ultra 32GB SD Card	$ 13	-	$ 13
	Purchased	Raspberry PI PWM HAT	$ 51.36	$ 51.36	-
	Purchased	Raspberry PI 3	$ 90	$ 90	-
	Re-used	GadgetSmyth Ethos Lite with cables	$ 250	-	$ 250
	Re-used	Camera tube assembly	$ 86	-	$ 86
	Purchased	Extra parts or electronics needed later in the year.	$ 700	$ 700	-
Sensors	Purchased	Cameras	$ 128	$ 128	-
	Re-used	Bar30 High Resolution 300m Depth/Pressure Sensor	$ 68	-	$ 68
		Totals	$ 4,554.36	$ 1769.36	$ 2,785
		Income:	$ 1630.17		
		Re-used:	$ 2,785		
	New Parts to Purchase Estimate:		$ 1,769.36		
		Expenses Estimate:	$ 4,554.36		
	Fundraising Needed Estimate:		$ 139.19		

13. Appendix B: Project Cost Report

Category	Type	Description	Amount	Purchase Cost	Re-used Cost	Running Balance
Electronics	Re-used	GadgetSmyth Ethos Lite with cables	$ 250	-	$ 250	$250
Hardware	Purchased	PLA	$ 150	$ 150	-	$400
Electronics	Purchased	Raspberry Pi 3 x3	$ 90	$ 90	-	$490
Electronics	Purchased	Raspberry PI PWM HAT x3	$ 51.36	$ 51.36	-	$541.36
Electronics	Re-used	SanDisk Ultra 32GB SD Card	$ 13	-	$ 13	$554.36
Electronics	Re-used	Tenda Adapter with Tether Signal Line Interface Board x2	$ 117	-	$ 117	$671.36
Sensors	Purchased	Low-Light Analog Camera x4	$ 128	$ 128	-	$799.36
Sensors	Purchased	Vivotek C Series VS8100-V2D1 1-Channel Analog-to-Digital Video Server x3	$ 245	$ 245	-	$1,044.36
Sensors	Re-used	Bar30 High Resolution 300m Depth/Pressure Sensor	$ 68	-	$ 68	$1,112.36
Electronics	Re-used	Voltage Regulator x3	$ 6	-	$ 6	$1,118.36
Electronics	Re-used	Blue Robotics T100 Thruster x8	$ 952	-	$ 952	$2,070.36
Electronics	Re-used	T100 Thruster Core x3	$ 240	-	$ 240	$2,310.36
Electronics	Re-used	M100 Motor Magnet Array x3	$ 210	-	$ 210	$2,520.36
Electronics	Re-used	Electronic Speed Controller x 10	$ 250	-	$ 250	$2,770.36
Hardware	Purchased	Main 11.75" Tube Assembly (11.75 tube, 2 O-ring flange, Clear Acrylic Cap, 15-hole Aluminum Cap, Vent)	$ 294	$ 294	-	$3,064.36
Hardware	Re-used	Tether Interface Tube Assembly	$ 93	-	$ 93	$3,157.36
Hardware	Re-used	Camera Tube Assembly	$86	-	$86	$3,243.36
Hardware	Re-used	8mm Penetrator x10	$37.5	-	$37.5	$3,280.86
Hardware	Re-used	6mm Penetrator x4	$ 12	-	$ 12	$3,292.86
Hardware	Re-used	Blank Penetrator x3	$ 12	-	$ 12	$3,304.86
Hardware	Re-used	Valve Penetrator x3	$ 24	-	$ 24	$3,328.86
Hardware	Purchased	Gearbox assembly (2 1/4" shafts, 1 worm, 2 gears, 1 rack, 3 bearings, 5 collars, 1 coupler, spacers, worm pin) x 2	$ 160	$ 160	-	$3,488.86
Electronics	Re-used	Laptop	$ 500	-	$ 500	$3,988.86
Hardware	Purchased	Pneumatic Connector Kit	$ 19	$ 19	-	$4,007.86
Hardware	Re-used	Buoyancy Foam Sheet x1	$ 34	-	$ 34	$4,041.86
Hardware	Purchased	Ballast Weights x6	$ 54	$ 54	-	$4,095.86
Electronics	Purchased	Terminal Blocks and Jumpers	$ 30	$ 30	-	$4,125.86
Hardware	Purchased	Anderson and Bullet Connectors	$ 25.83	$ 25.83	-	$4,151.69
Hardware	Purchased	Screws/Bolts/Nuts (M2, M2.5, M3, #6, #8, ¼")	$ 30	$ 30	-	$4,181.69
Electronics	Purchased	Microphone x2	$ 4	$ 4	-	$4,185.69
Electronics	Purchased	Speaker x2	$ 4	$ 4	-	$4,189.69
Hardware	Purchased	Epoxy	$ 20	$ 20	-	$4,209.69
Hardware	Purchased	Insulation Rubber	$ 5	$ 5	-	$4,214.69
General	Cash donated	Saint Mary's University / Lockheed Martin	$ 775.9			
		Totals		$ 1,310.19	$ 2,904.5	$ 4,214.69

Funds Raised:	$ 2,406.17
Paid For:	$ 1,310.19
Re-Used:	$ 2,904.5
Rov Cost:	$ 4214.69
ROV Surplus	$ 1,095.98

14.   Appendix C: Safety Checklists

PRE-LAUNCH
- o Operating area cleared of possible obstructions or tripping hazards
- o Power supply verified to be OFF
- o Tether connected to ROV
- o Tether connected to power supply
- o ROV visually inspected for loose wiring, obstructions, and other damage
- o Watertight enclosures checked for proper sealing
- o Air compressor verified to be regulated at 40 PSI
- o Power supply nominal output set at 48V
- o Thrusters, controls, cameras, articulators and pneumatics are tested for proper functionality

LAUNCH
- o Control crew calls "Prepare for Launch" upon conclusion of all pre-launch checks
- o Poolside crew fits the ROV with any necessary accessories and lowers it into the water
- o Poolside crew calls "Ready" while maintaining hold on the ROV
- o Control crew calls "Release"
- o Poolside crew releases the ROV

DURING MISSION
- o Poolside crew constantly monitors the ROV
    - • If significant bubbles are detected, indicating a leak, the ROV is promptly brought to the surface for inspection
    - • If the ROV incurs physical damage like a broken articulator, it is brought to the surface right away to be assessed and, if possible, repaired

ROV RETRIEVAL
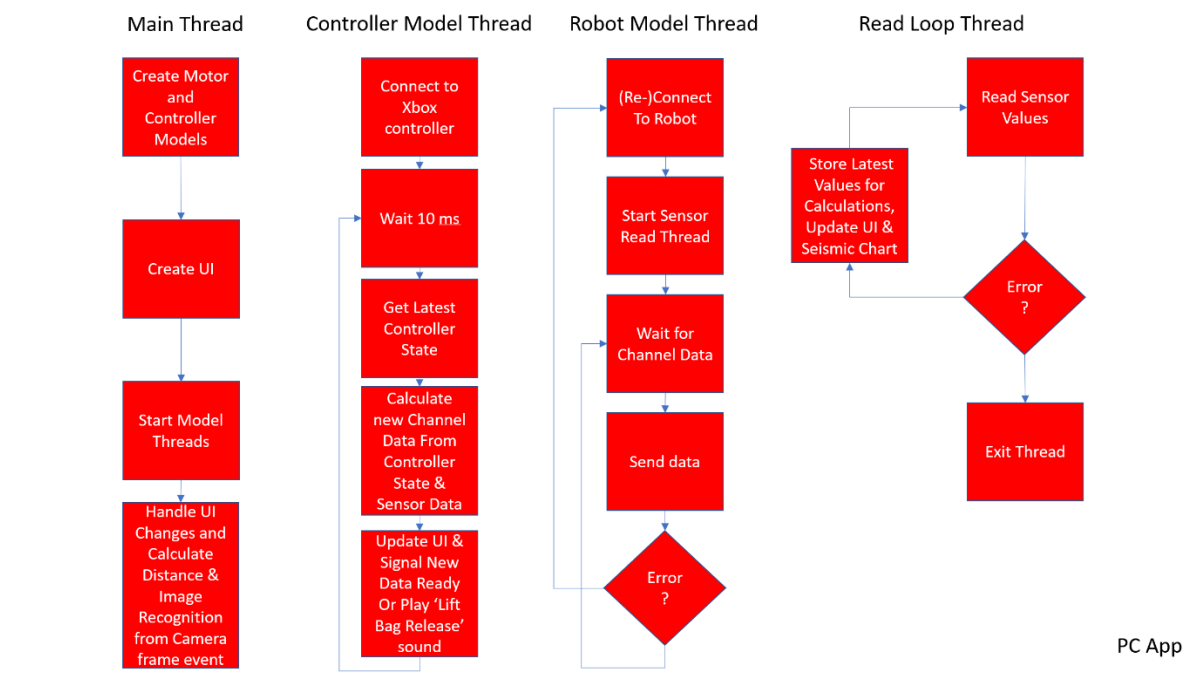- o Control crew requests retrieval from the poolside crew and maneuvers ROV to the surface
- o Poolside crew pulls the ROV from the water
- o Poolside crew calls "Retrieved" once the ROV is secure on the pool deck
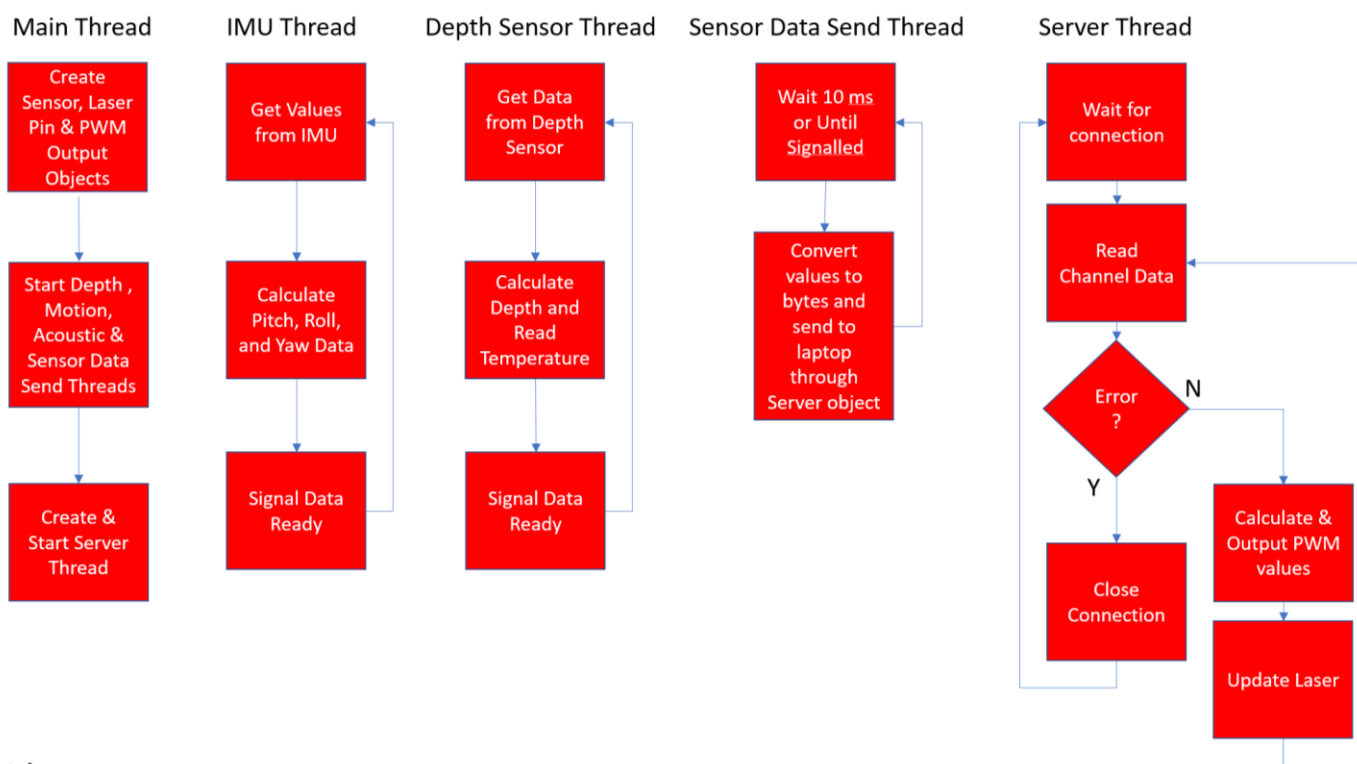- o Control crew powers down the ROV

END OF MISSION
- o Vehicle retrieval procedures followed
- o Air compressor turned off and depressurized
- o Tether disconnected from the ROV and stowed neatly

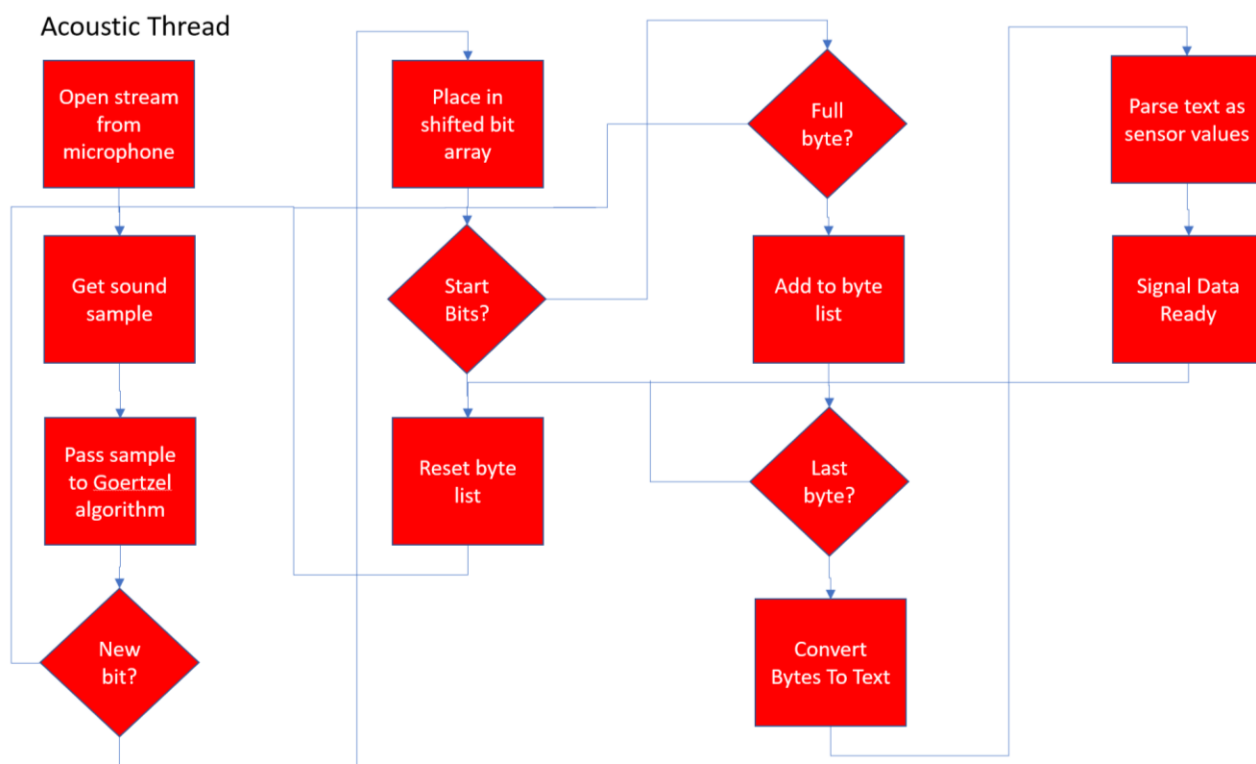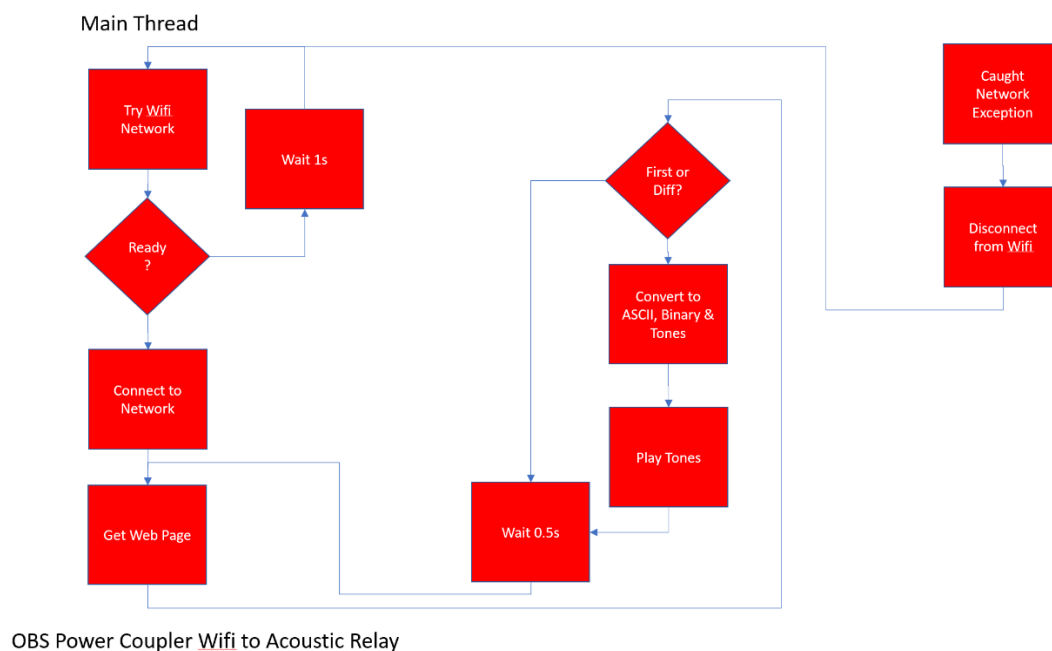# 15.   Appendix D: PC APP and Robot APP flow diagrams

15.1.   PC APP

Main Thread	Controller Model Thread	Robot Model Thread	Read Loop Thread
Create Motor and Controller Models	Connect to Xbox controller	(Re-)Connect To Robot	Read Sensor Values
Create UI	Wait 10 ms	Start Sensor Read Thread	Store Latest Values for Calculations, Update UI & Seismic Chart
Start Model Threads	Get Latest Controller State	Wait for Channel Data	Error ?
Handle UI Changes and Calculate Distance & Image Recognition from Camera frame event	Calculate new Channel Data From Controller State & Sensor Data	Send data	Exit Thread
	Update UI & Signal New Data Ready Or Play 'Lift Bag Release' sound	Error ?	

PC App

15.2.   Robot APP

Main Thread	IMU Thread	Depth Sensor Thread	Sensor Data Send Thread	Server Thread
Create Sensor, Laser Pin & PWM Output Objects	Get Values from IMU	Get Data from Depth Sensor	Wait 10 ms or Until Signalled	Wait for connection
Start Depth , Motion, Acoustic & Sensor Data Send Threads	Calculate Pitch, Roll, and Yaw Data	Calculate Depth and Read Temperature	Convert values to bytes and send to laptop through Server object	Read Channel Data
Create & Start Server Thread	Signal Data Ready	Signal Data Ready		Error ? N
				Y
				Close Connection — Calculate & Output PWM values
				Update Laser

Robot App

Acoustic Thread

Robot App (cont.)

16. Appendix E: OBS Power Coupler Flow Diagram

Main Thread

OBS Power Coupler Wifi to Acoustic Relay

17.   Appendix F: Lift Bag Flow Diagram