Maritime Underwater Solutions 2015 Technical Report

The Umbra

Prince Andrew High School 31, Woodlawn road Dartmouth, Nova Scotia, Canada B2W 2R7 2015 Technical Report	Alex Dewar (CEO) Jerrett DeMan (Mechanical Engineer) Tyler Robinson (CFO) Michael Pierrynowski (Mechanical Engineer) Charlie McKay (Marketing Director) Jake Graham (Electrical Engineer) Evan Terry (Mechanical Engineer) Peter Redmond (Mentor)

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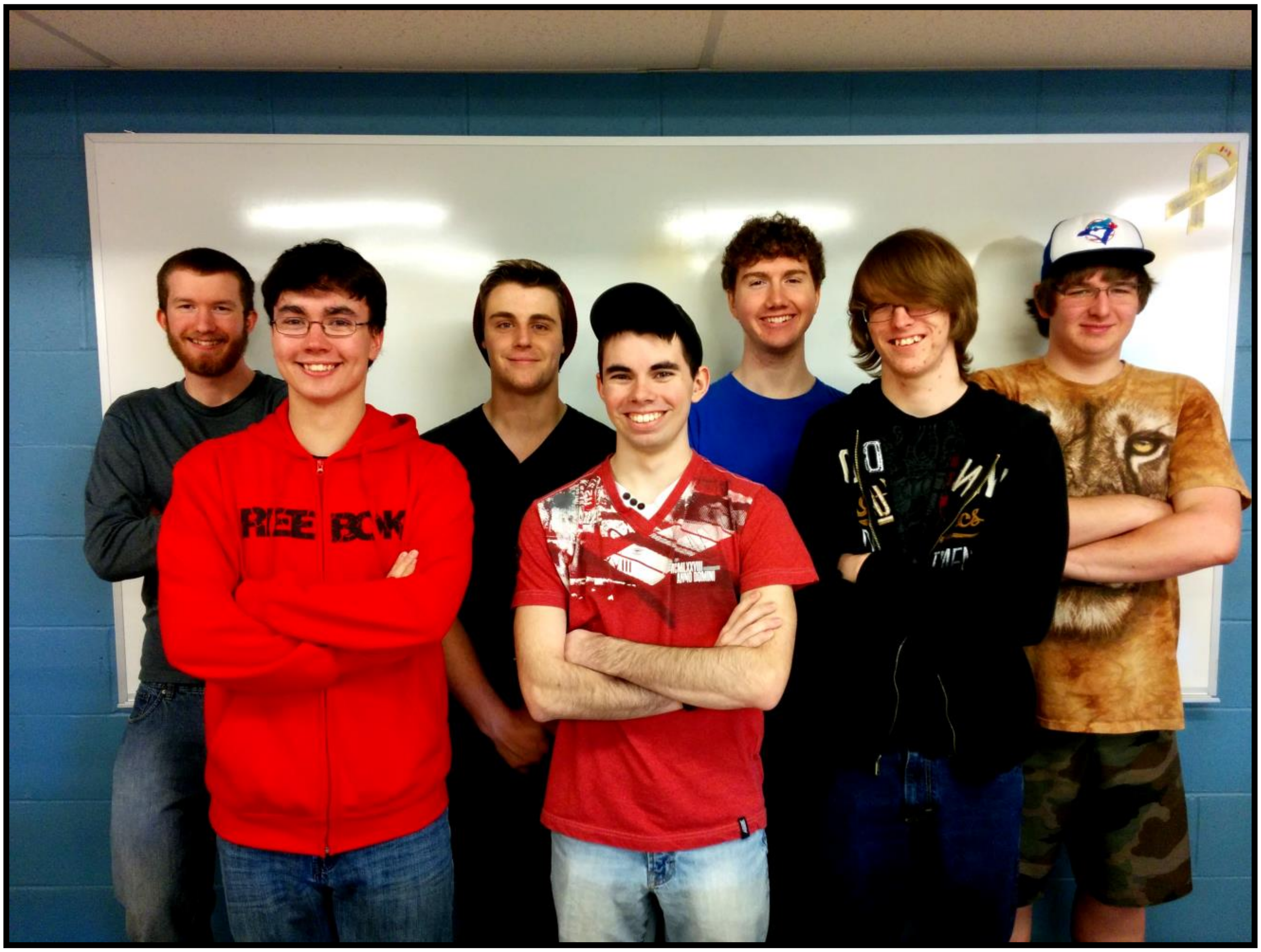
Abstract

Those of us at Maritime Underwater Solutions are committed to customer satisfaction, safety, environmental sustainability, and reliability through the simplicity and ingenuity of our designs. Our team is comprised of experienced workers with a wide variety of highly developed skills, allowing us to create the best products in the field of Remotely Operated Underwater Vehicles (ROVs). Capable of completing many different tasks, the ROVs from our line-up perform well in many different environments. The latest model, the Umbra is designed to operate in an arctic environment and includes various tools and systems, which are able to complete missions as set forth by MATE. The Umbra is controlled via a wireless Xbox 360 controller, which interfaces with an Arduino microcontroller, putting control of movement of the ROV, and its sensors in the hands of a single pilot. The frame of the Umbra is made of high-density polyethylene (HDPE), a lightweight plastic, while the tube housing the electronics is made of polycarbonate, commonly known as bulletproof glass, ensuring the sensitive electronics are kept safe. The Umbra features two cameras housed in the polycarbonate tube and one camera outside of the tube, housed in a waterproof container. This provides a wide field of view for the pilot and, along with the simple and intuitive control system, ensures that the Umbra is an easy and powerful platform to work with. The front camera is mounted on two servo motors which allow it to pan and tilt, drastically increasing the field of view.

Mission Orientation

The icy waters of the Atlantic Ocean pose many threats to the offshore oil industry. Icebergs constantly roam the unforgiving surface, while debris and decay can affect the functionality of underwater pumps. Very little is known about underwater environments, especially in the arctic. To aid in the smooth operation of wellheads and oil platforms, Maritime Underwater Solutions has created the Umbra, an ROV designed to withstand and explore the cold depths of the Atlantic.

Maritime Underwater Solutions Staff



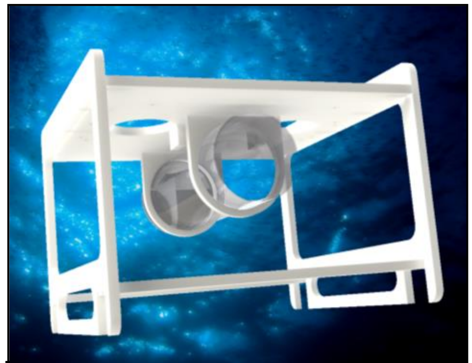
Maritime Underwater Solutions Team

(Left to Right)

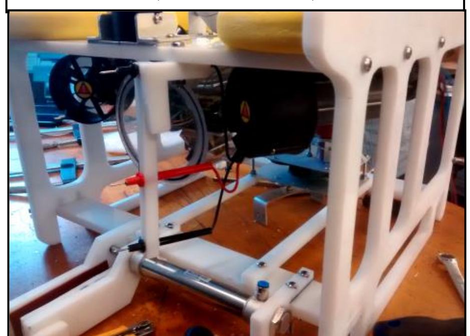
Jerrett DeMan (Mechanical Engineer)
Evan Terry (Mechanical Engineer)
Charlie McKay (Marketing Director)
Tyler Robinson (CFO)
Alex Dewar (CEO)
Jake Graham (Electrical Engineer)
Michael Pierrynowski (Mechanical Engineer)
Photo taken by mentor Peter Redmond

Design Rationale and Vehicle Systems

Frame: The Umbra's frame houses and protects all of the sensors, payload tools, and thrusters within the ROV, while remaining minimalistic to cut back on mass and drag. To aid in this, the main material used in the frame is HDPE, which is very strong and slightly positively buoyant. Having a buoyant frame aids in reducing the amount of material necessary to reach a neutral buoyancy which allows a smaller frame overall. As HDPE ships in large sheets, the frame is comprised of many panels and support bars, some of which are "skeletonized" to reduce mass. By positioning the thin 0.0127m sides of the HDPE parts along the X-axis, movement along this axis sees very little drag. Many different designs were discussed for the frame of the ROV, which underwent many revisions in the 3D modelling program *Solidworks*. After the finalized shape of the sides were constructed in *Solidworks*, thrusters were added to the model in strategic positions, allowing for efficient use of thrust. The dimensions of the Umbra then shrunk to leave enough room for the thrusters, electronics enclosure, payload tools and buoyancy. The final dimensions were 35cm tall by 46.5cm wide, by 45 cm long. A detailed drawing can be found at Appendix D.



Frame without thrusters
(Photo: J. D.)

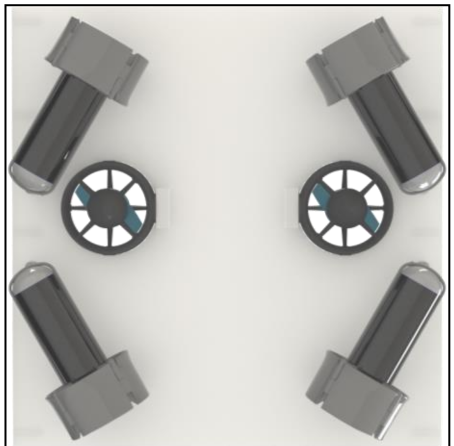


The Regional frame had extra supports; however, these are not present in the final frame. (Photo: A. D.)

Buoyancy: Buoyancy is essential to creating a high performance ROV. Knowing this, the Maritime Underwater Solutions team strived to create a ROV that is extremely close to being neutrally buoyant. The main advantage of this is that it allows the ROV to maintain a stable depth with little interaction from the pilot. To achieve this goal, the Umbra was designed with an HDPE frame, which is very close to being neutrally buoyant, allowing a major variable to be effectively eliminated. This left the various payload tools as ballast and the underwater tube as a source of buoyancy. After testing, the team determined that the payload tools slightly outweighed the tube, meaning another source of buoyancy had to be added. To combat this, flutter boards were affixed to the top of the Umbra on is top panel. The team had considered various materials, but eventually settled on the flutter boards due their nature of containing a high amount of air, and not absorbing water, meaning their buoyancy does not change as the ROV descends.

Tether: The tether is an ROV's lifeline to the surface. Knowing the importance of this component, the Umbra’s 21-meter tether system minimizes interference, has a small diameter, and is very flexible. The Umbra’s tether can also act as an anchor, keeping I close to the site it was dropped. When working in areas with current, the tether can act like a huge sail, and having a weight at the bottom ensures that this force will not affect the ROV. The largest components of the tether system are the two 10 AWG wires, providing power and ground to the Umbra. The Maritime Underwater Solutions engineers looked at many options for wire size, with the finalists being 12 AWG, 10 AWG, and 8 AWG. Using the estimated load from the Umbra, the calculated voltage drop was 5.56 volts, 3.5 volts, and 2.2 volts, respectively. While the voltage drop of the largest wire was ideal, the stiffness of an 8-gauge wire would reduce the ROV’s maneuverability. This is especially important for bodies of water with currents, as the tether would act like a sail. CAT6 cable is used for the Umbra’s Arduino – laptop communication. The team had little choice in this matter due to USB's maximum range of 5 metres because of interference, far shorter than the rest of the tether. To extend the range of the communication, a USB to CAT6 balun is used onboard the Umbra to take advantage of the highly shielded cable system. Another CAT6 cable carries the camera output up to the surface, providing very little interference. The team debated using heavily shielded telephone wire; however, after testing, we determined that interference was still too great. Thus we incorporated another CAT6 cable into our tether. The final part of the Umbra's tether is the two pneumatic lines. Serving as both pressurized and exhaust depending on the state of the above surface controller, they allow the Umbra's dual acting pneumatic piston to operate flawlessly. The tubes are rated to 100 PSI, ensuring that the chance of rupture from pressure is almost nonexistent. Air exhausts at the surface through a pneumatic diffuser, ensuring a safe system.

Propulsion: The most essential system in an ROV is the one that enables it to move: propulsion. There are many selections and ideas when it comes to moving an ROV. One of the early ideas for propelling the Umbra was to repurpose bilge pumps. This would provide an easy, familiar, and cheap method of movement. However, the Maritime Underwater Solutions team found that the high speed, low torque nature of bilge pumps meant that they were inefficient at accelerating the mass of the robot. Furthermore, they suffer from high power draw and a lack of integrated shroud. The decision was made to reuse Seabotix BTD150 thrusters from our previous ROV model. This was done because of the BTD150's high thrust coupled with a low power draw, measured by the team to be over 10 newtons of thrust, using 2.5 Amps of current in the process. These motors provide much higher performance than a motor the team could design ourselves, while already being waterproofed. The Umbra makes use of four Seabotix thrusters vectored at each corner of the ROV at an angle of 30 degrees off the frame. The team had considered using non-vectored thrusters; however, this did not allow the Umbra to utilize all four Seabotix thrusters for all horizontal movement. At the same time, non-vectored thrusters would complicate turning and not allow for strafing. The team had also thought about vectoring the thrusters at a greater angle, such as 45 degrees. We decided to reduce the angle to provide more power when moving forwards and backwards, at the expense of strafe performance. This decision was made because the team felt that movement in this direction was more important, and a smaller angle allowed a reduction in the profile of the frame.



Thruster Layout (Underside of top panel) (Photo: J. D.)

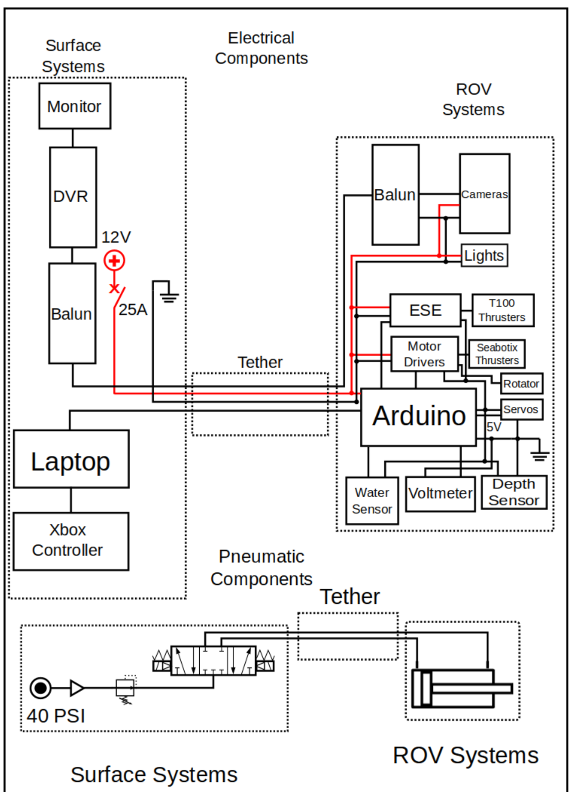
Two Blue Robotics T100's provide vertical movement to the Umbra. The team had considered purchasing more BTD150’s; however, they are very expensive. The Blue Robotics providing a far higher thrust at a higher current draw, coming out at 23 newtons and 11.5 Amps, respectively, while being 7 times cheaper. Due to this high power draw, the Umbra does not utilize the full power of the T100's, instead opting to use them at about 66% throttle. This provides about 16.9 newtons of thrust at six amps of current. Each T100 thruster aims directly upwards, maximizing vertical movement.

Pneumatics: The Umbra’s manipulator uses pneumatic pressure, keeping it robust and separate from the other ROV systems. The team considered using an electric claw, but this idea was discarded because of the need to waterproof the claw and its connections, the difficulty of creating an electric claw from scratch, and the added load placed on the Umbra's power supply. The pneumatic system consists of a double acting cylinder, pneumatic tubing, a pneumatic valve, a pressure regulator, compressed air tank, and compressor. Compressed air is stored in the compressed air tank and fed through a regulator set to 40 PSI to a 5/3 way valve used as a controller. The air can travel from the valve to the double acting cylinder through one of two pneumatic tubes. The pneumatic valve allows air to pass down one tube and exhaust out the other allowing the double acting cylinder to move in both directions. The 5/3 way valve is located at the control station and is controlled manually via an operator on the surface. All pneumatic operations beside the piston itself are located on the surface, to reduce the size of the ROV. Although pneumatics could be controlled electrically via solenoids underwater, utilising this system would require a manifold, upon which the electrically controlled valves known as solenoids would control air flow from. This system would take up a relatively large amount of room on the robot, potentially slowing it or forcing an increase in the size of the frame. The team decided to keep the system as simple as possible, using a manually controlled valve and two-way piston.

The Pneumatic Manipulator
(Photo: T. R.)

Payload Tools: The Umbra's manipulator actuates along a single axis, as opposed to a hinged claw design. The advantages of the sliding system over hinged systems are its simplicity; hinged systems have multiple moving parts, which can increase the chance of failure. Hinged systems also generally have a much smaller grip area, and require extra bulk. The Umbra's manipulator achieves a large amount of gripping surface while not adding too much weight to the frame. The manipulator is structurally based around a pneumatic piston, which is held onto the frame via two HDPE braces, one of which having a gripping surface extending out from it. The moving arm threads onto the head of the piston, and a rail prevents it from rotating on the pistons axis. The Umbra is also equipped with a "High Torque Rotator Module" on the bottom of the frame. This device allows us to rotate valves underwater. This is achieved by attaching a *C* shaped aluminum bar over the valve and activating a bilge pump. This is connects to a gearbox, providing reasonable speed and excess torque to the aluminum bar. The gearbox was created using 1/8” aluminum and plastic gears, with bolts as axles. HDPE and aluminum were also used to create bearings and reduce friction in around the gearboxes moving parts. The final payload tool the safe removal of “algae” from the underside of the ice sheet, and is constructed of ABS pipe and tape. Its simple design functions flawlessly, with very little effort from the ROV. The tube is essentially a “one way chute” for the algae simulated ping-pong ball. The ROV lines up the entrance to the tube with the ball and ascends. Once the algae goes into the tube, it is held by friction caused by the tape. Upon returning to the surface, a simple wingnut holds the entire payload tool in place, which can easily be removed for the safe recovery of algae.

Electronics: The Umbra utilizes a highly optimized and developed electronics system to ensure that it can easily and efficiently complete any task given to it. The central part of the electronics system is the Arduino Uno Microcontroller, which allows the control system of the Umbra to interface with the electronics system. The Uno was chosen because of its small form factor and its ability to interpret different voltages as inputs. The Umbra utilizes three Sabretooth 2x12 motor drivers from its previous ROV design to enable the high current draws of the Seabotix motors and high torque rotator to be controlled by the Arduino. These were reused because of their high performance, being able to handle up to 12 amps each, their ability to switch between linear and exponential control, and their coupling of two signals into a single motor driver, cutting down on space. New to the team were the Blue Robotics’ ESCs, which interface with the T100 thrusters. They utilize R/C signals to control the current given to the motors. These were chosen over the more expensive Blue ESCs because they were available sooner, allowed the team to have a simpler way



SID (A. D.)

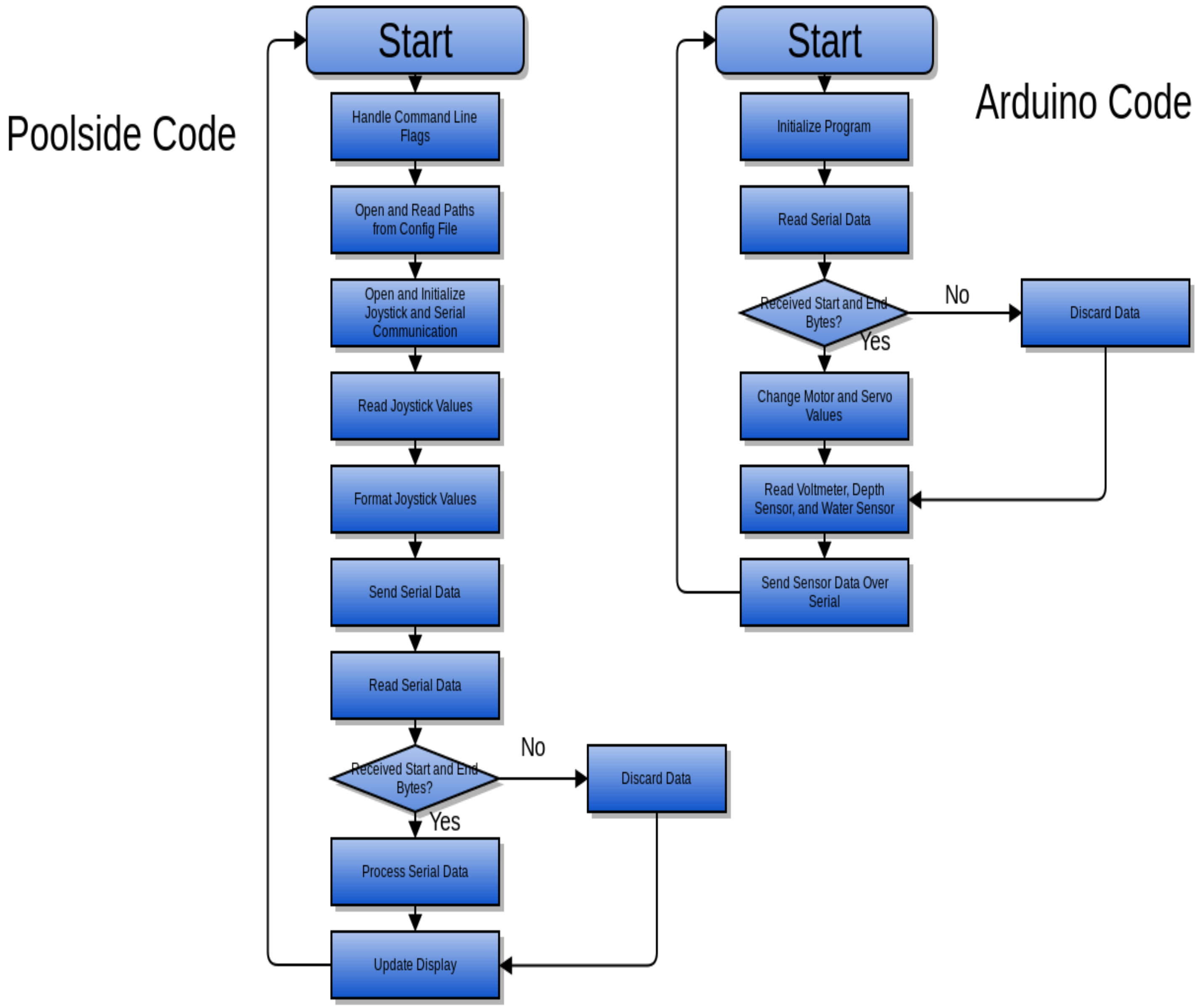
of interfacing with the motors, and allowed the team to cut expenses on the Umbra. One of the greatest additions to the Umbra's design was the use of a balun box to convert RCA signals from the Umbra's cameras to the signal, anti-signal pair that runs through CAT6 cables. The team had experimented with directly sending a camera signal to the surface through heavily shielded wire; however, despite the protection of the shield, the team still experienced interference in the signal, reducing its clarity and reliability. The signal, along with its anti-signal wrapped in a tight twisted pair give far more protection than a traditional heavily shielded cable. Furthermore, the single balun box handles all camera signals, allowing poolside connections to be simplified, thus reducing the probability of failure. The Umbra utilizes a breadboard for all of the electronics in the underwater tube.

The team had originally planned to use a homemade printed circuit board of all of its connections. The rapid development cycle of the Umbra, however, this meant that the design of the electronics system frequently changed. This made breadboard a much more viable option, as it provided the flexibility to change the electronics system at a moment’s notice. The flexibility of this system proved to be an asset when the team had to quickly change the mode of the motor driver from analog to R/C, thus removing resistors and capacitors from the system, as well as when the camera servos were incorporated.

Control System:

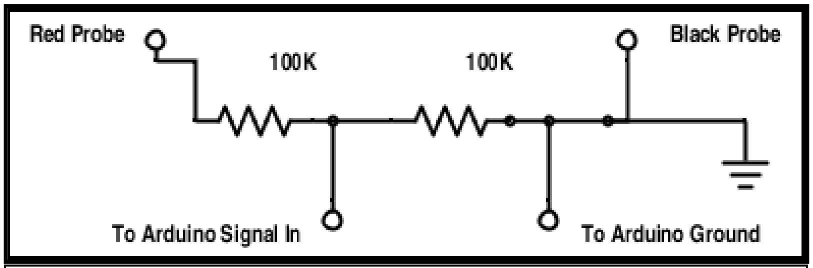
Xbox 360 Controller (Wikimedia.org)

The Umbra’s control system is very user friendly and intuitive. The Xbox 360 controller is the main way in which the Control of the Umbra was designed to be extremely simple and intuitive to use. The Xbox 360 controller is the main way in which the Umbra interfaces with the pilot, reused from Maritime Underwater Solution's previous model of ROV, where the team grew fond of the controller's comfortable and reliable design. It has the advantage of being widely known and used on the popular gaming console of the same name. We also found that the Xbox 360 controller was easy to interface with the poolside code. While the team debated on using a PlayStation 3 controller due to its wider array of buttons, the team felt that purchasing a new controller to replace an already functioning one was a waste of resources. Furthermore, the team ran into problems testing the code with the PS3 controller and had concerns with the controller's durability. The Xbox 360 controller interfaces with the rest of the Umbra through two sets of code. The first of these is the program on the poolside laptop, to which the controller is directly connected. This code, while being similar in function to the previous year's program, is a complete rewrite from last year's C# and Python code. The decision was made to use the C Programming Language because of its simplicity and nature as a lower level language than either Python or C#. The team had previously ran into issues with the higher level implementations of serial communication, with simple writes taking over a tenth of a second, far too slow for reasonable control. C has the advantage of directly using the API's of the operating system, bypassing any flaws in implementation. The decision to use C led to use of the Ubuntu operating system onboard the laptop. Microsoft Windows has less than ideal support for the newest specifications for the C language, some of which are utilized in the Umbra's code and are essential to its function. The team was quickly able to pick up knowledge of the language. The second set of code is the program onboard the Arduino, written in the Arduino's modified version of the C++ Programming Language. While the team had a working program from its previous model, this code was also rewritten. This was because we were unsatisfied with the readability of the code, making it more difficult to extend and fix bugs. The control method used for interfacing with the ESC's is R/C, which sends a digital signal which is timed with the movements of the thruster. This same method is used to communicate with the Sabertooth 2x12 motor drivers, as well as with the servos that control pan and tilt on the forward facing camera. The team realized that a software control system like the one onboard the Umbra would have major advantages. Some of the ones that the team highlighted when coming to a decision were that details of the system, such as how fast the Umbra accelerates and how much power it uses, could be changed on the fly. This provides greater control to the pilot and the pilot's team. Another reason is that it puts a greater majority of the controls into a single interface, which is both simpler and more intuitive.



Software Flowchart (A. D.)

Sensors: To aid in scientific and conservation missions, the Umbra is equipped with various sensors, allowing it to be deployed in a wide variety of environments.



Volt Meter Schematic (A. D.)

One of the most important sensors for use in offshore oil operations is the volt meter. Voltmeters work by measuring the potential difference between two points, interpreted as voltage and measured in volts. The Arduino used for the control and electronics systems is equipped with an onboard voltmeter. This, however, is only able to measure differences in a range of 0 to 5 volts, which is below the minimum acceptable range set by MATE (6 volts). To ensure the voltmeter can be used effectively, the Umbra utilizes two equal value resistors of 100k ohms to step the voltage down. This doubles the max voltage that the Umbra can safely measure through the equation $V_o/V_i = R2 / (R1 + R2)$. Due to the loss in precision that accompanies this voltage drop in that the Arduino's 1024 different possible measurement values are spread over a greater voltage, it was important to the Maritime Underwater Solutions team to choose resistors that resulted in a simple circuit and an acceptable measurement range with a relatively low loss in precision. The two 100k ohm resistors provide this. Outside of the ROV, the Umbra's probes for the voltmeter have springs on them, allowing the pilot to more easily measure voltages. A Flexiforce pressure sensor allows the Umbra to gauge its depth. As the Umbra dives, water pressure increases, and the resistance of the sensor goes down, allowing for accurate depth readings. The circuit used in this sensor is similar to the one used in the voltage sensor, except that the unknown voltage is replaced with the unknown of the resistance. The Umbra is also equipped with an emergency water sensor located in the electronics tube. This sensor has an open circuit that is closed in the presence of water, allowing leaks in the tube to be detected. The pilot is notified and may take appropriate action to minimize damage to the electronics and the surrounding ecosystem the catastrophic event of a leak.

Cameras: To ensure that its pilot can easily navigate underwater environments, the Umbra is equipped with three cameras. When design of the Umbra began, the Maritime Underwater Solutions team knew that proper placement of cameras was essential to building an industry leading ROV. Having more cameras allowed the pilot the gain more visual information from their surroundings; however, the space that these cameras would take up was also an important factor. Due to the increased range of vision that the ROV could see, as well as the extra space it freed up in the electronics tube, placing cameras outside the electronics tube was an attractive idea. In contrast to this was the difficulty of waterproofing the cameras and the limited amount of connections available from the electronic tube out. Considering this, the team designed the Umbra so that it used the fewest possible cameras while still providing an acceptable field of vision to the pilot. In the end, the team decided that placing two cameras inside the electronics tube and one outside the tube would provide a good balance between the aforementioned points. The original design of the Umbra featured four cameras, chosen because our DVR supported a maximum of four cameras. Later, however, we decided to remove one of the frontal cameras, replacing its roles with a pan-tilt kit. This decision was made because integrating a larger field of view into a single camera meant less switching between camera views and greater control of the field of vision. This frontward facing camera, placed within the electronics tube, allows the pilot to see all of the payload tools mounted on the front of the Umbra. The second internal camera gives a backwards view, allowing the pilot to view the rotation module for its operation. It also gives the pilot additional information about the areas around the back and below the Umbra. The final camera is mounted on the top panel of the Umbra, allowing the pilot to use the algae sampler and more easily navigate underwater enclosures. Due to the high cost of purchasing a waterproof enclosure, as well as the difficulty of designing one, our engineers elected to salvage the well-tested waterproof canister from last year.

In terms of cameras, the company Waleptega graciously donated four very high performance ROV cameras as well as a station to convert signal to a screen. Unfortunately, the team found that the software was not flexible enough to meet our needs. For example, the team had wanted to incorporate other cameras into the system; however, the two sets of cameras had incompatible output types (NTSC and PAL). The second frontrunner were CMOS Camera Modules from Sparkfun. These were chosen because they provided a solid resolution of 728x488 at 60 Hz, ensuring a clean and smooth image. They also perform well in low light conditions, having a minimum light sensitivity of 0.2 Lux. Another important feature is their small profile, allowing them to easily fit within the electronics enclosure.

Safety

Face masks were worn while cutting HDPE (Photo: T. R.)

Safety was a prime concern both during construction of the Umbra, and in its completed form. Various rules were emplaced in the shop, such as requiring supervision and protective eyewear regardless of the tool used. A first aid kit was always nearby, as well as eyewash stations and sinks. Tools were carefully maintained and visually inspected before their use to ensure flawless functionality. On the Umbra itself, all sharp edges inside and outside are bevelled, ensuring no pointed edges were present. For internal connections, all joints are cleanly soldered before being wrapped in electrical tape. For external underwater splices, the electrical tape was replaced by liquid electrical tape, room temperature vulcanization silicon, and self-fusing tape. A double O-ring system is used to seal the underwater tube, protecting it from the elements and water. The splashproof poolside box contains both a universal power switch and a 25 amp circuit breaker. The former allows the 12 volt power source to be disconnected in an emergency situation, while the latter ensures that high currents do not damage any of the Umbra's components. A water sensor onboard the Umbra alerts the pilot if water were to leak inside the tube, giving precious extra time to recover the ROV.

During operation of the Umbra, the team follows safety guidelines as highlighted in our safety checklist, ensuring safe operation of the Umbra. Even after applying all these precautions, one incident did occur when a team member cut himself on a stainless steel nut which had burred. Despite being small, the cut caused notable bleeding. The wound was quickly washed and covered, and the nut was discarded to prevent another similar incident.

Challenges

Technical Challenges: To perform well in each of the challenges, ROVs are required to be nimble and fast. All challenges require precision, but time is the overall decider in terms of performance. The Umbra's design incorporates vectored horizontal thrusters into the frame, allowing for strafing and increased torque during turns. This allows for an extreme amount of maneuverability, giving the Umbra an edge over other robots. The buoyant frame negates the need for excess buoyancy, allowing the frame to be smaller. This would also allow easier navigation under a current. Designing an ROV to be slim while not sacrificing on power or functionality proved to be a difficult task. The team overcame this by continually improving on designs, eventually coming upon the current design, which fits all of our needs.

Non-Technical Challenges: One of the greatest challenges that our team has faced so far has been time constraints. From September to late November, our mentor was on parental leave, grinding progress to a halt. Some days, we could locate another qualified teacher who was willing to give up their lunch hour to watch us plan and build, but very little progress occurred in this period. After school, work periods also fluctuated immensely as everyone's schedule changed. In January, the local pool we had previously used for testing shut down, leaving us without a true way to test the ROV. The lab was sometimes messy, with components or materials missing, as several tech classes shared the lab. Finally, in the weeks before the Regional Competition, our hometown of Dartmouth, Nova Scotia experienced one of the harshest winters in its history, with over a meter of snow on the ground without counting drifts. The weather made reaching the lab very difficult, and work on the ROV nearly halted.

Overcoming these issues proved to be a difficult task. We found that the best way of persevering was to use each other as motivation, allowing us to work longer with greater focus. We looked to each other for support, keeping our spirits high.

Work Week schedule							
Time:	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
11:00pm							
12:00pm							
1:00pm							
2:00pm							
3:00pm							
4:00pm							
5:00pm							

Hours worked shaded green

Lessons Learned

One of the most important skills that our staff developed was patience. During the build, numerous instances occurred in which team members had to use tools that were currently in use, causing frustration. This was compounded by the time constraints placed upon the team, especially during the end of the year. It was through these trials, however, that our team developed the patience needed to work with one another in stressful situations. This proved to be an invaluable skill during the regional competition, where team members had to work closely together to ensure that both runs were a success. The team also developed many technical skills throughout the year. One example of this is our programmers who had to deal with a new language this year, C. Due to its nature as an extremely simple and barebones language, C provides very little in the way of syntactic sugar. In spite of this, the team quickly learned the various nuances of the language and was able to build fast, maintainable, and reliable code.

Future Improvements

In the future, the Umbra will likely differ in payload tool design and with small additional features such as carrying handles for easy transportation. Skeletonizing the top panel would cut down on mass, and edges could bevel even more, to have less of an edge. The camera system could change to PAL instead of NTSC, allowing a screengrab and subsequently used to find the dimensions of the iceberg using the PVC as reference. An idea brought forth this year included having the video output have a graphical user interface layered on top of it, giving information such as depth, speed and power usage. This would cut back on the bulk of the devices necessary to function by eliminating the second monitor, as well as give the pilot more information on the ROV.

Troubleshooting

During the development of our ROV, we encountered a multitude of problems that had to be rectified. The first step in overcoming a problem was to identify it and then brainstorm solutions. Once we had a list of possible solutions we would eliminate unviable options and select the best remaining option based on the cost, time required and theorized functionality. After a solution was selected, we would come up with details on how to implement it and shortly execute it. For large problems encountered without much time to find a solution, a group meeting was held, with the person in charge of the section leading the discussion. To test the ROV, above water and in water testing took place, judging the ability of the robot to function properly. HDPE was tested prior to its use by tapping and threading bolts into it. It was found that HDPE was incredibly strong when tapped into, which encouraged the decision to use it in the frame. Our systems test began with running the motors outside of the water for short periods. This ensured that the controls properly mapped to the motors. The voltage sensor was tested outside of the water through both grounds. In the water, the strength of the motors, as well as the maneuverability of the ROV was assessed. A mission simulation was conducted to test design ideas using mission props.

Reflection

In comparison with previous years, we are amazed at how much we have grown, both as people and as a team. Through this competition, robotics has become a central part of our lives, occupying a large part of our free time. We have received a huge amount of support from companies around the Maritimes, making many business contacts in the process, setting us up for future success. The challenges of the competition have not only improved our work ethic, but also brought us closer together. We are very proud of the success we have experienced in the two years since entering the competition, winning the regional competition both years. We are very thankful for the incredible opportunities that the MATE competition has given us, and for all of the fun we had while participating.

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L.E. Cruickshanks
Shell Canada
DRDC
RED Space
Dominion Diving

Budget

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Budget (New Purchases)	
Frame	***$350***
Sensors	***$250***
Thrusters	***$400***
Misc.	***$200***
Total	***$1200***

Purchases

Object	Manufacturer	#	Cost	
5"Dx24" Polycarbonate Tube	McMaster Carr	1	$ 56.10	
HDPE Sheets 4'x4'x1/2"	Piedmont Plastics	1	$ 138.00	
T100 Underwater Thrusters	Blue Robotics	2	$ 313.00	
CMOS Camera	Sparkfun	3	$ 117.94	
Aluminum block (1.5x6x12")	Metals R Us	1	$ 46.00	
Polycarbonate Sheet 1'x1'x1/8"	McMaster Carr	1	$ 9.16	
RTV, sealant tape, self fusing tape	McMaster Carr	1	$ 62.13	
Polyester Sleeving (1/2" D)	McMaster Carr	1	$ 37.64	
Great Stuff Insulation Foam	Home Depot		$ 19.37	
CAT6 & BNC connectors	Jentronics		$ 32.40	
SS 1/4"-20x1.5" Machine Screws	McMaster Carr		$ 18.78	
SS Fasteners and Rivets	Kent		$ 16.39	
O-ring Kit	McMaster Carr	1	$ 35.95	
SS 10-24 Machine Screws & Nuts	McMaster Carr		$ 28.40	
LED Light Strips (12V 5M)	Amazon	1	$ 10.32	
Stainless Steel Measuring Tape	McMaster Carr	1	$ 19.94	
Aluminum Panel 6"x16"x1/8"	L. E. Cruickshanks	1	$ 17.49	Donated
Pressure Sensor	Sparkfun	1	$ 25.24	
Dagu Mini Pan/Tilt (Servo motors)	Robotshop	1	$ 20.19	
	Total Purchases		$1,024.44	

Donators	Donations
Shell Canada	$3,000.00
Saint Mary's University	$ 200.00
Steele Canada	$ 100.00
NSCC	$ 750.00
Total Donated	$4,050.00

Reused Materials

Object	Manufacturer	#	Cost
Sabretooth 2x12 Motor Drivers	Dimension Engineering	3	$ 275.97
Arduino Uno Microcontroller	Robotshop	1	$ 30.23
Seabotix BTD150 Thrusters	Seabotix	4	$ 2,897.92
70' 10AWG Wire (Red & Black)	NAPA	2	$ 105.00
70' CAT6 Network Cable	Jentronics	1	$ 47.49
5/3 Control Solenoid, Piston, Valves	Princess Auto	1	$ 128.83
Rosewill Capstone Power Supply	Newegg	1	$ 87.38
Xbox 360 Controller	BestBuy	1	$ 57.49
Gateway Laptop	Techmania	1	$ 460.00
Underwater Connectors	Binder USA	6	$ 345.65
Bilge Pump	Stright Mackay	1	$ 31.90
	Reused Materials Total		$4,467.8
	Total Cost of ROV		**$5,492.3**

Object	Manufacturer	#	Cost
Flights and Accomodations	NSCC (Donated)		$ 5,045.00

APPENDIX A:
Safety Check list

Workspace:

- Eye and ear protection worn when working with power tools
- All work with tools done under proper supervision
- Long hair tied back
- Appropriate clothing worn when working with ROV
    - No dangling jewellery, hair, loose clothing
    - Long pants, closed shoes/boots, and safety goggles

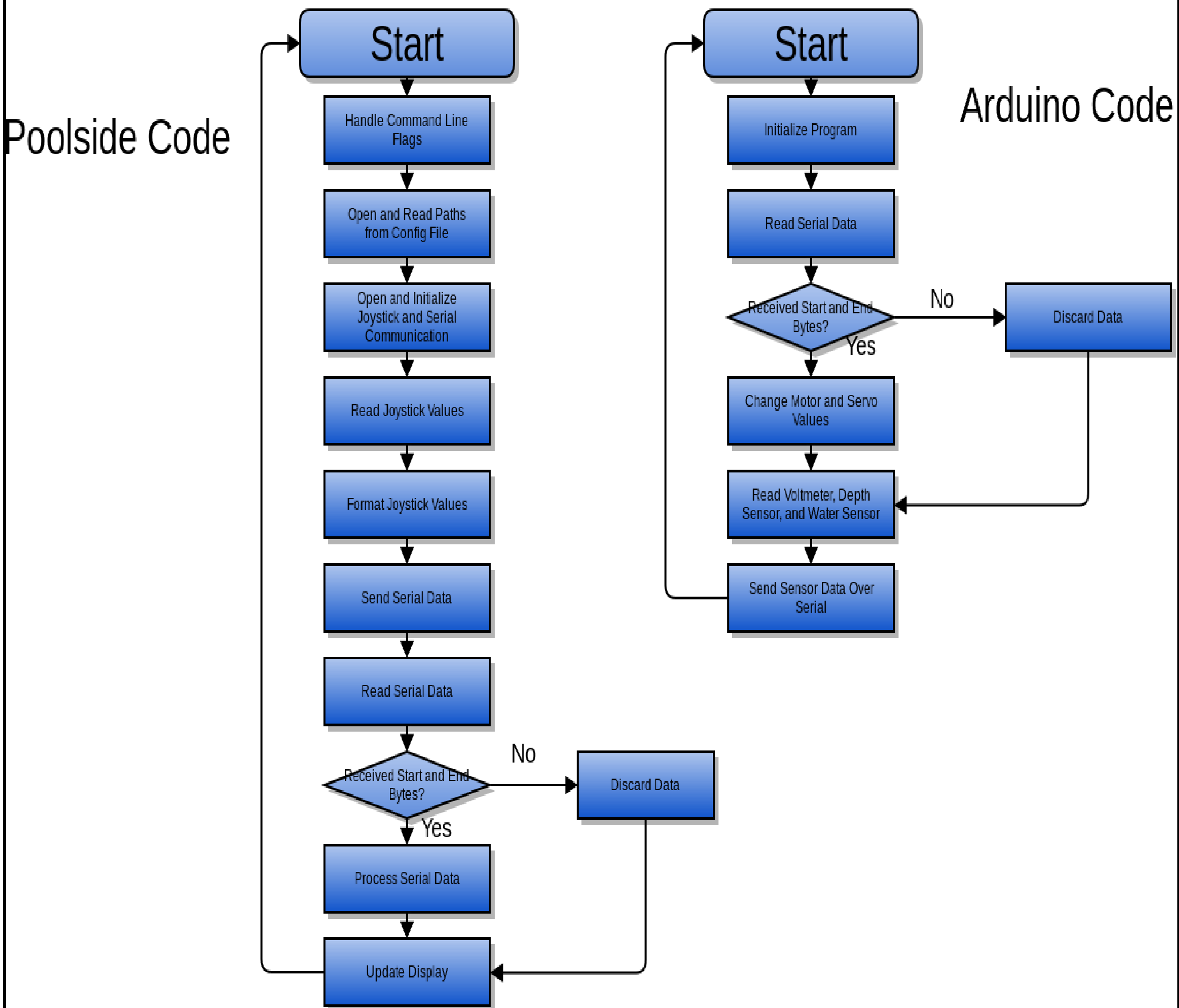
Mechanical and Physical Systems

- No sharp/jagged edges on ROV
- No exposed propellers on motors (shrouded)
- All nuts, bolts, and screws tightly fastened
- Electronics tube waterproof
- Tether has strain relief
- Dangerous areas visibly marked (motors, payload tools, etc.)
- Tether connections secure

Electrical and Pneumatics Systems

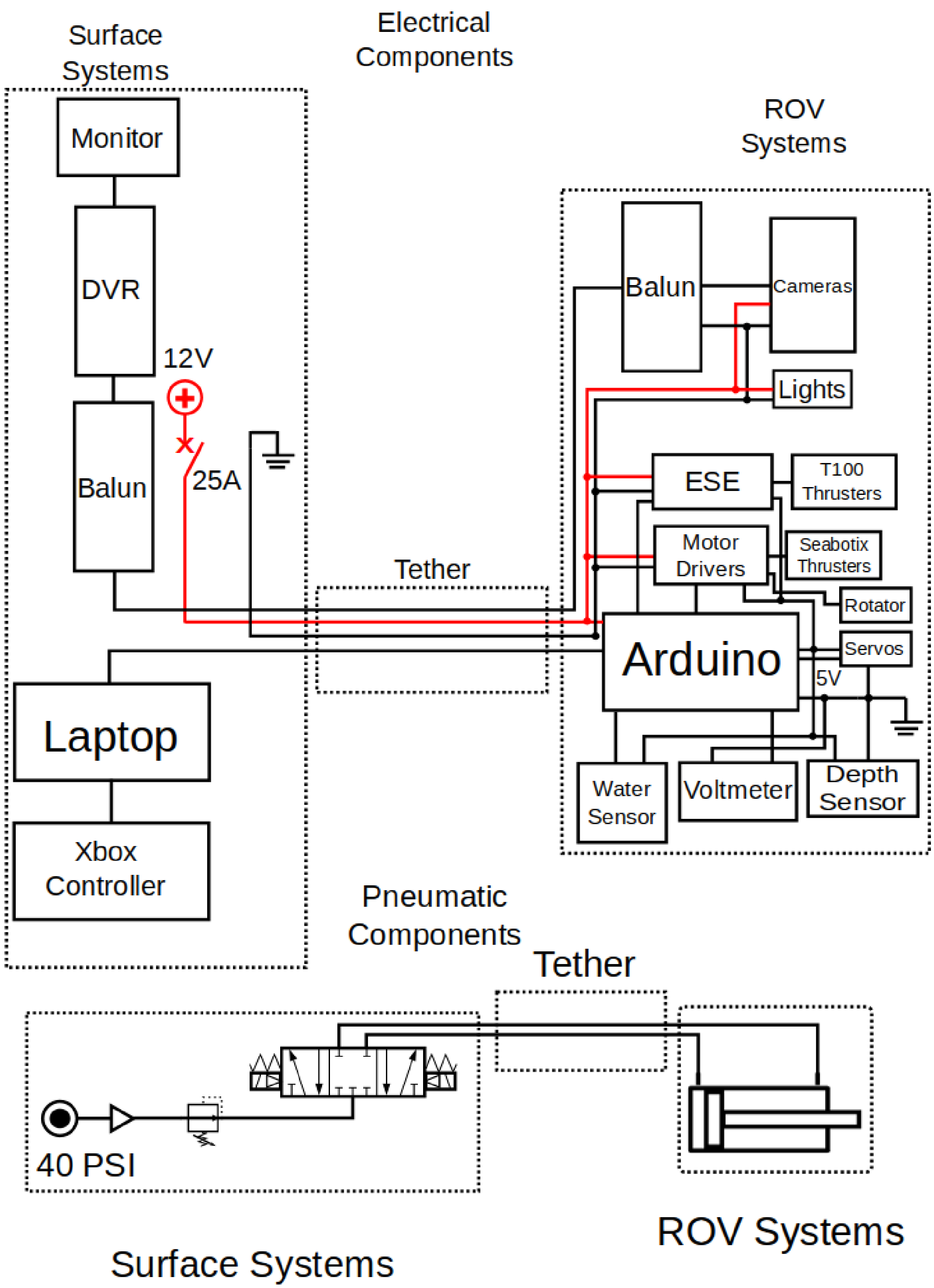
- 25-amp circuit breaker connected to the positive voltage within 30cm of the power supply.
- All electronics in waterproof or connectors.
- All electrical components in splash proof box at surface.
- All wires and connections secure from water.
- All splices properly sealed using RTV silicon and heat shrink.
- Both positive and negative terminals connected to splash proof electrical box.

APPENDIX B:
Software Flowchart
(Photo: A. D.)

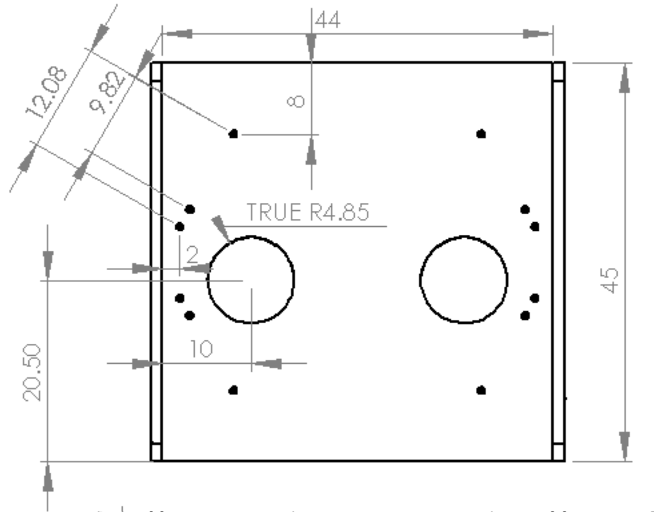


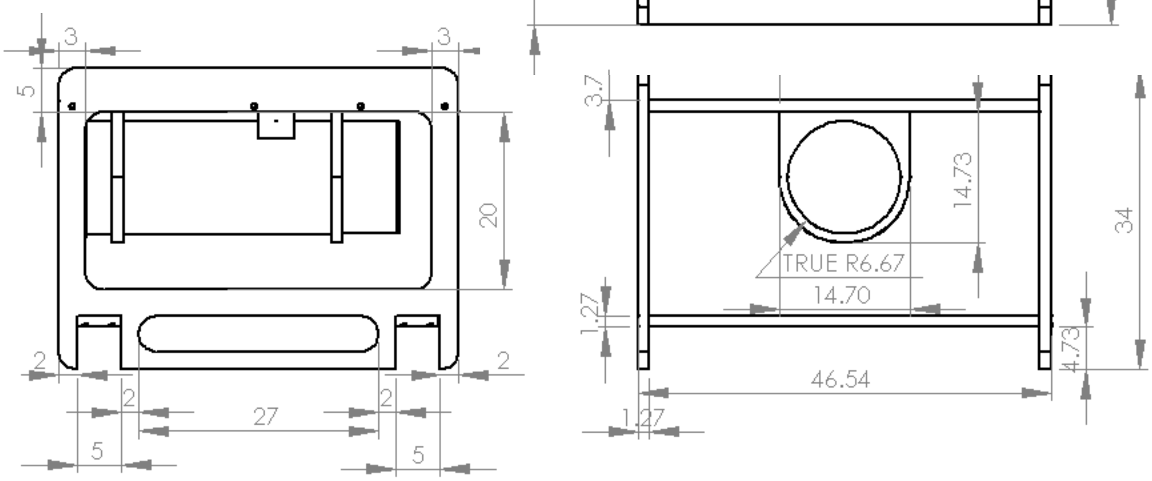
APPENDIX C:

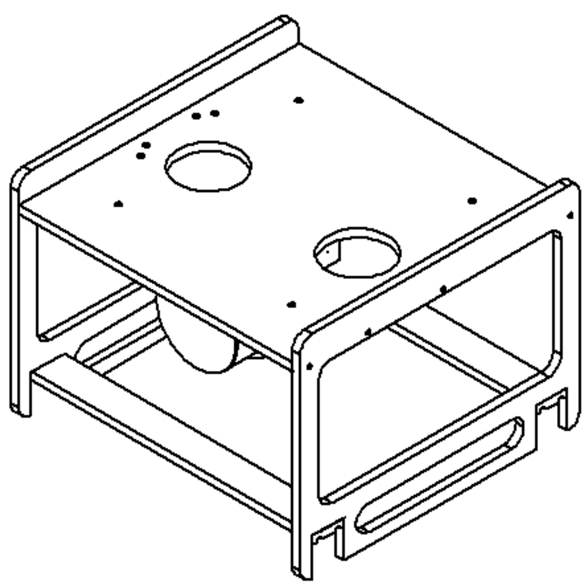
SID (A. D.)



APPENDIX D:
Technical Drawing







Umbra Frame
Designer: Jerrett DeMan
1:10

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