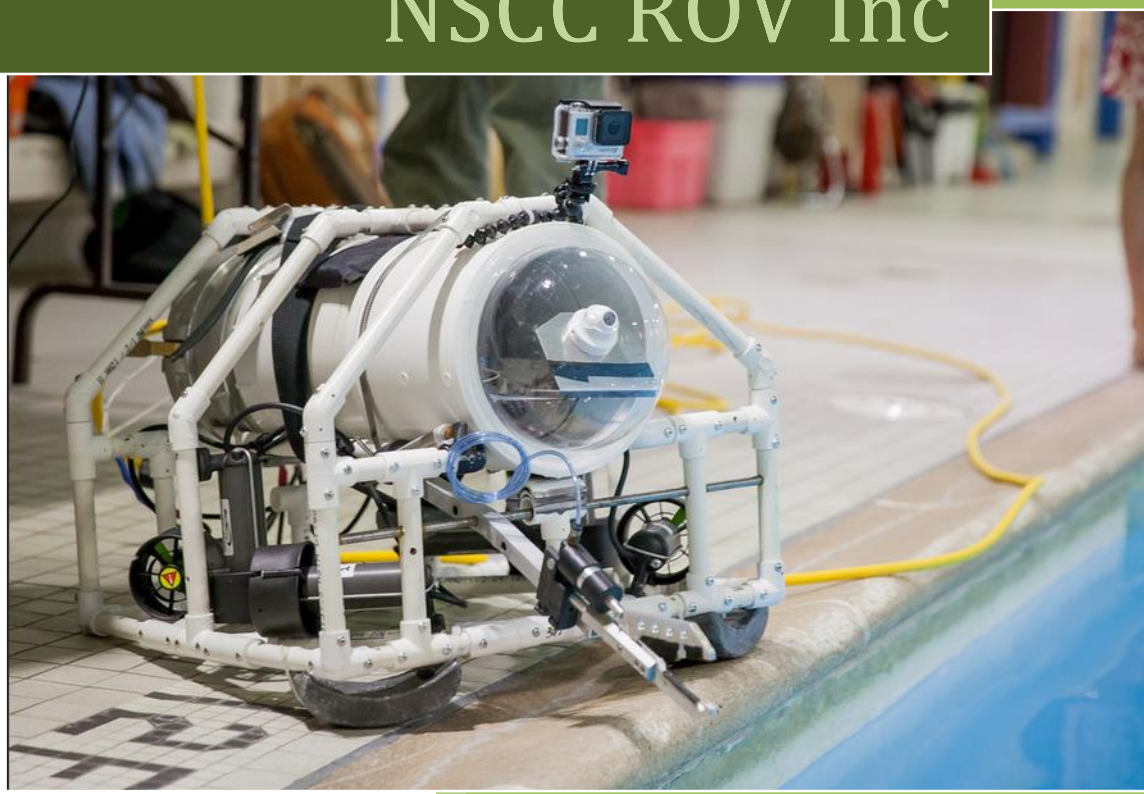
2014

Nova Scotia Community College
NSCC ROV Inc



Thunder Bay National Marine Sanctuary Alpena, Michigan

Nick Greeno -CEO (2nd Year Electronic Technology)

Andrew Gardiner-CEO (2nd Year Electronic Technology)

Jon MacDonald-COO (1st Year Electronic Technology)

Chris Langille-Electronics Lead (2nd Year Electrical Technician)

Alan Polvi –Electronics (1st Year Electronic Technology)

Barry Babin –Electrical Lead (2nd Year Electrical Technology)

Matt McNair-Mechanical Lean (1st Year Electronic Technician)

Katherine Hudak-CFO(1st Year Electronic Technology)

Wayne Douglas-Mechanical- (2nd Year Electronic Technician)

Peter Oster (Instructor/ Mentor)

Corey Cauvier (Mentor)

Abstract

NSCC ROV Inc. presents the First Person View (FPV) ROV, a remotely operated vehicle designed for the 2014 Marine Advanced Technology Education (MATE) International Competition. Engineered for conservation and exploration, the craft integrates the Oculus Rift vision system for a first person view of the underwater environment. The FPV-ROV is equipped with a pneumatic arm and task specific tooling for obtaining samples and measurements of its surroundings. Also included in the design, are several safety features to ensure the well-being of the ROV team and the preservation of the habitat in which it operates. The FPV-ROV is a versatile craft, which enables our company to explore and interact with the marine environment in addition to meeting the objectives set forth by MATE for this year's competition. Building the FPV-ROV and competing in the MATE International Competition provide the opportunity for students to apply the skills learned in the classroom to a practical application that develops teamwork, problem solving, project management, and new technical skills. Beginning with a design, and culminating in the competition at the Thunder Bay National Marine Sanctuary in Alpena, Michigan, this experience has allowed students to gain valuable practical skills that can be employed in the marine technical workforce.

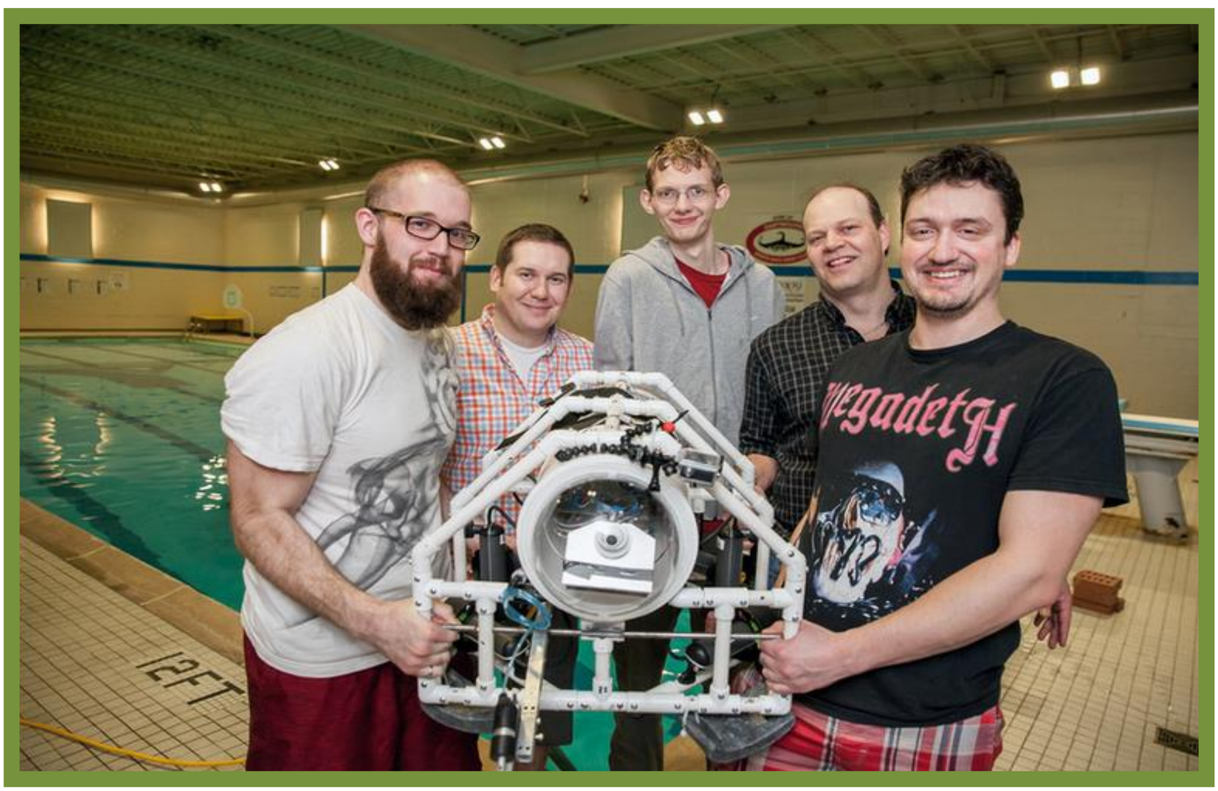


Table of Contents

Design Rationale

Structure

The built by the 2011 NSCC ROV team incorporated a metal tube for the electronics housing. Due to the new camera system and added electronics, this would not be sufficient for our needs and a new housing had to be constructed. The design rationale for the ROV structure was to keep the craft as light as possible. In order to achieve this, 1/2" PVC piping was used to construct the frame and the same material was used for the body of the electronics housing. Though a metal frame would have been more robust, it would have increased the craft's weight significantly while costing more time and money in fabrication. PVC was chosen because it is light, durable, cost effective, and easy to work with. The electronics housing dimensions also had to be large enough to accommodate the two-axis gimbal designed for the camera system. A clearance of eight inches was required to provide full range of motion resulting in 8" nominal schedule 40 PVC pipe being chosen for the housing body.

The front dome was formed using clear acrylic. This allows a clear viewing area for the camera system while keeping viewing distortion to a minimum to provide the most accurate sight picture while piloting the craft. The initial intent was to include a flange that would be secured with bolts and made waterproof by a pair of O-rings between the body and the acrylic. This would allow the dome to be removed if needed. It was later decided that removal would not be necessary and that it would be secured to the body using specific glue and instructions provided by the manufacturer. Care had to be taken in this process to prevent uneven pressure that would result in warping and cracking, making it unusable. To attach the dome, a cap was glued to the housing body to provide enough surface area for the flange to be securely glued. The center of the cap was cut out and the remaining material used to attach the dome for a waterproof fit.

The end cap of the electronics housing needed to be able to accommodate the required number of connections, sturdy enough to support the frame holding the internal electronics, and maintain the waterproof seal of the housing itself. A cast aluminum end cap was chosen and screwed on to the body using pipe dope to lubricate and seal the threads for the watertight connection. Attached to the end cap was the electronics frame, which holds the camera assembly, relay board, and electronic circuitry. This design allowed the electronics to be removed with the cap as one unit to prevent wires and pneumatic connections from getting tangled and obstructing the movement of the frame when removing or replacing the electronics for troubleshooting. The volume of the housing is a major source of positive buoyancy for the craft so the added weight of the aluminum end cap helps to counteract the effects while providing a reliable and practical solution to the electronics housing unit for the craft.

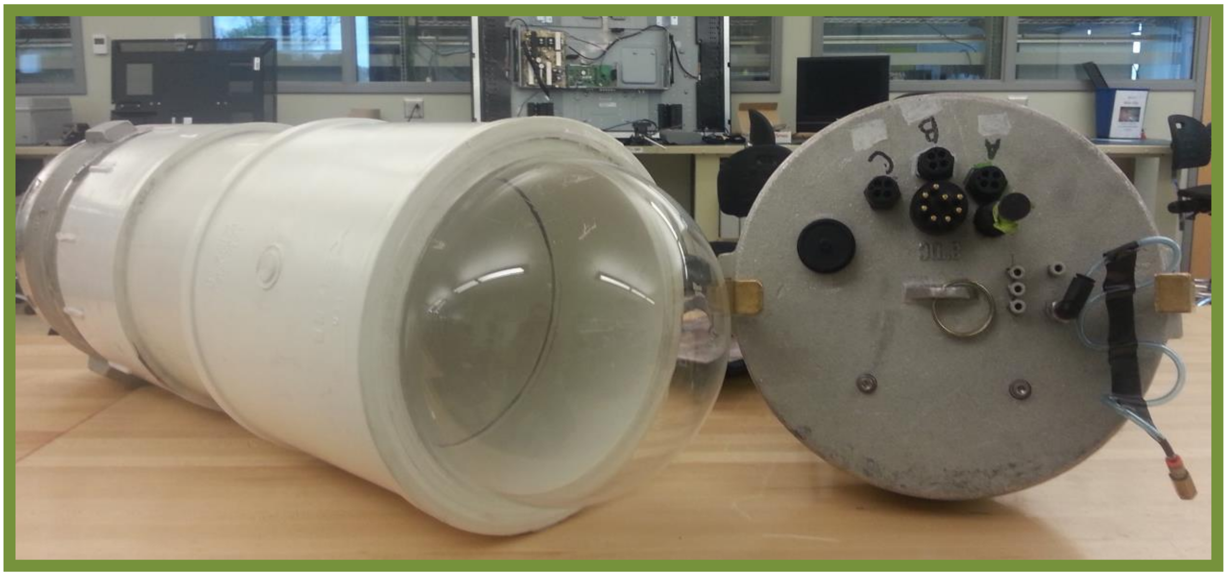


Figure 1 Electronics Housing

Control System

The company decided to keep the existing control system implemented by NSCC's previous ROV teams, while making only minor changes. Input is taken from an Xbox 360 video game controller and read using LabVIEW running on a laptop computer. The LabVIEW program (also known as virtual instrument or VI for short) uses the controller input to construct two bytes of data which it sends via serial communication, over a 75 foot tether, to a PIC microprocessor onboard the ROV. The PIC reads this data and uses it to control the electronic solenoid operation for the pneumatic arm and to control relays, which in turn operate the propulsion motors. The decision to reuse the control system was made for two reasons:

- The previous system works well and is easily understood.
- Many team members were already familiar with the Xbox controller, LabVIEW, and PIC microcontroller programming.

Controller

An Xbox 360 controller, manufactured by Microsoft Corporation, is used to control the ROV. The company voted against constructing a custom controller as it was deemed to be too time consuming and unnecessary, whereas the Xbox controller already connects to a computer via USB, is ergonomic, and is familiar to every member of the team. The Xbox controller provides more than enough inputs to accurately control the ROV during competition. There was only one change made from the previous year. The controller had to be replaced due to faulty wiring. The controller inputs are read by a LabVIEW virtual instrument.

LabVIEW Virtual Instrument

LabVIEW is a graphical programming language used to create virtual instruments (VIs). National Instruments, the creators of LabVIEW, provide a tool suite for interfacing with the Xbox Controller. This allowed for the construction of a VI by dragging and dropping icons into the LabVIEW workspace. The provided tool suite is used to read which buttons are being pressed on the controller. Each button is assigned a bit in one of two control bytes. The bits can be either 0 (digital LOW i.e. OFF) or 1 (digital HIGH i.e. ON). When a button is pressed its corresponding bit is set high. This will be addressed in the Peripheral Interface Controller **(**PIC) Microprocessor section of this report. The control bytes are constantly being sent to the PIC microprocessor via the tether, using serial communication. This allows for button presses to be recognized essentially instantly. The previous LabVIEW VI was modified to add some additional debugging features and a code to initialize the system check protocol, to be performed when the ROV is first turned on.

PIC Microprocessor

The ROV utilizes three PIC microprocessors, commonly referred to as PICs or PIC chips. They are the brains of the ROV. One PIC is used to control propulsion and the tooling arm. This is known as the control PIC. The other two PICs are used to control the two-axis gimbal for the vision system. These are known as the Gimbal PICs, and will be discussed in a later section. The control PIC reads the two bytes of data sent from the LabVIEW VI. It uses this information to control an array of 14 transistors. A HIGH bit in the data byte results in the saturation of its corresponding transistor. The transistors control relatively high voltage power lines (12 V is too high for the PIC to control) which then supply power to the propulsion motors or the solenoids which actuate pneumatic cylinders in the arm.

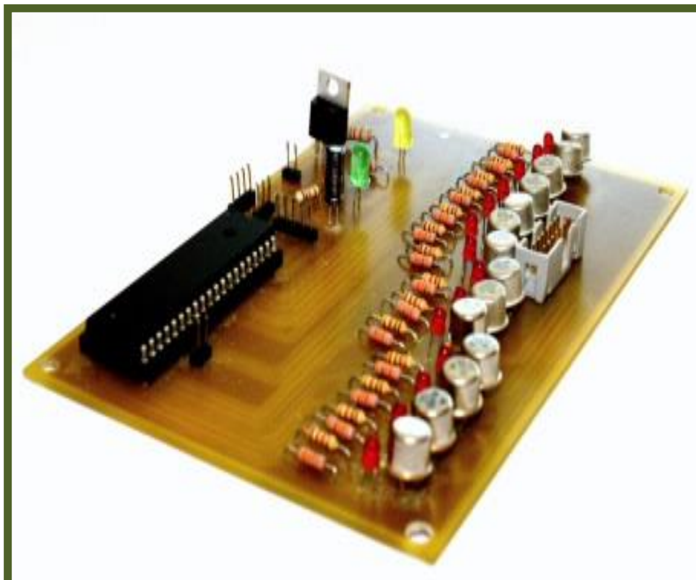


Figure 2 PIC Control Circuit Board

The PIC microprocessor and transistor circuit used is a spare from last year. The circuit board is reliable and has built in LEDs for easy debugging. The PIC Control circuit board is shown in Figure 2. The company did not feel it was necessary to create a new board. The architecture of the code used to program the PIC is very robust. Only a few changes were made, namely, a few lines of code to clear the serial receive buffer before an incoming transmission to ensure it does not get overloaded. Past teams experienced motors and tooling turning on randomly when other commands were given. This will ensure that there are no left over bits in the buffer from the last byte of data transmitted.

Mechanical

Motors

The motors selected for this years' ROV are the Seabotix SBT150 Thrusters. It was decided that the thrusters themselves would be purchased commercially due to problems that had been encountered in previous competitions as well as being an investment for future ROV teams. Three manufacturers were considered for the purchase of the motors. The Seabotix motors were chosen since they met the minimum requirements of the ROV specifications and were the most economical of the three options. Specifications considered were the Locked Rotor Amperage (LRA), Full Load Amperage (FLA), depth rating, and bollard thrust. It was necessary to ensure the LRA was below the maximum current limitations set by the MATE competition. Rated at 4.2A at 24V, six motors resulted in a total LRA of 25.2A, well within the 40A maximum. The FLA rating of 4.2A per motor is the same as the LRA for a total of 25.2A at 24V. Once again, this is well within the 40A maximum and provides enough current for the other onboard systems to function normally. The Seabotix motors also meet the depth requirements of the competition. Rated for 150 meters, the depth rating easily exceeds the 6 meter requirement set by MATE. Since the competition is timed and involves a number of objectives that require items to be moved within the competition area, including the Danforth anchor, it was important that the motors would allow the craft to move quickly and be able to accommodate the added weight of the competition props. The SBT150 thrusters are rated for 2.2kg·f, making them very efficient for their size. The six motor configuration provides sufficient thrust to carry the various items required by the competition. The motors were received fully assembled and were easily integrated into the ROV with the included 1m whip for connecting power and ground through watertight connections to the electronics housing.

The connectors required for wiring the motors had to be watertight in order to avoid short circuits while providing the number of terminals needed for the internal and external components. The quick disconnect plugs used for the craft were chosen because they were available at the school and met the requirements for the craft. Other connectors were considered, the difference being the number of pins per connector. The connections available at the school were four pin connectors while the other watertight connectors considered, provided six pins. It was decided that there were enough four-pin connectors to accommodate the connections required. With six motors in total, three connectors were required, resulting in three holes being tapped in the aluminum end cap of the electronic housing. With the connectors installed, the connections were soldered to the motor leads and then shrink-wrap was applied to ensure watertight connections.

Pneumatics

Interacting with the mission props and the competition environment are integral in performing well at the MATE competition. The majority of the tasks require manipulating props or moving items from the pool floor to the surface. Therefore, pneumatics plays a major role in this year's craft for task completion. Since the pneumatic connectors and ballast tanks were available from a previous craft, they were adapted to this year's ROV with functional and safety updates incorporated for the conservation concentration of the competition. Using the available connectors and layout from the previous craft, the team was able to save money while having an established pneumatics system to adapt rather than starting from scratch. Operating at 276 kPa as required by MATE, the pneumatics system is used to operate the craft's tooling while also providing a variable buoyancy system that functions as a fail-safe ballast system in the event of a power failure to the craft.

The pneumatic system employs a poolside air compressor to provide air to the craft via pneumatics tubing that is attached to the tether. At the craft, the supply passes through a connector in the end cap, which splits the source to three valves inside the electronics housing. The valves are operated by 12VDC signals received through the LabVIEW program, operated by the pilot, using the Xbox controller. The two valves dedicated to the tooling are normally closed while the third valve is normally open and allows air to flow to the ballast system. The pneumatic system actively exhausts the air out of the exhaust connection at the end cap, releasing backpressure acting on the valves. To operate the valves, the function is mapped to the Xbox controller, and when the signal is received, the normally closed valve opens, allowing air to pass through the manifold, operating the linear actuator to close the jaw on the tool or change the position of the arm. The arm is positioned on a fulcrum so that when the actuator moves, the arm is moved up or down while staying within view of the camera system. The program operates in a toggle mode so that the associated button on the controller can be pressed once to allow 12V to the valve, which operates the actuator. Pressing the button again will close the valve and the actuator returns to its' resting position, venting the air through the exhaust outside of the craft.

The active buoyancy system employs the normally open valve to allow air in to the ballast tanks on the side of the craft. The craft itself is engineered to be positively buoyant. When the ROV enters the water, holes in the bottom of the ballast tanks allow water to enter and air is displaced out of the top of the tanks. The normally open valve is kept closed by a signal from the program so that the pilot must allow air to enter the ballast tanks and increase buoyancy within the craft. In the event of a power failure inside the craft, the valve would lose the 12V signal keeping it closed, allowing air from the surface to pass through to the ballast tanks, increasing buoyancy and causing the craft to rise to the surface for retrieval. Including this fail safe will limit any damage the craft would incur by losing power and remaining below the waterline.

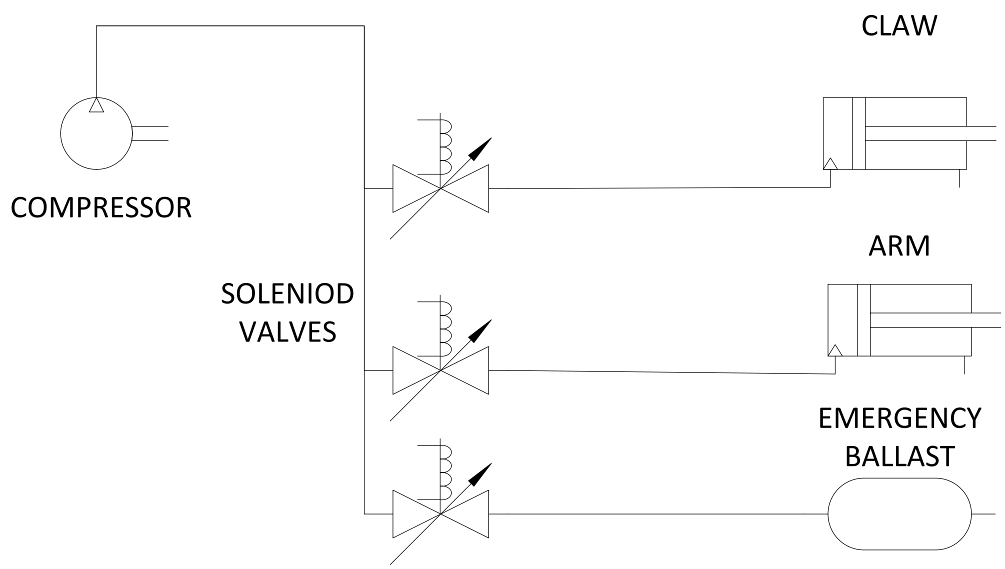


Figure 3 Pneumatics SID

Claw

Since the pneumatic system was adopted from the 2011 craft, the claw was also incorporated in to this year's design. All of the components still worked and once the frame was built, it was transferred to the new craft. The pneumatic system was then connected to test its' strength and maneuverability. After a few tests with the competition props, it was decided that some improvements could be made.

The first improvement was to have the lower "jaw", to have a wider platform. The existing setup had upper and lower components that were the same width, which was roughly 6mm, with contact points at the tip that were less than a square centimeter. The rationale behind having a larger lower platform would be for increased stability. Picking up any slim objects between two long and slender surfaces leaves the possibility of the object to pivot where either portion of the claw could act as a fulcrum. Having a larger lower platform would provide more stability, decreasing the likelihood of a collected object slipping from our grasp.

The second improvement was for the claw to be flush with the surface upon which any objects might be resting (i.e. the pool's floor). To achieve this, the point at which the lever arm was attached to our craft had to be modified. To determine where on the arm this would be, the neutral position (i.e. the lowest point at which the claw would lie) was found. A small portion of the lower jaw would be discarded, so the chosen point was one that gave us the desired cut-line. The excess of the lower jaw was trimmed off at a line slightly below ground level (the bottom of the craft). This would enable the arm to press slightly against the bottom of the pool when our craft was flush with the bottom, allowing it to scoop underneath target objects. An attachment was then designed that would go over the remainder of the lower jaw, which would compensate for the length that was removed, while keeping in mind the angle at which it should protrude. In the end, a medium between utility and simplicity was used, and the necessary measurements were taken to make a template.

It was decided that aluminum sheet metal would be the best material for the application. One piece would be cut, bent, fitted, and bolted on, using plastic spacers to create the platform wideness that was desired (4.45cm). Aluminum welding was utilized to secure selected areas. As a finishing touch, paint-on rubber was used to increase gripping ability.

Tether

In 2011 an industrial grade tether was purchased. The tether is neutrally buoyant and light weight so it will allow the craft to maintain maneuverability at long distances. It consists of four power wires and six data communications lines. The previous team found the tether to be noisy so an opto oscillator was installed in the transmission line. Doing so fully resolved the noise problems. This tether will suit the needs of the company this year and will be reused. The only modification made is the addition of a strain relief on the cable where it connects to the ROV.

Agar Sample Tool

The initial concept for the agar sample was a solenoid pump. Unfortunately it was not possible to create a system to collect the thick substance. For testing purposes the agar container (16oz. solo cup) was recreated with the bottom cut out so that it could be placed on top of the competition prop. A small funnel was connected onto the bottom of the cup where the hole pointed upwards; thus, creating a chamber in which the agar could be funneled into by the pressure of the collector cup on top of the containment cup. When this happens, the area around the funnel fills up, but the height of the funnel stops the sample from returning into the containment cup. To improve the design, a pastry nozzle was included on top of the funnel to eliminate any agar from returning into the containment cup. Side fins were attached along the sample device to break down any agar stuck to the sides of the containment cup so we may try to collect it on the next try. Finally, a soft but strong lip to the outside of the cup was added to stop any overflow of the agar thus maximizing our chances to get the most amount in the collector cup. After several tests, sample size was increased from 100ml to over 175ml of 300ml of the agar type substance (Jello) using the method above.

Vision System

With the recent developments in virtual reality, the company decided to incorporate this ground breaking technology in the ROV to create an immersive piloting experience. The vision system uses a virtual reality headset and stereoscopic cameras placed in the dome of the ROV. The cameras are attached to a two-axis gimbal which is controlled using head tracking hardware onboard an Oculus Rift virtual reality headset. Head tracking data will be read by a laptop and sent serially to two PICs. The PICs use this data to change the orientation of two servos on a two-axis gimbal via pulse width modulation. The servos will match the pitch and yaw of the pilots head in real time, as if they were sitting in the ROV.

Oculus Rift

The Oculus Rift, also referred to as Rift for short, is a head mounted virtual reality system. The device displays two video feeds side by side, approximately 7 cm to 10 cm from the user's face. A magnifying lens, one for each eye, ensures that the right eye only sees the right video feed and the left eye only sees the left video feed. This causes the user's brain to interpret the video as a 3D signal. This is shown in the diagram below.

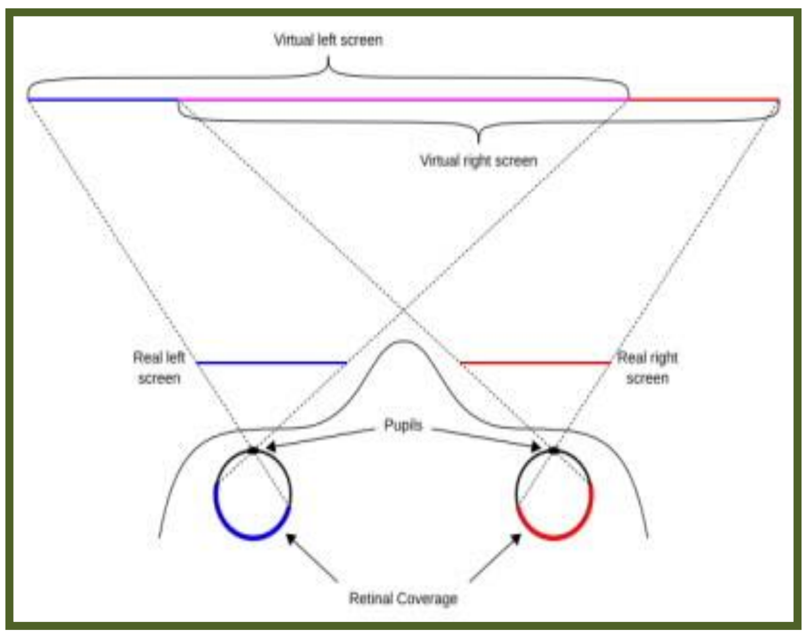


Figure 4 Oculus Rift

The Rift includes hardware used to track the users head position via an accelerometer, magnetometer, and gyroscope. This information is used to control the position of the cameras onboard the ROV. The company felt that the ability to reposition the cameras, without having to move the ROV, would give the pilot a more natural experience, akin to making a shoulder check while driving a car.

Gimbal

The company found many two and three axis gimbals available for purchase. However, they were too big, too expensive, or not robust enough. For this reason, it was decided that the company would build their own two-axis gimbal. The gimbal was designed using components familiar to the team members that were readily available at NSCC. For this reason, it had to be designed to fit inside an 8” nominal, schedule 40 PVC pipe. Preliminary design sketches are shown below.

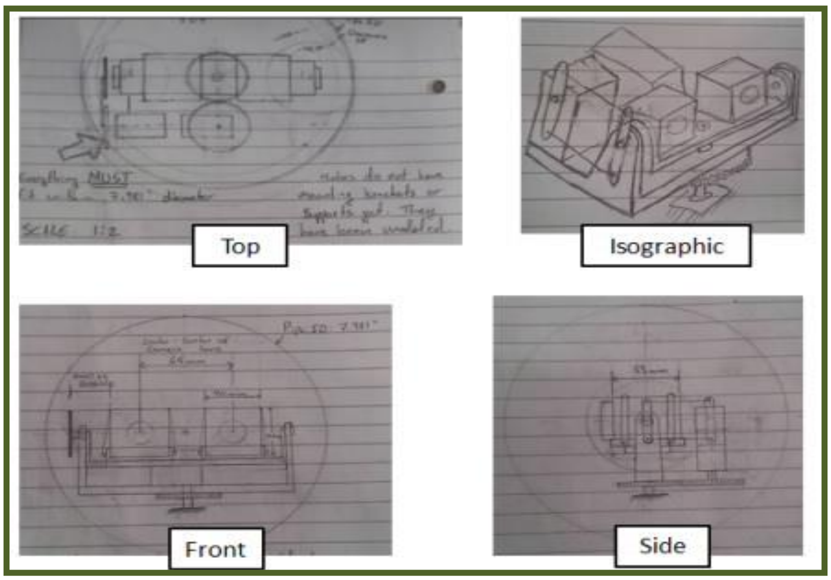


Figure 5 Gimbal Sketches

Initial designs show the use of both four-bar mechanisms and gears to position the gimbal. Gears were designed and attempted to be printed out of Cobalt Chromium using a 3D printer. Unfortunately, the printing failed. Four bar mechanisms made out of spring steel proved to accomplish the goal, and were much cheaper.

Gimbal PICs

Two of the three PICs onboard the ROV are used to manipulate the gimbal. One pic controls the pitch and one controls the yaw. Each pic receives the same data string. There is a control character that signals to the PIC when the pitch or yaw information is being sent. This setup up was chosen such that the gimbal could be maneuvered in two directions at the same time, which would reduce latency in signal transmission. Preliminary research showed that a system with high latency, i.e. lagging camera movements, could cause disorientation and nausea for the pilot.

Cameras

The cameras are an integral part of the project. If they do not meet the specifications of the Oculus Rift they will not only cause the pilot to feel nauseous, but they will make the ROV un-pilotable due to low resolution video combined with choppy frame rate. The recommended specifications for cameras to use for the Oculus Rift and ROV are as follows:

Oculus Rift Specifications:

- Resolution: 800x600 pixels per camera

  This is the per-eye resolution of the OR. This can be over spec'd as it is easy to down sample and will provide some future proofing for the design.

- Sensor aspect ratio: 1.33:1

  This will match each eye of the Rift's display. It is preferred over Full HD which has an aspect ratio of 1.78:1. The side-by-side stereo used in the rift has 1 ratio term as the horizontal dimension and the 1.33 term as the vertical. Therefore, the cameras should be rotated 90° to achieve the best results.

- Field of view (FOV): 120°

  The OR has a FOV of 90°. Using a camera with an aspect ratio of 1.33:1 and FOV of 120° will yield 90°on the lesser dimension.

- Frame Rate: 60 fps

  The refresh rate of the Oculus Rift's screen is 60Hz, this also boarders the limits of the human eye. Having significantly less frames per second (FPS) will result in unsmooth video and could cause nausea.

ROV Specifications:

- Lens: Infinite Focal Length with Auto-Focus

  The ROV will need to focus on objects in range of 30 cm to 10 m. in order to accomplish this a lens with infinite focal length will be required.

- Size: 50x50x50 mm max

  A board-level camera without bulky components on the back of the board would be ideal. Both cameras need to fit side by side on the gimbal, which will be rotating inside the hull of the ROV. Real-estate inside the craft will be scarce.

- Interface: USB3.0 or GigE

In order to transmit HD video with as few losses as possible, the video signal will need to be transmitted via USB 3.0 or GigE. Icron Technologies has graciously donated their Spectra USB 3.0 extender so USB 3.0 cameras will be used.

Due to the company's limited knowledge in camera hardware, serious issues were encountered with choosing the proper cameras. This is explained further in the technical challenge section.

Electronic and Electrical

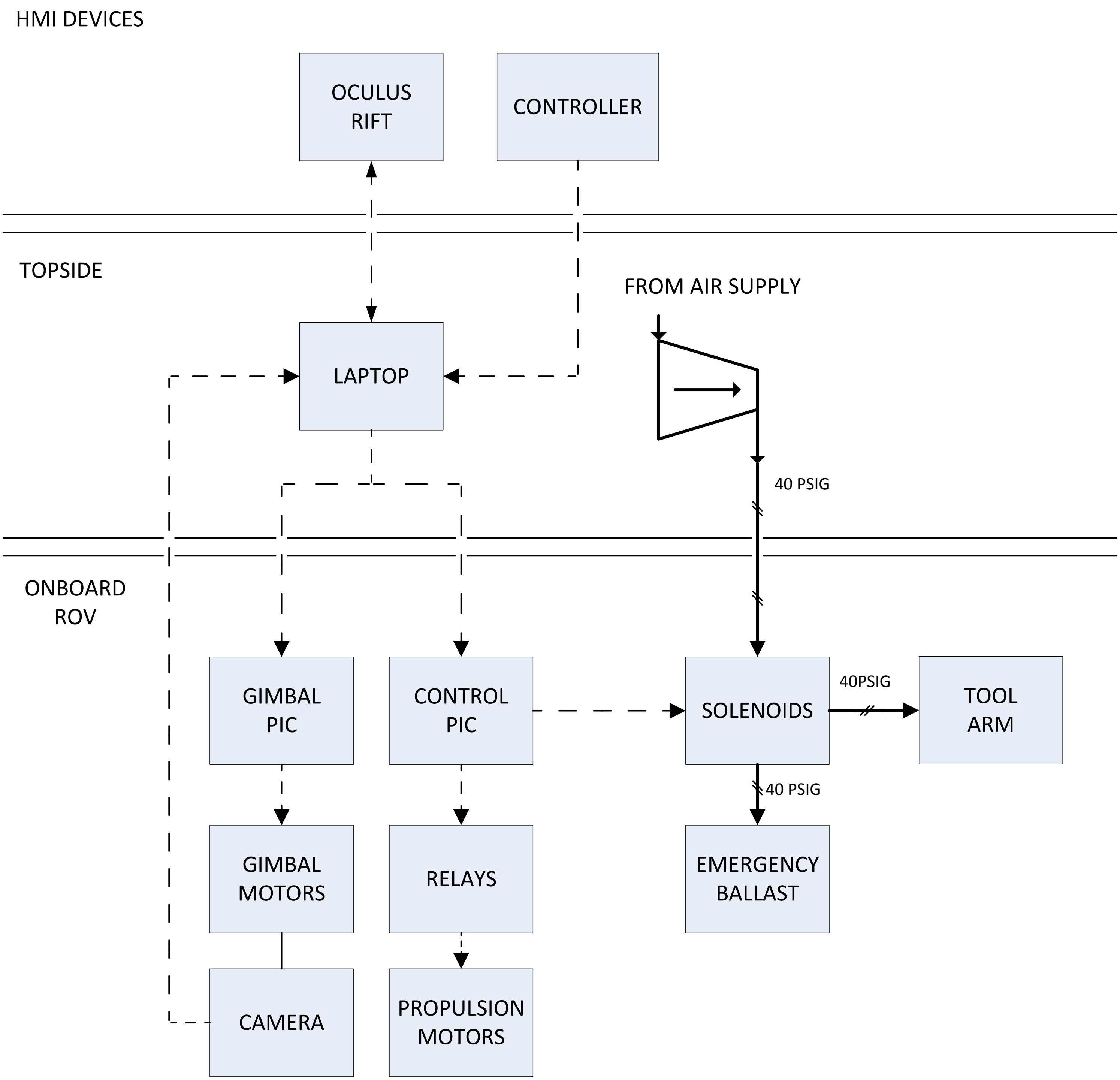
Relay Board

Since new thrusters were purchased for this year's craft, a new relay board had to be designed and milled by the team. MOSFETs were considered for controlling the motors but it was decided that the potential for overheating made the option undesirable and relays were used. Relays allow for a simple, reliable circuit that suits the operation of the DC motors. The previous relay board employed double pole double throw switches. To meet the size specifications of the electronics housing, single pole double throw relays were chosen. For safety concerns, the current rating of the relays was doubled to prevent potential hazards with the relays as well as prolonging the life expectancy of the coils. The coils were arranged in H bridge circuits to allow the motors to operate in both directions with diodes in line to prevent back Electromotive Force (emf) damaging the coils. The relays are activated by signals received through the PIC which supplies 12VDC to the four horizontally positioned motors or 24VDC to the two vertically positioned motors. The motors are operated in full on and full off modes, pulse width modulation was not considered since time is a major factor in the competition and practice piloting the craft would overcome any control issues. In addition to the relay circuits, the board also includes paths for operation of the pneumatic system on board. The pneumatic valves which permit air to flow through the system are operated by a 12VDC signal which is received via the PIC through terminals connected to the board. Producing the relay board provided technical challenges but the result was an efficient, reliable, and necessary addition to the craft.

Conductivity Sensor

Our conductivity sensor was designed around using the AD670JN 8-bit ADC to compare the resistance of the water to the value of an accurate known resistor. The AD670JN was biased using a voltage divider circuit with the voltage drop across a known resistor being compared to the voltage drop across the water. The chip output an 8-bit binary number which is sent through a multiplexer and returned to the control station. The 8 bit binary value is feed into lab view where it is converted into a percentage of the known resistor. This value is then used to calculate the conductivity of the water.

ROV SYSTEM OVERVIEW BLOCK DIAGRAM



Safety

Safety is a primary concern for the company, so it was made sure that safety measures were integrated into all aspects of the craft and the construction process. The craft is equipped with an inline fuse from the main power supply to protect the device from any possible power spikes. If the craft does lose all power an emergency ballast system will automatically surface the vessel. The six motors are all shrouded to prevent any accidental contact with moving parts that may result in injury. The components used in the pneumatic system are all rated well over the 40 PSI used during the operation of the craft. The pneumatic system is also feed through solenoids that will vent pressure to stop pressure from building past safe limits and causing damage to any components.

During the construction of the craft safety measures were strictly followed. Proper Personal protective equipment (PPE) was worn anytime power tools were in operation and proper safety practices were used whenever power or hand tools were in use. Soldering was a task required during the construction that posed possible injury. Soldering was only performed in dedicated areas equipped with proper ventilation and specialized surface. While working on the electrical system various safety measures were used. The work was only performed by students experienced with working with circuits and was never performed alone. When pneumatics were in use the student certified in pneumatic safety was always present. The ROV is only moved by two people using proper lifting techniques as it is heavy enough to cause injury when lifted by one person.

Safety Check list	
1. Visually inspect ROV for damage	
2. Check fuse is properly installed	
3. Connect tether to ROV and control station	
4. Verify strain relief is properly secured to tether	
5. Verify pneumatic source is properly connected and in good condition.	
6. Check all electrical connections	
7. Clear the area around the ROV	
8. Power up ROV and test motors and camera are operating properly	
9. Put pressure to ROV and test claw is working properly	
10. Run BIT (built in test)	
11. Clear area between ROV and launch site	
12. Have two people Use proper lifting technique s to move ROV to pool side	
13. Have two people launch ROV	
14. Verify pneumatic and electrical and visual systems are operating properly once submerged	

Table 1 Safety Check List

Budget

Phase	Component	Cost	Condition	Notes
ROV: Prototype	PVC Frame	$50.00	Reused	
	Cameras	$100.00	New	
	Trigger fish ROV kit	$540.00	New	
Reused Total		$50.00		
New Total		$640.00		
Sub Total		$690.00		

Phase	Component	Cost	Condition	Notes
ROV: Competition	Motors	$4,297.00	Reused	
	Oculus Rift	$300.00	Reused	
	PVC Frame	$50.00	Reused	
	Buoyancy	*$25.00*	Reused	Donation
	Tools and Misc	*$500.00*	Reused	Donation
	Spectra USB 3.0 Extender	*$748.00*	Reused	Donation
	75' Fibre Optic Cable	*$50.00*	Reused	Donation
	Laptop	$1,034.99	New	
	Xbox Controller	$36.21	New	
	Connectors	$184.00	New	
	Electronics	$745.00	New	
	Dome	$100.00	New	
	Tether	$162.00	New	
	Cameras	$600.00	New	
Donation Total		$1,323.00		
Reused Total		$5,287.00		Not including donations
New Total		$2,862.20		
Sub Total		$7,957.20		

Phase	Component	Cost	Notes
Competition Expenses	Air Fare	$5,720.00	
	Bus Travel	$2,100.00	
	Van Rental + Gas (Aprox)	$800.00	
	Food and Accommodations	$1,600.00	
	Shipping	$700.00	
Sub Total		$10,920.00	(Expected)

TOTAL COST	$19,567.20	Expected

Funds raised	Local Hockey Team	$1,000.00	
	NSCC	$5,800.00	
	NSCC SA	$300.00	Awarded upon rectification of ROV Society

Challenge

Technical Challenge

One of the biggest technical challenges the company faced was with the cameras. To achieve the best results with the Oculus Rift it was determined that the single CCTV style camera on the ROV would have to be upgraded to two high definition cameras, capable of streaming video at 60 frames per second. Many cameras on the market meet this specification; however, transmitting the video footage to the surface, over 75 feet of cable would prove to be quite difficult.

The first challenge was deciding how to transmit the video signal. A Canadian based company, Icron Technologies Inc. offered to donate one of their Spectra USB 3.0 extenders. They also introduced the company to Lin Huay and Lumenera, who would donated 75 feet of fiber optic cable and two high end cameras, respectively, to be used in the competition. This seemed like the ideal solution and the company proceeded.

Due to some complications in communication between Lumenera and the company, cameras were improperly chosen. The cameras met the specifications, however, it was not disclosed that they would need lenses with additional hardware to control the focus. For this reason they would prove to be unusable.

The company looked at using GoPro cameras. The school had a few for another program that were used for testing. Unfortunately, they would require too many converters to be a viable solution. The GoPros only stream video via an HDMI output. This would have to be converted to USB 3.0 to interface with the extender, and then converted back to HDMI in order to interface with a capture card attached to the Laptop. This would have to be repeated for each video feed which would be far too expensive.

The only viable solution was to get a second CCTV camera and a dual channel RCA capture card. This will result in lower quality video signal, but allow the team to continue using the Oculus Rift.

The recommended solution is to use a 360° high definition camera, such as the Giroptic 360 panoramic camera. This particular device is an array of three cameras, simultaneously streaming or recording, and stitching the video feeds together, capturing a 360°x 300°sphere of video. The user, or ROV pilot, can then pan digitally during the live stream or video playback. This will eliminate the need for a two-axis gimbal. The camera is compatible with the Oculus Rift, allowing for the immersive piloting experience desired by the company without any additional coding. Furthermore, due to its small footprint, the size of the circuit housing can be reduced giving the ROV more maneuverability. The Giroptic camera will be capable of transmitting video over Ethernet, which is how the current camera system works. It will not be available as a commercial product until November 2014.

Non-Technical Challenge

A major challenge over the course of the year involved maintaining a stable number of team members and continuous commitment of the members to the ROV team. The beginning of the school year saw an excellent turnout of interested students from several disciplines within the college. As the year progressed, fewer members were able to commit to team meetings and attendance continued to decline. The result was a reduced depth of skills within the team and higher workload per member. Fortunately, those members that remained were committed and accepted the challenging conditions in stride. In order to overcome the challenges of a small team, communication was improved significantly by regularly updating all members of individual progress while also consolidating work on major components to the team as a whole. This provided a larger knowledge base to overcome the challenge and continue with the project. As a result, cross discipline knowledge significantly increased and each member developed a more thorough understanding of the ROV and its' individual systems.

Lesson Learned and Skill Gained

In preparation for the MATE competition there have been several non-technical and technical lessons learned and skills gained. As a non-technical lesson/skill, project management has proven to be a significant contributor. Planning a project with a team of people from various disciplines has developed leadership and communication skills among all members of the team. Setting goals and time lines is a must for a successful project. It is also important to tailor to each member's skills while providing as many learning opportunities as possible to make the most of the experience. Communicating within the team is important, but being able deal directly with suppliers has also proven to be an invaluable skill. Determining the suitable material or connector for a certain part of the craft and then finding a supplier for that item at a reasonable price is a must when developing a product like the ROV. Technical lessons and skills include the milling of printed circuit boards (PCBs) and developing fabrication skills. Multiple iterations of the completed relay PCB had to be milled prior to the final product. Inadequate spacing of the physical connections between the relays caused issues with the footprint of the PCB. Thorough planning when creating parts will prevent the loss of time and money, allowing the project to stay on track. Finally, fabrication skills were an important aspect of developing several portions of the ROV. Care had to be taken to properly tap the end cap for the waterproof connectors while the acrylic dome had to be glued using a specific set of instructions to avoid cracking once the glue had dried. Building an ROV is a very hands on project and the skills developed here will play a major role in future projects.

Future Improvements

Future improvements for the ROV include an improved claw tool and additional sensors. The current claw is adequate for the tasks involved at this year's competition. An improved, more articulated claw would allow for greater dexterity and increased function for a wider range of applications. The current two-jaw claw would be replaced with three jaws for better gripping of objects underwater. The claw would also incorporate the ability to rotate, allowing the craft to remain stationary while the tool moves as required to manipulate objects. A worm gear could also be incorporated to reduce the requirement of pneumatics for operation. Including more sensors in to the ROV would provide a more complete report on the environmental conditions within the electronics housing as well as obstacle detection outside of the craft itself. Environmental sensors would provide early detection of leaks or faults within the craft while obstacle detection sensors would allow a more complete spatial recognition without the addition of extra cameras. The detection sensors would also allow the craft to operate in more confined and fragile spaces where the environment must be impacted as little as possible.

Troubleshooting

A troubleshooting technique that was employed while building the ROV was the half split method. An issue arose when testing the craft that a specific motor would cut out unexpectedly. The initial assumption was a short in the connection but the half split method was used to determine the fault. Since the ROV involves above and below water components, the halfway point was to determine if the craft was receiving the signal at the motor connections on the end cap. Using a multimeter, it was found that no voltage was present indicating the fault was contained to the above water components. Again, the halfway point was found, this time being the laptop. The program provides an LED indicator to show the operation of the controller. The LED indicator was not consistently displayed for the specific function, while other functions were working normally. This symptom indicated a problem with the controller. A new controller replaced the expected faulty one, removing the fault. The faulty controller was taken apart and a short was found. Research online showed that this was a common fault caused by storing the controller with the USB cord wrapped around the controller, applying unnecessary stress to the connection.

For troubleshooting purposes, a Built in Test (BIT) has been incorporated into the LabVIEW VI which controls the ROV. This test is a programmed verification of the ROV's systems. It is used to turn on each motor in succession, followed by the pneumatic system check which operates the claw, arm, and emergency ballast system. Conducting the BIT involves every aspect of the craft, ensuring it is ready for operation each time the craft is powered up.

Reflections

Living so close to the ocean, marine technology plays a major role in the industry of our city. Participating in the ROV team has given each of us a taste of what that industry is, and how we can establish a place in it as we move forward with our careers. It has given us the opportunity to work with new technologies, interact with suppliers, learn from our mentors and see a project through to the end.

Overall, it has been a great process. Coordination is a big thing that needs to occur. People on the team have different schedules, including school, work, homework, and other obligations. We sometimes struggled to maintain dedicated blocks of time to all work together on our tasks, and it often seemed that things were easily prolonged. This wasn't solely due to students, though- sometimes we had to wait on parts, or information, or a combination of the two. Money was another thing we had to keep in mind. While we didn't struggle much to maintain our budget, more money would definitely have changed a few things on the craft.

Time management is something that goes hand-in-hand with coordination, which is something else we could have improved upon. It is easy to look ahead at the calendar, and say "great, we have another 6 months to go." As deadlines near, it's easy to see how time could have been used more efficiently (hindsight is 20/20). We look forward to applying our lessons learned to next year's team and continuing to be a part of the MATE competition.

"I was unsure of exactly what I would be able to bring to the table, but I was sure of the fact that I wanted to take something away from it."

Matt McNair (1st Year Electronics Technician)

"I wish that I was a student again next year so that I could complete any unfinished goals and also have more knowledge from the start."

Andrew Gardiner (2nd Year Electronics Technology)

Acknowledgments

Peter Oster- Instructor/Mentor

Dale Jollimore- Instructor/Mentor

Corey Cauvier- Mentor

Ocean Technology Council of Nova Scotia (OCTNS)

Nova Scotia Economic and Rural Development and Tourism (NSERDT)

Nova Scotia Community College (NSCC)

Nova Scotia Community College Student Association (NSCCSA)

Surface Mount Technology Association

NSCC Marconi Campus Hockey Team

Icron Technologies Corporation

Lin Huay

Boston Pizza

Survival Systems

Bibliography

Bell, C., & Bayliss, M. (1997). *Handbook for ROV pilot/technicians* (Rev. 2d ed.). Ledbury, Herefordshire, England: Oilfield Publ. Ltd..

Christ, R. D., & Wernli, R. L. (2007). *The ROV manual a user guide to observation-class remotely operated vehicles*. Amsterdam: Butterworth-Heinemann.

Last, G., & Williams, P. (1991). *An introduction to ROV operations*. Ledbury, England: Oilfield Publications.

Moore, S. W. (2010). *Underwater robotics: science, design & fabrication*. Monterey, CA: Marine Advanced Technology Education (MATE) Center.

Angeli, E., Wagner, J., Lawrick, E., Moore, K., Anderson, M., Soderlund, L., & Brizee, A. (2010, May 5). *General format*. Retrieved from http://owl.english.purdue.edu/owl/resource/560/01/

Oculus Rift, Inc. *Oculus Rift Development Kit, Version 1.1.* Retrieved from static.oculusvr.com/sdk-downloads/documents/Oculus_Rift_Development_Kit_Instruction_Manual.pdf

Oculus Rift, Inc. *SDK C API Overview.* Retrieved from static.oculusvr.com/sdk-downloads/documents/Oculus_SDK_Overview_0.3.1_Preview.pdf

Oculus Rift, Inc. *Oculus VR Best Practices Guide.* Retrieved from static.oculusvr.com/sdk-downloads/documents/OculusBestPractices.pdf

Microchip. *PIC16F882/883/884/886/887 Datasheet.* Retrieved from http://ww1.microchip.com/downloads/en/DeviceDoc/41291G.pdf