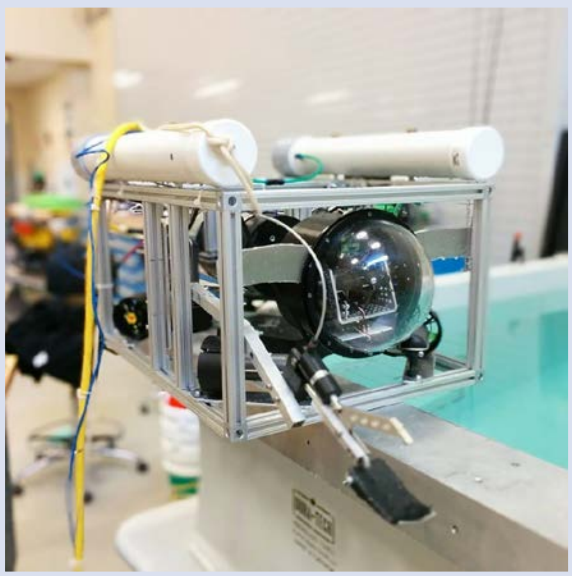
2015 INTERNATIONAL MATE ROV COMPETITION

NOVA SCOTIA COMMUNITY COLLEGE

ST.JOHN'S NEWFOUNDLAND AND LABRADOR, CANADA JUNE 25-27 2015

SCIENCE AND INDUSTRY IN THE ARCTIC

DEEP HARBOUR RESEARCH



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Abstract

Deep Habour Research proudly presents the First Person View (FPV) ROV, a remotely operated vehicle designed for the 2015 Marine Advanced Technology Education (MATE) International Competition held at Memorial University in St. John's Newfoundland. The FPV ROV has been designed to work in harsh Arctic waters and currents. The craft includes a visual system that includes the Oculus Rift vision system giving the pilot a first person view of their surroundings; thrusters in a vectored formation to combat arctic currents; a loaded sensor suite with heads-up display (HUD) to aid the pilot and co-pilot in navigation; as well as several mission specific tools to complete the competition tasks. Competing in MATE International Competition allows company members to use the skills they have learned in their various disciplines to build, design and test a craft they built on their own. It provides them with the experience and knowledge to enter the workforce confident in their abilities.

FIGURE 1: TEAM PHOTO BACK ROW LEFT TO RIGHT, ROBBIE AGGAS, BLAKE BENNETT, ALAN POLVI, MALCOM SURETTE, ERICA BARBER. FRONT ROW LEFT TO RIGHT ZACH VIVA, ADAM WHYTE, KATHERINE HUDAK, JON MACDONALD

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Safety

Safety is one of the main concerns of Deep Harbour Research. For this reason it was taken into account in all aspects of the design, construction and testing of the craft. Some safety features of the craft are;

- There is an inline fuse between the main power supply and the FPV ROV to protect from any sort of power spike.
- If the craft loses power, the emergency ballast system will activate and cause the craft to surface.
- The motors are shrouded in order to prevent any object or person from coming into contact with the blades.
- All pneumatic components are rated over 100 PSI.
- Lasers operate on a momentary switch so they cannot be left on.

Safety of team members is also very important to Deep Harbour Research. Work was only done after ensuring that the task could be and would be carried out safely. For example

- Proper Personal protective equipment (PPE) was worn when using power tools or the in house PCB milling machine. .
- Along with proper safety practices being used whenever power or hand tools used.
- Soldering was performed on specialized surfaces, in well ventilated areas while wearing safety glasses.
- No soldering or operation of power tools was ever done alone. Two team members were always present.
- When using pneumatics, the team member certified in pneumatic safety was always present.
- Two or more team members were present when moving the ROV.
- When operating lasers, proper eye protection was worn.
- All team members had completed WHMIS and OSHA training.

Emergency Recovery Procedure

In case of primary camera failure:

1. Determine cause of fault with aid of internal sensors.
2. If craft is deemed fit to continue, proceed mission with back up camera.
3. If craft is deemed unfit, use the backup camera to aid in recovery.

If main enclosure preliminary temperature (60°C) warning is tripped:

1. Reduce speed of craft to limit heat
2. Continue to monitor temperature closely.

In case of complete camera failure and/or internal sensors indicate a catastrophic issue (example leak or over temperature):

1. Power is immediately cut to the craft.
2. Emergency ballast are engaged.

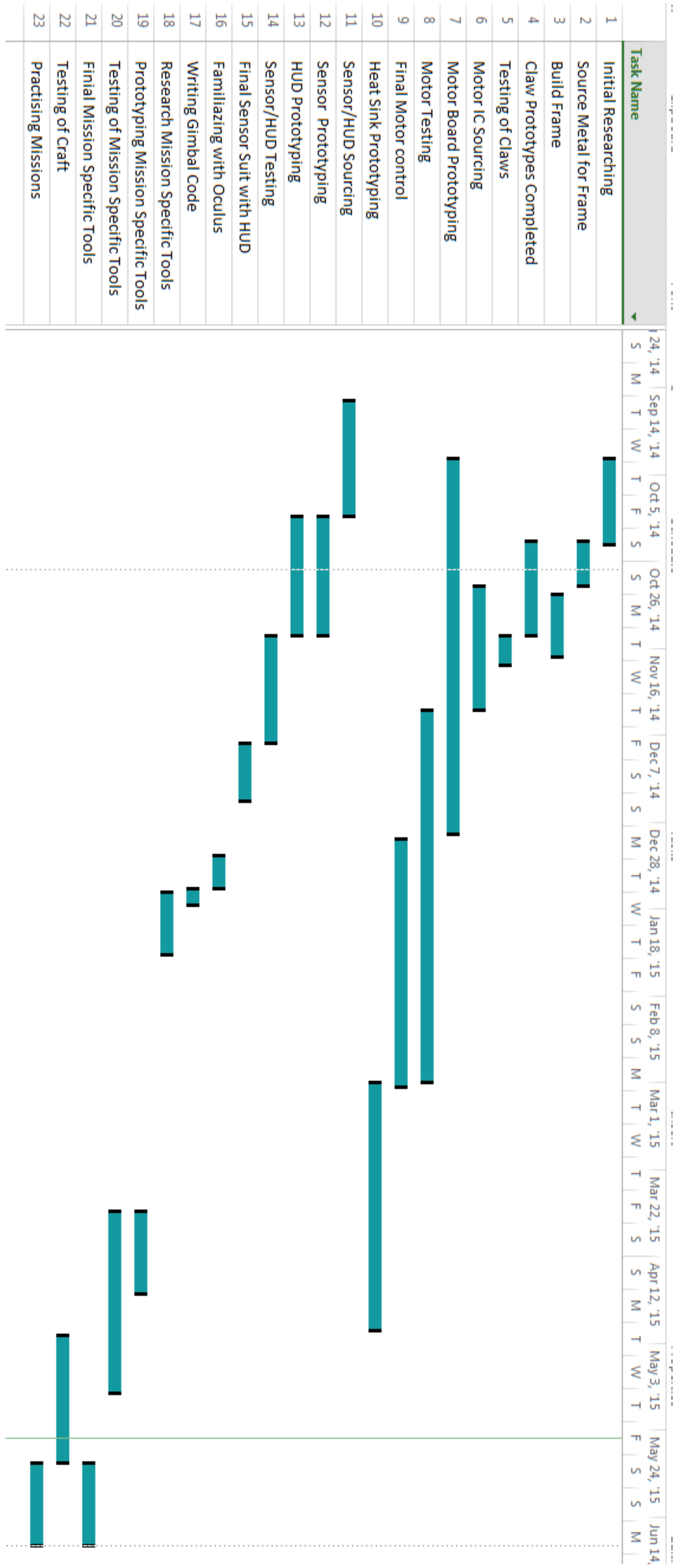
Safety Checklist

Prior to powering the ROV	
Do a visual inspection of the craft	
Check the inline fuse	
Check all connections and cables for damage	
Verify strain relief is attached properly	
Inspect the pneumatic connections	
After powering up the ROV, before launch	
Check to make sure camera and monitors are working correctly	
Check to make sure thrusters are working correctly	
Check to make sure LabVIEW is receiving the data from the sensors.	
Test the Claw	
Clear area around ROV and path to pool	
Two team members launch the ROV	
After launch	
Check sensor readings for indication of leak	
Test thrusters	
Before Retrieval	
Cut power to ROV	
Have two people retrieve ROV from water	
After Retrieval	
Check ROV for mechanical damage	
Check connections	

Budget

Qty	Type	Category	Expense	Description	Notes	Price per Unit	Amount
1	Purchased	Sensors	Compass	IMU 10 DOF	Used in sensor suite	$43.89	$43.89
2	Purchased	Sensors	Proximity Sensor	I2CXL-MaxSonar-WRC Weather Resistant Sonar	Used in sensor suite	$105.82	$211.64
2	Purchased	Sensors	Internal Humidity and Pressure	Phidgets Humidity/ Temperature Sensor	Used in sensor suite	$50.00	$100.00
1	Purchased	Sensors	External Temperature and Pressure Sensor	MS5541-CM	Used in sensor suite	$32.82	$32.82
3	Purchased	Sensors	Laser Diodes		Used to build laser	$4.24	$12.72
2	Purchased	Frame	Head Cap Screw	Type 316 Stainless Steel Socket Head Cap Screw		$5.68	$11.36
16	Purchased	Frame	3-Way External Connector	3-Way External Connector		$9.86	$157.76
16	Purchased	Frame	Ball Fastener	Spring Loaded Ball Fastener		$1.12	$17.92
12	Purchased	Frame	Drop-in Fastener	Drop-in Fastener with Stud		$1.52	$18.24
20	Purchased	Frame	Cable Tie Holder	Cable Tie Holder		$0.72	$14.40
8	Purchased	Frame	Aluminum T- Slotted Framing Extrusion	Aluminum T- Slotted Framing Extrusion		$17.75	$142.00
1	Purchased	Frame	Wye Inline Connector	Wye Inline Connector		$17.75	$17.75
1	Re-used	Frame	Bubble	Repurposed		$300.00	$300.00
1	Re-used	Frame	Dome	Repurposed		$150.00	$150.00
1	Donated	Frame	Housing		Donated by Romor Ocean Solutions	$3,500.00	$3,500.00
6	Purchased	Motor	MOSFET motor controls	MC33886		$8.19	$49.14
6	Re-used	Motor	Motors	Seabotix Thrusters		$716.00	$4,296.00
2	Purchased	Control System	Ardunio Mega 2560		One for sensor suite, one for motor control	$47.04	$94.08
1	Re-used	Control System	Laptop	Re-used from 2014's craft		$1,034.99	$1,034.99
1	Re-used	Control System	Xbox Controller	Re-used from 2014's craft		$36.21	$36.21
1	Purchased	Camera	Waterproof Analog			$200	$200.00
1	Purchased	Camera	USB extenders			$236	$236.00
2	Purchased	Camera	Mobius ActionCam			$86.99	$173.98
1	Re-used	Camera	Oculus Rift	Re-used from 2014's craft		$300.00	$300.00
1	Re-Used	Camera	Video Overlay Board	MAX7456		$35.95	$35.95
1	Purchased	Pneumatics	Pistons			$11.52	$11.52
1	Re-Used	Pneumatics	Solenoids	Re-used from 2014's craft		$36.00	$36.00
1	Re-Used	DeckBox		Repurposed		$100	$100.00
1	Donated	Tooling	Blige Pump		Donated by NSCC	$22	$22.00
2	Donated	Tooling	Claw	2 hours man labour	Built in house(NSCC)	$100	$200.00
1	Purchased	Travel	Plane Tickets for team members	7 tickets		$2,500	$2,500.00
1	Purchased	Travel	Ferry ticket	ROV plus two mentors		$2,000	$2,000.00
1	Purchased	Travel	Memorial Dorms	9 people		$1,900	$1,900.00
1	Cash Donated		NSCC student association				$1000
1	Cash Donated		Geoforce				$250
				Total Purchased			$7,945.22
				Total Re-used			$6,289.15
				Total Parts Donated			$3,722.00
				Total Cash Donated			$1250
				Final Amount (not including cash donated)			$17,956.37

Gantt Chart



Gantt chart showing the intended timeline

Design Rationale

The FPV ROV was designed for work in Arctic waters. For this reason all components were chosen with arctic temperatures in mind. Exterior parts were chosen to decrease drag and increase control when exposed to currents. Work on the craft began as individual projects designated to specific student groups. The craft was broken into three major components propulsion, sensor suite, and mechanical. These groups originally worked independently but as the individual systems began to come together system integration was worked on by the team as a whole.

Motors and their Control

The thrusters used in the maneuvering of the craft are the Seabotix BTD 150 continuous bollard shrouded thrusters. These thrusters are mounted in a vectored formation allowing for four thrusters to contribute to all lateral movement, leaving the remaining two thrusters to handle all vertical movement. The BTD150 thrusters used in this configuration performed well in maneuvering last year's craft.

The harsher conditions found in this year's competition required a more sophisticated control scheme. The relay based system used in 2014's craft was replaced with a MOSFET based system. The mission has simulated arctic currents that the motors have to battle, in response to this, the new motor design utilized power MOSFETS to maximize the craft's potential thrust and to increase the overall control in the simulated currents.

Switching to power MOSFETS was a major upgrade for the craft, it maximized functionality while decreasing the overall physical size. The increased functionality came from the ability to reverse the polarity to each thruster individually, giving bi-directional control of each motor. This was accomplished using H-bridges. The previous design was also limited since it only allowed the thrusters to operate at either full on or full off. The new design allows for the implementation of variable speed and bi-directional motor control. Variable speed offers the pilot more control over the crafts operation while attempting to steer in the simulated currents. Bi-directional motor control maximizes the craft's potential thrust by allowing all four of the horizontal motors to work together. The control system does this by using two of the motors to push the craft while the other two pull.

After attempting to design and implement a custom H-bridge complete with circuit protection a local ROV expert was consulted. He suggested a few different ICs which could be utilized as motor drivers for the craft. After researching the suggested ICs the MC33886 was chosen. It allowed the team to employ the new specifications of the control system and could power the motors with the Pulse Width Modulation (PWM) output from the Arduino. Using the MOSFETS in conjunction with the PWM output from the Arduino allows the thrusters to be run at various speeds based on the controller's input.

MOSFETS switch at very high speeds, this characteristic while being vital to the craft's design also created other issues to be dealt with. The internal resistance of the MC33886 causes the ICs to dissipate large amounts energy in the form of heat. Due to this characteristic, heat sinking became a large aspect of the motor control board design.

The MC33886 motor controller features an exposed metallic pad on the underside of the package for heat dissipation. This feature presented several options that could be implemented into the design to properly sink all the heat produced by the MOSFET. The initial design, was to have the control board itself being the heat sink, was fabricated and tested with the Seabotix BTD 150 under a full load. During the testing, the temperature rose to 100°C after just a couple minutes of continuous use. The MC33886 is rated for use up to 140°C but the test was halted at 100°C to prevent any potential damage.

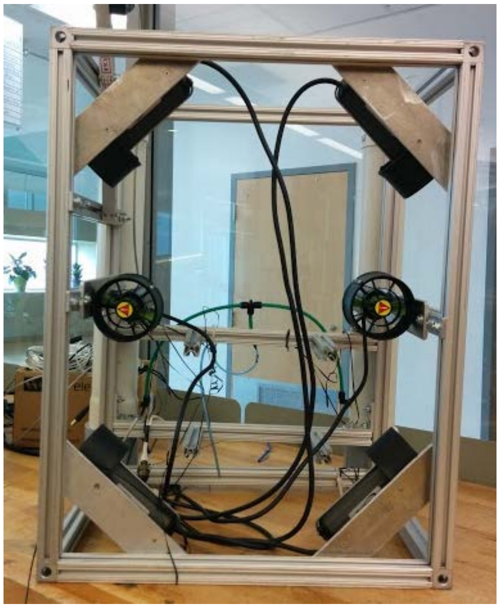


Figure 2 This photo shows the vector formation of the thrusters as it appears from the underside of the craft. Housings not shown)

A second attempt to dissipate the heat buildup was done with an aluminum bridge connecting the underside of the IC's directly to the main housing. Since the copper board no longer required an exposed heat plane, a much smaller motor controller was designed to expose the MC33886's metallic pad. This design attempted to utilize the craft's electronic housing as a heat sink, having the heat transferred to the housing, where it would be dissipated into the surrounding water. Each of the six MC33886's made contact with a custom aluminum heat sink via thermal transfer tape. The plate did not make a satisfactory thermal connection with the housing which is why this idea was unused.

For the final design, the team consulted the local expert who had suggested the MC33886. The design once again used six custom aluminum heat sinks to bridge to aluminum finned heat sink. A laptop fan is mounted to circulate air around the finned heat sink. This method also allowed some of the heat to be transferred to the enclosure itself and finally to the surrounding water.

Mechanics

Claw

The first design idea for the claw was to use a piston or screw rod to actuate a series of links that would open the claw vertically while each of the three fingers of the claw was separated by 120°. Prototyping this design proved this design would have taken far too long and be too complicated. There were also many joints that resulted in weak points.

The final concept for the claw was chosen due to the ease of producing the parts and its ability to perform the required tasks. The design kept the three finger idea but had the fingers positioned parallel to one another having the middle slide through the outer two. Pneumatics are used in actuating of the design over hydraulics due to the ease of use and the elimination of any possibility of fluid leakage. The operation of the fingers was attained by using a two way pneumatic actuator. A second single acting spring return actuator is then used to rotate the wrist and arm of the claw by 90 degrees to attain both an underhand and a sideways grabbing action.

A robust and versatile claw is required for many of the mission tasks. The second mission especially requires the manipulation of many variously sized and shaped objects.

FIGURE 3 TOP-THIS IS A MECHANICAL DRAWING DONE IN INVENTOR OF THE CLAW
BOTTOM-THIS PHOTO SHOWS THE COMPLETED CLAW

Frame

The frame this year was built completely from the ground up instead of using the 2014 craft's frame. The frame is built from light-weight aluminum to decrease the overall weight of the craft both in the water and during transportation. It is also far sturdier than the PCB frames used in previous years. It is easy to work with using the tools available at NSCC. The aluminum bars that make up the frame are slotted to allow for the easy swapping of tools, making the craft more modular. This will allow mission specific tooling to be swapped out during missions with ease. It will also allow upcoming years to use the base of the frame and add whatever is needed that year, and remove what is not.

Tether

The tether was reused from previous year's crafts. This was done in order to save money for purchasing new components for the craft and because it is neutrally buoyant. It also worked well, and the team did not see a reason to replace it. The tether consists of three main parts. One is the pneumatic line providing the craft with pneumatic energy to operate the claw and ballast. The second part is a cat5 cable that carries the analog camera signal from the craft to the surface. The main part is an eight conductor cable that carries all other data and power to and from the craft.

Visual system

Overlay

The video overlay is programmed using the MAX 7456 On Screen Display (OSD) breakout board. The breakout board communicates with the Arduino Mega using the Serial Peripheral Interface (SPI) communication protocol. This board was available in house, and an Arduino library was available online, making it the best option for the video overlay requirement. Using the available Arduino library for the chip and the incoming sensor data, a Heads-Up Display (HUD) is overlayed on to the analog video signal from the backup external waterproof camera. The video is then displayed on the TV monitor. This setup provides the co-pilot and remaining team members with an informed view of the mission and craft parameters. Included in the HUD is the compass with simulated analog heading, ROV depth, mission timer, and warnings. The main objective of the HUD is safety. By monitoring the conditions and location of the craft, Deep Harbour Research can ensure the safety of the ROV and its internal components as well as the safety of the environment in which it operates. Included in the warning system is a proximity alert for the port and starboard proximity sensors. When an object is detected within 150cm of the craft, the distance to the object is displayed on the respective side of the screen. This information can then be passed to the pilot for their own situational awareness. In case of temperature or humidity issues, a warning message is flashed in the center of the screen, alerting the team members to a potential catastrophic problem, which will result in immediate recovery of the craft using the procedures outlined in the safety checklist.

Oculus Rift

The Oculus Rift headset has been carried over from last year's craft. The unique viewing experience provided by the headset is a defining feature of the FPV-ROV. Since the headset was not used to its full potential, the video system has been completely overhauled to meet the potential of the OR headset. The hardware for the headset includes a 7" LCD screen with built in accelerometer for head tracking. The Oculus Rift functions using stereoscopic imaging. By using two cameras positioned roughly the same distance apart as the average human's pupillary distance (space between the center of the pupil), a three dimensional image can be simulated. The brain naturally combines the two overlapping images to provide the first person viewing experience. As the pilot's head moves, the accelerometer sends the position data to the sensor Arduino located on the ROV. Using pulse width modulation, stepper motors position the gimbal on the x and y axes to coincide with the movement of the pilot's head. The first person view and ability to observe the area around the craft without repositioning the ROV is an incredible asset for the pilot. Specifically in the observational tasks such as the sea star recognition and pipeline inspection. The video system will reduce operating time, and the improved video quality will allow the operators to make confident, informed decisions, as the competition progresses.

Cameras

A planned improvement from last year's craft was to replace the analog video cameras used for the stereoscopic display with the Oculus Rift (OR) headset. The optimal video specifications for the OR is a resolution of 720p at 60 frames per second (fps). These specifications meant a digital video signal was required. The Mobius ActionCam was chosen to meet the video requirements for the FPV-ROV. Other cameras were considered, but the ability to be used in multiple modes, the physical dimensions, and cost of the cameras, made the Mobius ActionCam the preferred camera for this year's ROV. The operating modes of the camera include; analog video out, High Definition (HD) recording to SD card, and webcam mode. In addition to the main video modes, the camera can also be used for still images if desired. Early operation of the craft involved the analog video out. With a specially fabricated USB connector, an analog video signal was viewed using the Oculus Rift headset. Later, the cameras were setup for webcam mode to produce the desired 720p at 60fps. Due to the bandwidth required for the HD video signal, and the distance required for the USB 2.0 connection, a powered USB over Cat5 extender was incorporated into the craft, making it possible to send the desired video signal to the control laptop connected to the OR headset. Where last year's craft required manual setup of the video windows for the headset, a program has been written in C using the OpenCV libraries to open the camera windows at specific points on the display, reducing setup time, and removing error in the setup process. This also reduces the amount of hardware required in the topside unit by removing the capture cards used previously.

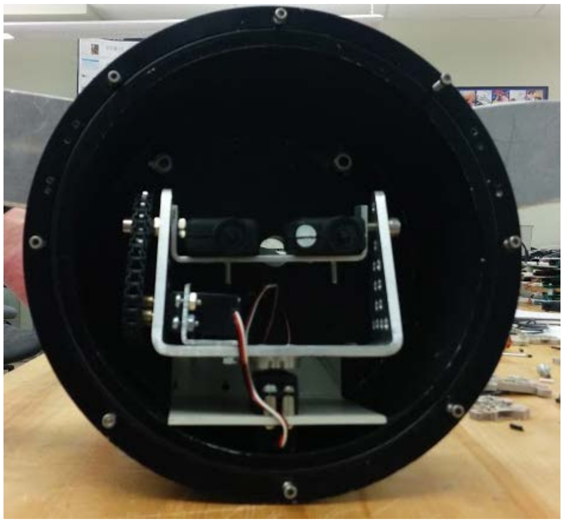


FIGURE 4 THIS PHOTO SHOWS THE MOBIUS ACTIONCAM'S MOUNTED ON THE GIMBAL IN THE CAMERA HOUSING

Electronics

Arduinos

The FPV ROV uses two Arduino Mega2560s as its "brains". These two Arduinos each have specific tasks that they are responsible for. The first is the "Motors Arduino". This Arduino is responsible for controlling and monitoring the motors. It sends the PWM data signals to the motor driver ICs to turn the motors on and off. It also read the fault status of the ICs to monitor if there is a problem. The other Arduino is the "Sensor Arduino". This Arduino is responsible for collecting the data from the sensors and formatting so it can be sent to the surface. It also controls the gimbals, being sent the accelerometer data from the Oculus via the tether. There is a one way communication between the two Arduinos, where the Motor Arduino sends data to the Sensor Arduino. This data includes the status of the motors and commands from the X-box controller.

Two Arduinos were also required for several other reasons. A major one being SPI clock speeds. The pressure sensor and the MAX7456 both communicated via SPI, but at different speeds, so the simplest solution is to run each one off a different Arduino. Two Arduinos also provides more input pins which will allow for future enhancements.

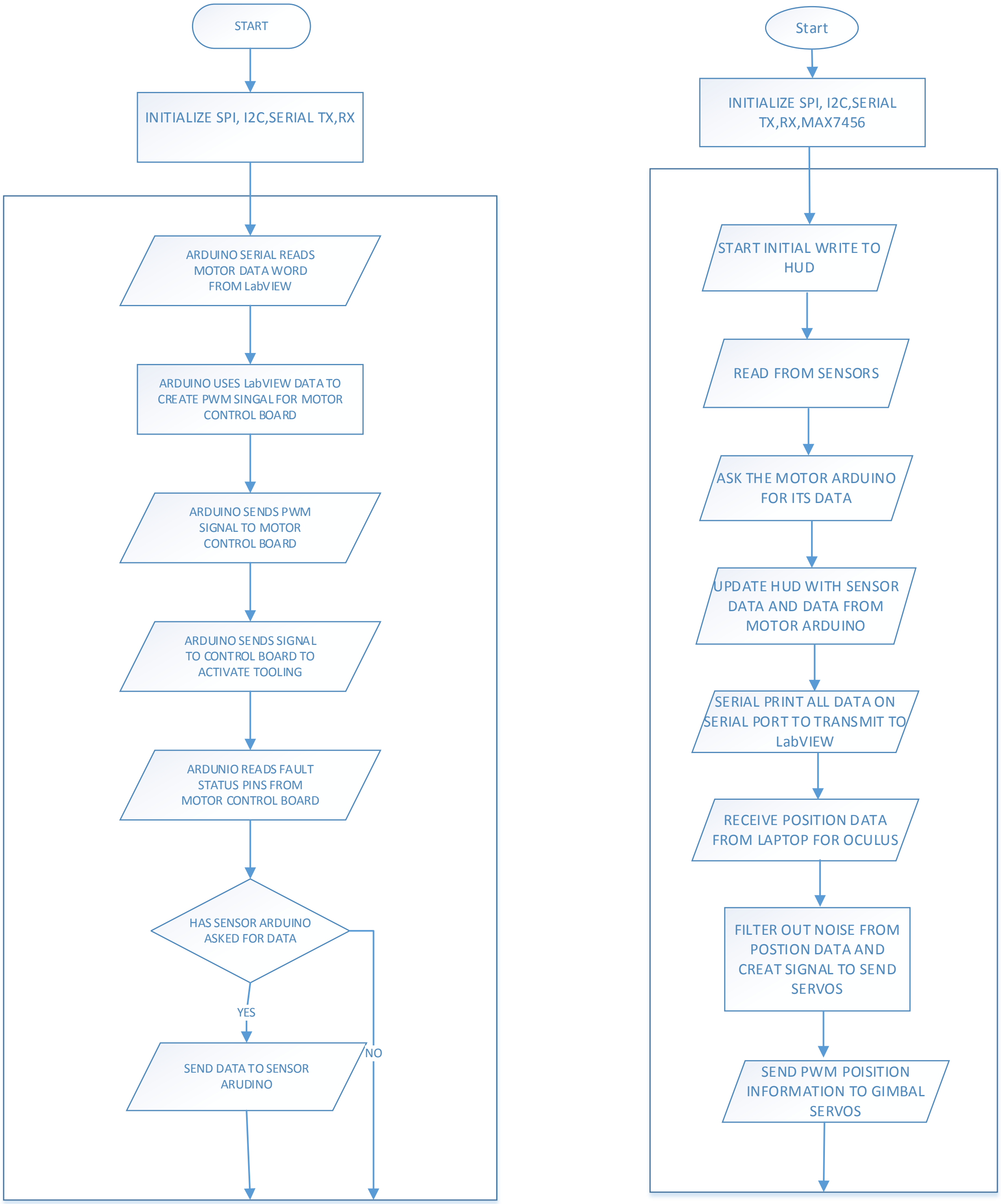


Figure 5 Flowchart showing the software flow of the Arduinos. Motor Arduino on left, Sensor Arduino on right

X-box

The X-box 360 PC controller is the human machine interface used to control all aspects of the craft's thrusters and tooling. This controller was chosen as it is easily interfaced with LabVIEW, our chosen control program, and has proven an effective and reliable means of control over the past several years of competition. The X-box controller provides sufficient input options for control over the many different devices on board the craft.

Sensors

The FPV ROV comes equipped with a sensor suite to enhance the situational awareness of pilot and co-pilot. The data gathered by these sensors are displayed on a LabVIEW front panel as well as a Heads-Up Display.

Internal Temperature and Humidity Sensors

The Phidgets 1125 Humidity and Temperature Sensor was chosen for this application. The FPV ROV uses MOSFET motor driver ICs. These ICs can operate at up to 140°C, however, many components inside the craft cannot operate at such high temperatures. This is why the internal temperature sensor was implemented. If the temperature inside the craft gets too high, the motor speed can be reduced or shut off entirely and the ballasts can be used to recover the craft.

The humidity sensor is used to help detect leaks inside the craft's housings. If the humidity gets too high or starts to change too fast, this could indicate a leak and the craft can be resurfaced. This was an improvement that the 2014 team wished to make.

Compass

The CMPS11 was chosen for the FPV ROV's compass. A compass is important to ensure that the pilot has a complete idea of where they are. Knowing the location of mission specific or dangerous objects, the heading can be used to find or avoid these once under the water.

External Temperature and Pressure Sensor

The MS5541C was chosen as the centerpiece of the external temperature and pressure sensor. This component is often used in devices such as dive watches, leading Deep Harbour Research to believe that it would be ideal for the craft. The mission theme is Arctic water, thus it is important to be able to monitor the external temperature as many of the components that make up the FPV ROV are temperature sensitive.

The other use of this sensor is for measuring the depth of the craft. By using the pressure sensor and, $^{pressure\ in\ mBar\ *\ 0.01}/_{gravity\ *\ density\ of water}$ the depth of the craft can be calculated. Components in the craft are only rated to particular depths and pressures. With this sensor, the pilot and co-pilot can monitor the depth and keep the craft from harm.

Proximity Sensors

Another addition that the 2014 team thought would be helpful for the craft was proximity sensors. The I2CVL-Max Sonars were chosen for this task. There are two sensors, one monitors the port side, and the other monitors starboard. These are important in helping the pilot and co-pilot monitor where the craft is in relation to other objects. They give spatial awareness without the need for additional cameras.

Software

Arduino Communication

The FPV ROV has two Arduinos that control it. The two communicate via a master slave relationship. The motor Arduino receives instruction from LabVIEW in order to operate the motors. In the data word that is sent, there is also instructions for the sensor Arduino. This is transmitted to the sensor Arduino via the master slave connection. This transmission includes fault status of the motors and the instructions from LabVIEW. The sensor Arduino then uses this data to run its test and to transmit the results back to LabVIEW.

The sensor Arduino also receives data on a different serial port from the C++ application that compiles the information from the Oculus Rift's accelerometers and uses it to operate the camera gimbal.

LabVIEW

The main means of controlling the FPV ROV and displaying its data is with the use of National Instruments LabVIEW program. The LabVIEW code has two main parts, the motor control section and the sensor section. This was done in two sections rather than one because the motor control code needs to run very quickly in order to effectively translate the user's commands into movement with no lag. The sensor code on the other hand, runs only once it receives the data from all the sensors, approximately once every second. For this reason, the two loops run separately.

LabVIEW receives instructions from the X-box controller. The LabVIEW program takes the data from controller and converts it into a form that the Arduino will be able to understand. It then transmits this data word down the tether to the motor Arduino. The LabVIEW program also receives the data from the sensor Arduino and displays it in an easy to read format.

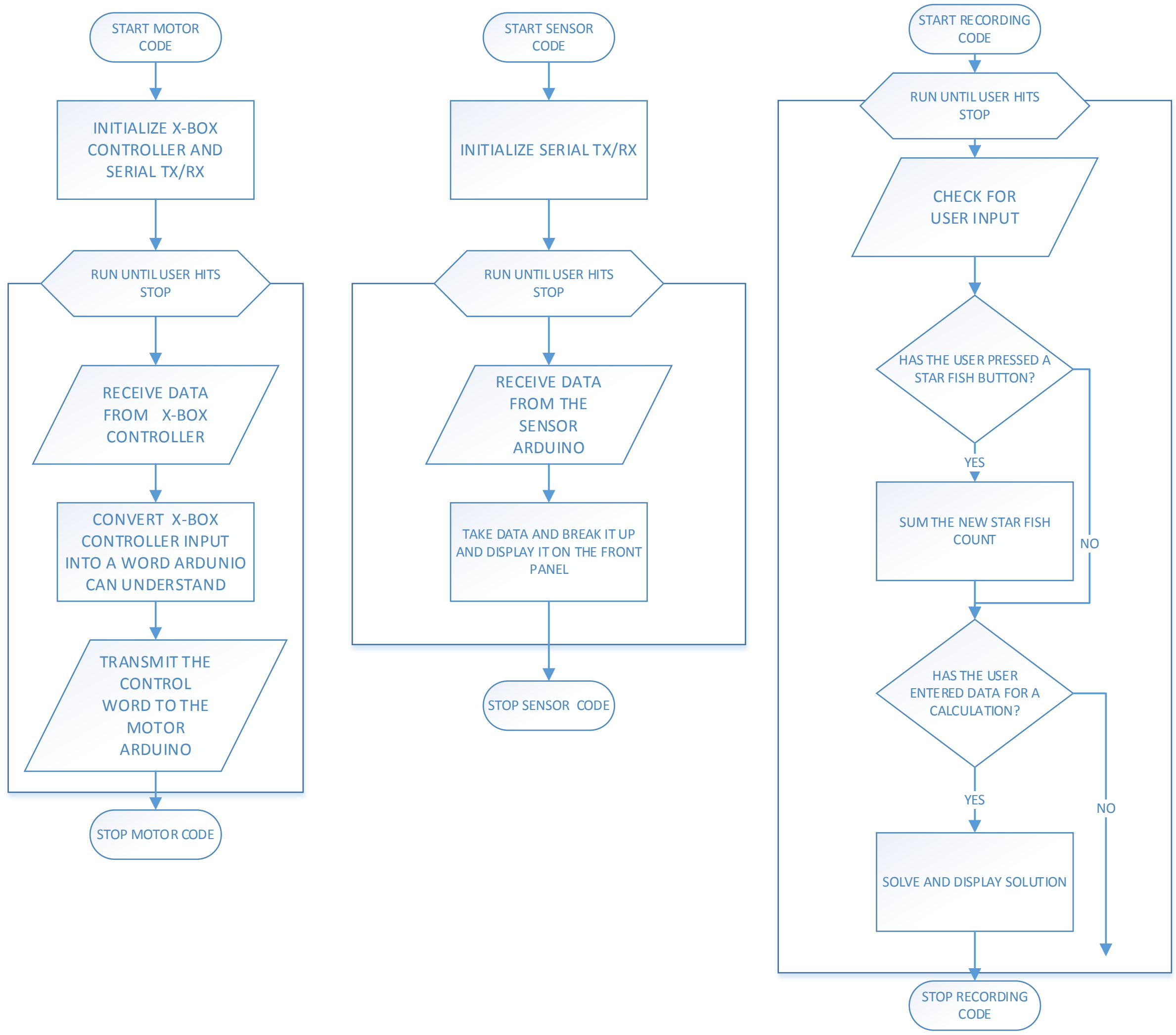


Figure 6 Flowchart showing the three main loops of the LabVIEW Code

Mission Specific Tooling

Science under the ice

Algae collection

Much thought was put into creating an algae collector. Several ideas were passed around such as building a cup like tool to collect the sample. It was decided the bilge pump intake would be used to create suction in a tube that would hold on to the sample and bring it to the surface.

Sea star identification

In order to properly identify the sea stars, colour cameras were chosen in order to properly identify the individual colours. A simple check system was built into the LabVIEW front panel in order to check off when a sea star was spotted. This list allows for an easy tally at the end of the mission run.

Measuring iceberg

Measuring the dimensions of the iceberg and using them to determine the volume of it can be completed using lasers and LabVIEW. The FPV ROV includes a laser measuring system. This system consist of three lasers which are positioned in an L configuration on three of the four points on the front of the box frame. The lasers can be used on the iceberg and because they are a known distance apart “Pixel Window” (a pixel counting software) can be used to determine distance between the lasers and thus the length, height etc of the object in question. Once the required values are measured with the software, they are entered in to LabVIEW where $\frac{1}{3} * \pi * radius^2$ calculates the volume of the iceberg.

Subsea pipeline inspection and repair

Measuring length of corroded section and removing it

As previously mentioned in the measuring the iceberg section, the FPV ROV has a laser measuring system. Simply shining the lasers at the corroded section allows the co-pilot, using the pixel counting software and LabVIEW, to determine the length of the section.

Inserting hot stab

A specialized PVC attachment is mounted to the front of the craft to hold the hot stab at an angle to allow for easy insertion into the port in the wellhead.

Offshore Oilfield production and maintenance

Testing the anodes

In the third task, the grounding of anodes on the leg of an oil platform must be measured. In order to complete this task, an anode tester was built. The tester consist of two leads. Both of these leads are attached to the sensor Arduino. A logic high is written to one of these terminals using the Arduino. The second terminal is attached to an Arduino pin that is configured for reading logic values. If the high is read on this pin, then there is a short, if the high is not read, then the connection is open.

Measuring the angle of wellhead

As mentioned previously, the FPV ROV includes a laser system for measuring lengths and heights of objects. Once the height and the length of the base is determined, they are entered in to the LabVIEW front panel where the angle of the wellhead with respect to the ground is calculated.

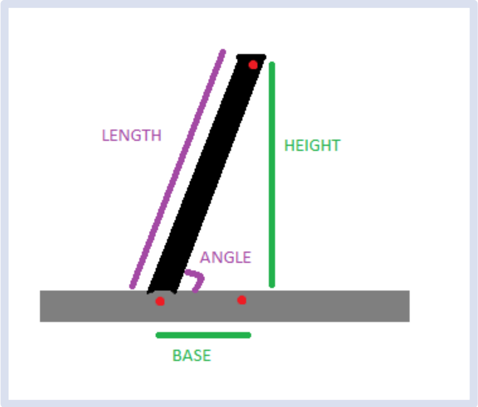
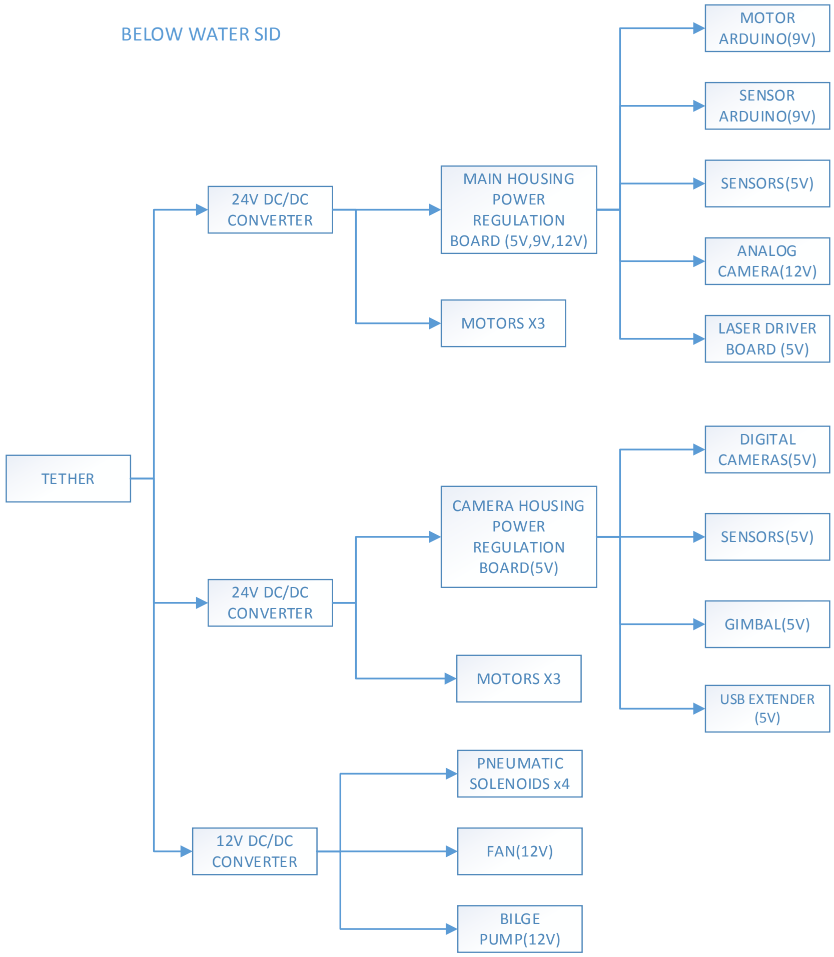


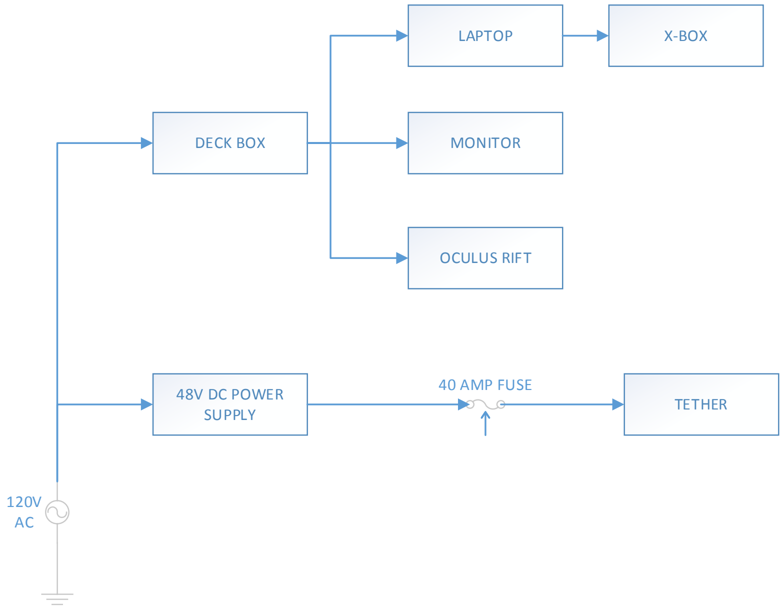
FIGURE 7 ARTIST INTERPRETATION OF THE LASER'S BEING USED TO DETERMINE THE LENGTH AND ANGLE OF THE WELLHEAD. PURPLE INDICATED CALCULATED VALUES, GREEN INDICATED MEASURE VALUES

System Intergraded Diagrams (SID)

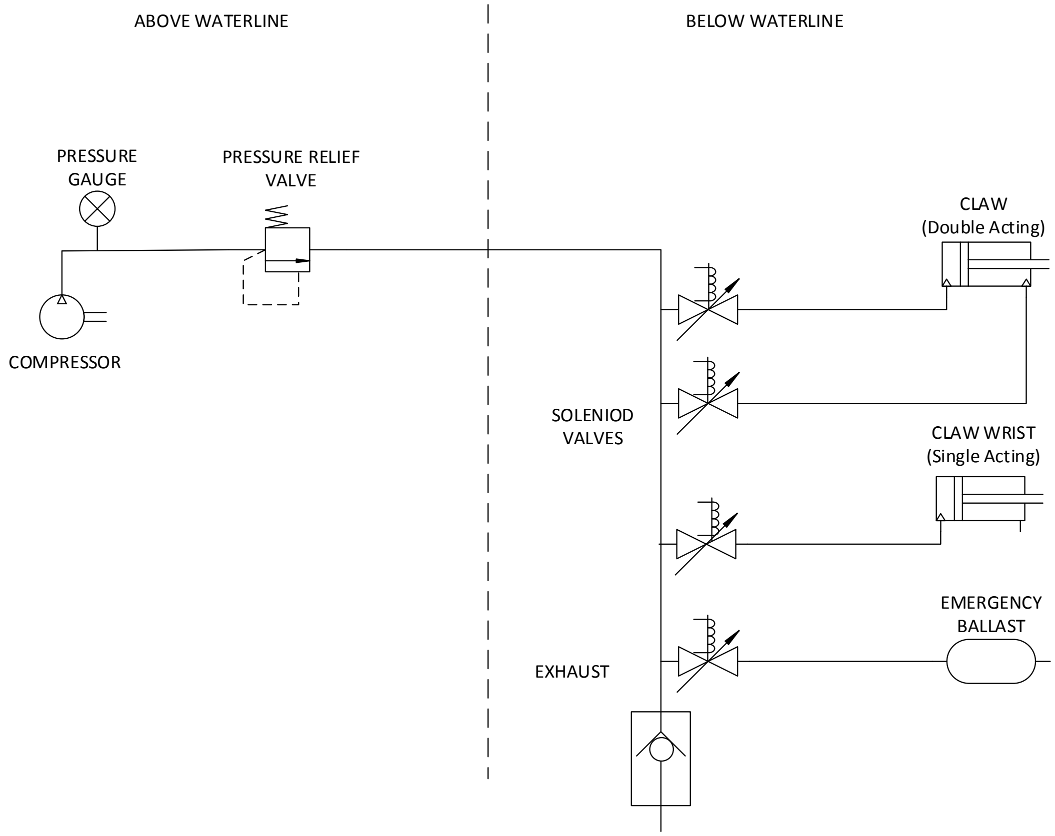
BELOW WATER SID



ABOVE WATER SID



ROV PNEUMATIC SYSTEM



Troubleshooting

Since this year's craft incorporated a number of new systems, a significant amount of time and resources were dedicated to troubleshooting the craft and its components. This section will describe the troubleshooting techniques employed, and how they were applied to each section of the ROV. General troubleshooting was accomplished via a three step method;

1. Visual Inspection
2. Power Requirements
3. Signal testing

This simple three step process was used to avoid inconsistencies in the troubleshooting process and to prevent wrongfully diagnosing a problem with the craft. Step one, visual inspection, required all members to conduct a thorough visual inspection of the craft or faulty section. A significant amount of time in the design and early construction phases were devoted to prototyping and proof of concept. This meant there were a lot of wired connections that could easily result in loose or improper connections, causing faults within the electronic systems. By conducting a visual inspection, it was insured that all connections were made as outlined in the documentation. Later in the testing phase the visual inspection step was applied to the mechanical systems of the craft. In the case of water ingress in to the electronics housing, a visual inspection was conducted on the housing itself and then it was determined the pneumatic system was causing the unwanted water inside the bottle. This was due to improper connections between the pneumatic tubing and connected valves. Great care was taken to remedy the problem and prevent further leaks by regularly checking the pneumatic connections.

Once the visual inspection was complete and the proper connections made, the power requirements are checked. This step confirms that all voltages are available. Step two tests the full ROV system each time the voltage checks are made. It confirms the availability of the +48VDC to the topside deckbox, down the tether to the DC-DC converters located on the craft, and then to each board/circuit within the craft. During construction, this step was necessary in troubleshooting problems with the motors. Operation of the motors was being tested with the on board power from the DC-DC converters. When the motors would only work momentarily, the voltage levels were monitored to determine that back EMF was causing the converters to enter a safe mode which shut them down, leaving no power available to operate the motors again. By placing a diode in line with the positive terminal, the back EMF was prevented from reaching the converters and resolved the issue.

The final and most time consuming step in the troubleshooting process is the signal testing. Within this crucial step is another troubleshooting technique known as the half split method. This method allows the efficient tracking of a signal by splitting the observed circuit in half to determine the status of the signal. The circuit is halved repeatedly until the faulty component is found. Signal testing requires the use of an oscilloscope in order to view the electronic signals being passed between components. The focus of signal testing is to ensure the desired data signal is being passed as expected through the system. The data travels between the topside computer, tether, onboard microcontrollers, and the component control boards. Observing the data signal will determine if the fault is due to a component, or the presence of noise on the signal. In some cases, observing the data signal can also indicate a problem or possible solution with the program used to operate the craft. When testing the gimbal code for the craft's vision system, there was constant movement of the gimbal, despite the Oculus Rift headset remaining stationary. By observing the data signal, it was found that too much noise was causing the servo motors to operate independent of the headset sensor information. The gimbal code was modified to conduct a serial check each time information was passed from the headset to the Arduino microcontroller. If the exact string expected was not received, the data was dumped, then the next string was received and checked. When the proper format was received, the servo motor would adjust accordingly. This removed the jitter from the gimbal system and prevented motion sickness for the pilot.

Troubleshooting is a necessary skill when developing a system such as an ROV. The techniques and experience learned from this process are invaluable. New and returning team members were consistently encountering and overcoming new and exciting problems that without effective troubleshooting skills, could have prevented the success of the craft.

Challenges

Technical

One of the main challenges encountered while building the FPV ROV was dissipating heat. The motor driver ICs, under load, could produce up to 140°C in heat. The other components in the craft could only operate in temperatures up to 70°C. For this reason, it was clear early on that heat sinking would be very important. A lot of different methods of heat sinking were tried. From using the PCB board itself to dissipate the heat, to aluminum heat sinks being attached to the ICs. Finally it was discovered that the heat sinking could be accomplished by using aluminum finned heat sinks on the ICs as well as a fan which could be used to push the air away from the ICs and turn the entire housing into a heat sink.

A major issue encountered was space in the craft's electronics housings. As the design process progressed and more components were added to the craft, it became clear that there was a limited amount of space inside both the main and camera housings. There was thought put into installing a third housing to help create space. This was not implemented for several reasons, one being it created an undesirable profile for currents; and another being that it would require another housing to housing connector, creating another point for potential leaks. Instead there was a rework, both mechanical and electronic, to help reduce the size of the electronics tray. One way was to implement a shelving system in the main housing. Another was doing most of power conversion for the camera dome on a compact power board located in the dome itself.

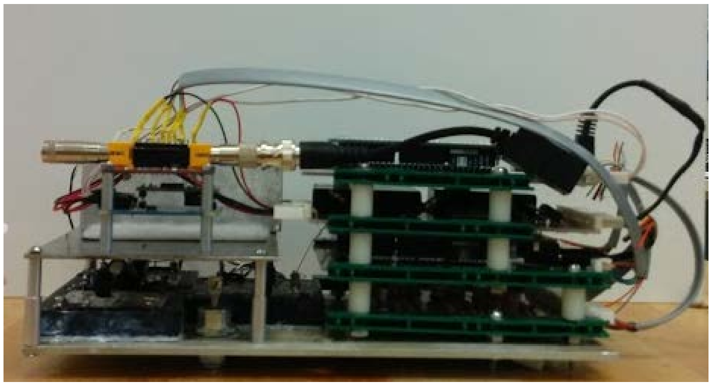


FIGURE 8 THIS PHOTO SHOWS A SIDE VIEW OF THE SHELVING SYSTEM DEVELOPED TO SAVE SPACE INSIDE THE MAIN HOUSING

One of the largest setbacks while building the FPV ROV came from power conversion. The craft was originally supposed to have two 24V, one 12V and one 5V, switching converters. No one on the team had much experience with this type of converter and it was found that the 5V converter was far too noisy (2V swing) to run anything that needed it. The 5V converter had been chosen because of the current it could provide. There were spare 12V converters available at the school that could only source 835mA each, but by using three of them and three voltage regulators, everything on the craft was able to be powered.

Non-Technical

The biggest non-technical challenge was keeping a well-rounded team. At the beginning of the school year, many students from a wide variety of disciplines showed interest in the ROV. However this number quickly declined. This resulted in the remaining members being given more and more responsibility. It also forced members who had no knowledge of a certain subject to research and complete projects with little direction. For example, an electronic student learning how to machine components.

Another issue experienced this year was the budget for the ROV. The limited funding created the need to reuse parts from previous crafts, and repurpose many components found around the college.

Lessons Learned

Many lessons were learned during the design, build and testing of the FPV ROV, both technical and interpersonal.

One of the major lessons learned was time management. The design, building and testing of an ROV requires planning and time management to make sure it is completed on schedule. Another lesson learned was communication and teamwork. Not all team members were always able to meet at the same times, so communication was needed to keep all members updated on what was done and what was left to do.

Technical lessons learned, included the design and milling of PCB board and fabrication. Lessons in power conversion, heat dissipation and coding were also extremely useful. The designing of the craft required the milling and testing of PCBs to determine how they would perform in the real world before picking a final design. There were also tests done to compare different heat sinks and how they would dissipate heat caused by the power conversion and MOSFET motor drivers. The FPV ROV is made up of many different components that all have different power requirements. This required a lot of conversion and filtering. The different components also meant that different coding would have to be used. Learning to get LabVIEW and Visual Studio to communicate with the Arduinos was also an issue.

Waterproofing was another major lesson learned, whether it was waterproofing exterior sensors or bulkhead connectors. Special care had to be taken in both cases in order to make sure no water came in contact with the electronics of the craft.

Future Improvements

Many improvements have been made from the 2014 FPV-ROV. These were discussed in last year's technical report. The planned improvements involved redesigning the claw, and including a sensor suite to monitor the health of the craft and the environment. Additional improvements include a more robust frame, Arduino microprocessors, HD cameras, and an included deck box for more efficient deployment and recovery of the system. Future improvements for the 2016 FPV-ROV will be, Bluetooth connectivity with the Arduinos for faster uploading of system software, further heat sinking and temperature management for the MOSFET motor controller ICs, and video overlay of the sensor information on the pilot's Oculus Rift screen. Ideally however, improvements will be made to the process in which the craft is made. Having read the hacking vs. engineering article posted by MATE, the main focus for next year's team will be to shift more towards the engineering spectrum of the process. Ensuring that the experience gained from the build process as well as the competition is passed on to all potential members in 2016 will help to develop the engineering process as the craft progresses through the development stages.

Reflections

Going into the design and build of the FPV ROV, many team members expected to be working primarily in their field of study. However, it was quickly realized that members would have to step outside their knowledge zones and work on other sections. For example, there were electronic students machining parts for the frame and attaching them. This left many members feeling like they got more out of the experience then they had planned, having learned new skills as well and strengthening old ones. Members also learned to be flexible with time management, sometimes things would not work out as planned and a new plan would have to be developed and the timeline would have to be adjusted to match. All team members feel more prepared for their future plans, whether they are returning to study or entering the workforce.

"This was my second year as a member of the NSCC ROV team. My experience from last year was a major asset as I took on the role of CEO for this year's team. Participating in Alpena gave me firsthand knowledge of the international competition and the benefits of participating. I tried to use this experience to introduce more people to the MATE competition and ROVs in general at NSCC. My involvement helped to maintain the focus of the team on the essential components of the build prior to the release of the Explorer and props manuals. Setting design goals for myself and the team was how I assessed our success. In addition to developing my project management and leadership skills, the hands on experience of building the craft exposed me to every aspect of the craft. As a senior member I was involved in fabrication, programming, circuit design and construction, allowing me to become a much more well-rounded member of the team."

- Jon MacDonald-CEO

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